RESEARCH ARTICLE

CLINICAL REASONING

Explicit teaching in the operating room: Adding the why to the what

Patrick Nieboer[1] 🔘 | Mike Huiskes[2] | Fokie Cnossen[3] | Martin Stevens[1] |
Sjoerd K. Bulstra[1] | Debbie A. D. C. Jaarsma[4]

[1]Department of Orthopedic Surgery, University Medical Center Groningen, Groningen, The Netherlands

[2]Center for Language and Cognition, University of Groningen, Groningen, The Netherlands

[3]Department of Artificial Intelligence, Bernouilli Institute of Mathematics, Computer Science and Artificial Intelligence, University of Groningen, Groningen, The Netherlands

[4]Center for Research and Innovation in Medical Education, University Medical Center Groningen, Groningen, The Netherlands

Correspondence
Patrick Nieboer, Department of Orthopedic Surgery, University Medical Center Groningen, Groningen, The Netherlands.
Email: p.nieboer01@umcg.nl

Abstract

Context: Residents need their supervisors in the operating room to inform them on how to use expertise in present and future occasions. A few studies hint at such explicit teaching behaviour, however without explaining its underlying mechanisms. Understanding and improving explicit teaching becomes more salient nowadays, as access of residents to relevant procedures is decreasing, while end-terms of training programs remain unchanged: high quality patient care.

Objectives: A structured analysis of (1) the practices supervisors use for explicit teaching and (2) how supervisors introduce explicit teaching in real time during surgical procedures.

Methods: An observational qualitative collection study in which all actions of nine supervisor–resident dyads during a total hip replacement procedure were videotaped. Interactions in which supervisors explicitly or implicitly inform residents how to use their expertise now and in future occasions were included for further analysis, using the iterative inductive process of conversation analysis.

Results: 1. Supervisors used a basic template of if/then rules for explicit teaching, which they regularly customised by adding metaphors, motivations, and information about preference, prevalence and consequence.

2. If/then rules are introduced by supervisors to solve a (potential) problem in outcome for the present patient in reaction to local circumstances, for example, what residents said, did or were about to do.

Conclusions: If/then rules add the *why* to the *what*. Supervisors upgrade residents' insights in surgical procedures (professional vision) and teach the degree of individual freedom and variation of their expert standards for future occasions. These insights can be beneficial in improving supervisors' teaching skills.

1 | INTRODUCTION

Supervisors without question are essential for the development of residents towards independent practise. They embody a huge stock of experiences and expert standards, and regulate the residents' autonomy during procedures, creating opportunities for residents to automate their skills.[1-6]

Access to expert standards and supervisors' experiences is essential for residents need to learn how to manipulate tissues for the best possible patient outcome as experts do. Textbooks and manuals provide general templates of tasks and steps surgeons have to follow. Information about how to read the surgical field, keep control, avoid unnecessary harm and how decision now may affect other parts of the procedure is stored in the minds of experienced supervisors.[7-9] This raises the question of how supervisors make that expertise accessible to residents during actual procedures. For this we have to turn to the day-to-day practice of intraoperative teaching and learning.

Observational studies of teaching interactions in the operating room show how residents use strategies to recruit the supervisors' expertise, and, far more often, supervisors supply expertise without any specific request of residents, usually when they observe or perceive substandard performances of residents.[4,5,10-14] The supply of expertise by supervisors during surgical procedures offers residents opportunities to learn how experts solve a particular problem, at a particular moment, for a particular patient. However, understanding which features of that expertise are context specific and what information can or should be transferred to similar situations and future patients is crucial for the residents' development towards independent professional practice.[9,15]

Understanding what expertise might be beneficial for future procedures is even more relevant in the changing landscape of intraoperative teaching. Working hour restrictions, higher demands to secure patient safety and governmental demands to shorten surgical training programs (in some countries) affect learning curves of residents.[16-20] One way to ensure safe and high quality surgical care by residents at the end of their training is to optimise the flow of expertise to residents during procedures, especially inform residents how to use expert information in future patients. The problem is that knowledge about this phenomenon in medical educational literature is limited to anecdotal information. Some studies focused on surgical heuristics while other authors analysed these heuristics as if/then rules as a means for supervisors to teach and explicitly point out the usefulness of their expertise in future patients.[12,21,22] In cognitive science, if/then rules are considered as fundamental building blocks of procedural rules. However, as an interactional practice in the daily routine of teaching residents in the OR, they remain understudied.[23,24]

This study offers a detailed analysis of the ways in which if/then rules are occasioned, introduced and formulated during surgical procedures, a structured approach of the question how supervisors inform their residents about how to use their expertise in future occasions. Insight in these teaching practices may help supervisors in teaching residents in their daily practise.

This study focused on the following research questions: What interactional practices do supervisors use to construct heuristics (if/then rules)? How are these heuristics (if/then-rules) locally licensed and occasioned in real time in the everyday practice op the operation theatre?

2 | METHODS

2.1 | Setting and participants

This qualitative collection study was executed at University Medical Center Groningen (UMCG) in Groningen, the Netherlands. The procedure of choice was an uncemented total hip arthroplasty, a procedure that is highly standardised, but contains crucial decision making that carry considerable medical risks for the patients (Figure 1).

Eight supervisors and residents participated and formed nine different dyads (one supervisor and one resident participated twice, but the second time combined with others) (Table 1). The authors did not participate as supervisors and were not present during the procedure.
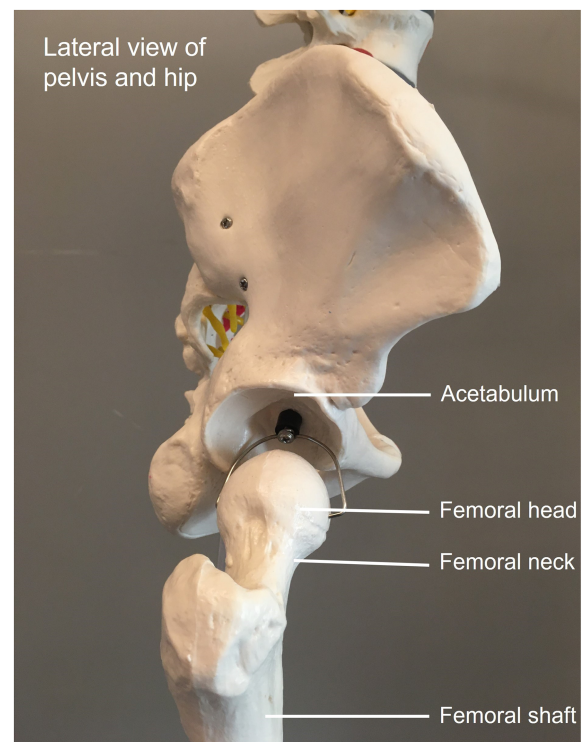

FIGURE 1 Basic anatomy and background of the procedure. In an uncemented total hip arthroplasty the hip joint (acetabulum and femoral head) is replaced by an artificial acetabular and femoral component. The crucial tasks are the resection of the femoral head and neck to expose the acetabulum and femoral shaft. Then both the acetabulum and femoral shaft are prepared to the standard size of the prosthesis in a process named *reaming*. Reaming is mechanically removing bone (and cartilage) until the patient's anatomy is compatible to the prosthesis. When the reaming process is finished, the acetabular and the femoral component of the prosthesis are inserted [Color figure can be viewed at wileyonlinelibrary.com]

Dyad	Supervisor	Gender	Resident-PY	Gender	Duration (h/min/s)
1	Physician assistant A	Male	Resident A PY 4	Male	1.04.29
2	Orthopaedic surgeon B	Female	Resident B PY 4	Male	1.26.35
3	Orthopaedic surgeon C	Male	Resident C PY 2	Female	0.36.00
4	Orthopaedic surgeon D	Male	Resident D PY 5	Male	1.31.11
5	Senior resident E (PY 6)	Male	Resident E PY 5	Male	1.56.20
6	Orthopaedic surgeon D	Male	Resident E PY 5	Male	1.01.25
7	Physician assistant E	Male	Resident F PY	Male	1.01.10
8	Physician assistant A	Male	Resident G PY 6	Male	1.20.22
9	Orthopaedic surgeon F	Male	Resident H PY 6	Male	1.29.04
Total					11.26.36

Abbreviation: PY, program year.

In our hospital, supervisors with different backgrounds guide residents (e.g., orthopaedic surgeons, senior residents and physician assistants). Physician assistants in our institution are trained as supervisors and only guide residents that demonstrated sufficient progress. In the Netherlands, the training program of residents consists of a 6-year program in which residents start with an 18-month rotation in general surgery, followed by multiple rotations in different teaching hospitals. The residents in this study varied in years of training between program year 2 and 6.

Each supervisor, resident, patient and OR team member was informed about the goal of the study and written consent was obtained. The ethical review board of our hospital discussed the study and confirmed that the Medical Research Involving Human Subjects Act (WMO) did not apply.[25] We followed the declaration of medical research of Helsinki for all participants in this study.[26]

2.2 | Data collection

Data was collected between 2016 and 2019. Nine procedures were videotaped (total recording time 11 h, 26 min and 36 s), and all interactions were captured between supervisors and residents from three different angles: one overview camera and two head cameras on both the resident and the supervisor.

The whole corpus was transcribed using a subset of the Jefferson transcription system.[27,28] Excerpts in the collections were transcribed in more detail during the analyses. To facilitate the readers, we present our results using simplified transcription conventions in the text (orthographic transcription including overlap and pauses).

2.3 | Data analysis

We used conversation analysis (CA) to analyse data.[29] CA is a "distinctive approach within the social sciences that aims to describe, analyze and understand talk as a basic feature of human social life."[27,28] CA starts with observing the data and creating a collection of relevant datapoints. In this study, the first two authors (trauma-surgeon/

educator and a linguist) included all interactions in which supervisors verbalise their expertise using a heuristic. Next, they selected those interactions in which supervisors added a heuristic (if/then rule) that informs residents not only how to move forward in the current procedure but also how to use this expertise in future occasions. Subsequently specific interactional practices (categories) were identified based on the formal properties of the supervisors' utterances and the sequential environment of these practices (looking both backward and forward in time to identify the context, i.e., how the practices were occasioned in in the interaction and how they were responded to).[29] This iterative, inductive process continued until all instances in the collection were categorised and no new categories could be identified in the collection (i.e., when saturation was achieved).

All the practices were discussed during data sessions both within the team (including a cognitive scientist, a senior researcher in orthopaedics, a senior orthopaedic surgeon and a medical educational scientist) and between the first two authors until consensus was achieved about the specific interactional practices used to formulate the heuristics (if/then-rules) and how these specific interactional practices were occasioned in the interaction (that is how supervisors introduced these practices during supervisor-residents interactions).

3 | RESULTS

3.1 | Practices of supervisors to inform residents how to use expert information now and in future occasions

The nine supervisors in this study informed residents 59 times about the scope of their expertise using heuristics that stressed the future applicability of their expertise. Below, we present the interactional practices supervisors used to articulate these heuristics. All these practices to formulate heuristics in our corpus were instances of the if/the rule schema discussed in the literature (reference). Supervisors either used if/then rules in their textbook appearance or modified these rules to emphasise the particularities of their expertise.

3.1.1 | The textbook if/then rule

Case example 1 shows a textbook example of the basic if/then template:

IF situation X occurs ⟶ THEN Y is applicable.

Case example 1: If/then rule, the basic template (a brief overview of the anatomy and background of the procedure is provided in Figure 1)

The resident was preparing the femur with a reamer, a task that has serious consequences for the stability of the final prosthesis when not performed at the right angle and on the correct plane. The supervisor in this procedure observed how the resident executed the task. Then he supplied expert information by stating: "*When I'm not sure, I occasionally remove the inserter and put an awl on the reamer to determine where the center of rotation will be.*"

This information is constructed following an if/then format: IF I'm not sure about the final centre of rotation, THEN I remove the inserter and put an awl on the reamer to determine the centre of rotation. Such information gives the resident insight into how the supervisor acts when confronted with a problem of assessing and evaluating the proper position of the reamer, which is information that can be used by the resident now and in future procedures.

3.1.2 | Analogies and metaphors in if/then rules

Supervisors also provided residents with insights of the situation by using a metaphor or analogy to describe the if-part of the rule (case example 2).

Case example 2: An if/then rule constructed with a metaphor.

The resident finished preparing the acetabulum, using a reamer to mechanically remove bone to establish a shape corresponding to the implant. Then he inserted the trial prosthesis into the acetabulum to assess if there is a press fit between the prosthesis and the bone. The resident initiated a turn in talk (line 2) when he expressed an assessment of the stability of the trial prosthesis.

1. *4.7 sec. silence*
2. *Resident: Is not sufficient*
3. *Supervisor: Yes, it is a tulip, so you must widen the entry of the acetabulum*
4. *Resident: Yes*
5. *2.1 sec. silence*
6. *Resident: A tulip?*
7. *Supervisor: Yes a tulip, instead of a regular spheric contour*
8. *Resident: I understand.*

The supervisor explains why the trial prosthesis was not press fit by using an if/then construction: If the prosthesis does not press fit, then you need to widen the entry. In this case, she does not give a factual explanation but provides a metaphor instead. The metaphor she used describes the shape of the acetabulum in arthrosis: like a tulip. The resident requests an explanation for this metaphor (line 6), which is given by the supervisor (line 7): She adds information about the required contour of the acetabulum—a regular spheric contour and not the contour of a tulip. The resident confirms he understands the metaphor that a tulip is wide at the bottom and narrow at the top (line 8).

By using metaphors, supervisors provide residents with a conceptual framework to assess the current situation. The current situation is framed not in its particularity (*token*) but as an instance of a recurrent phenomenon (*type*), categorised by a specific metaphor ("tulip") available for future use.

3.1.3 | Adding explanations to if/then rules

Supervisors also expanded the basic template in about half of the cases (24 out of 59) by adding an explanation as an account for the applicability of the heuristic:

IF situation X occurs ⟶ THEN Y is applicable, because of Z

These accounts provide supervisors with an optional building block for the template (case example 3).

Case example 3: If/then-because rule.

In the next case example, the resident just inserted the definitive acetabular component of the prosthesis. The endpoint of this task is a stable and solid fixation of the acetabular component. A turn in talk started when the resident gave his final evaluation after inserting the acetabular component.

1. *Resident: Fits*
2. *0.4 sec. silence*
3. *Resident: Yes*
4. *Supervisor: In most cases you need to test the component at three different points*
5. *Resident: Do I?*
6. *Supervisor: Yes*
7. *1.1 sec. silence*
8. *Resident to the scrub-nurse: Can I have a forceps?*
9. *Supervisor: You can test the component at the 10, 12 and 2 o'clock position*
10. *1.6 sec. silence*
11. *Supervisor: Sometimes it seems a tight fit, but it is possible that at another test position the component is less stable*

In this case example, the if/then rule is: If you evaluate the acetabular component, you need to test this at three different positions. By using "in most cases," the supervisor emphasises that the rule is not specifically expressed for this particular procedure but for any similar situations in future procedures. Furthermore, the supervisor extended the if/then rule by supplying an expert explanation (line 11).

Interestingly, although these inf-then rules are clearly oriented towards applicability beyond the here and now, they are also firmly rooted in the task at hand: they are formulated as occasioned by case-specific characteristics of the current task (see case examples 1 and 2), in the *if*-part; the *then*-part formulates the instruction, in these cases the supervisor's expert solutions to a problem, including an explanation.

3.1.4 | Making public the preference, prevalence and consequence of the if/then rule

Supervisors also often specify and modify the applicability and the epistemic status of the rule: How often does the rule apply and are

we dealing with a preference or a necessary rule? The supervisor in case example 1 clearly formulated a personal rule, accentuating his preference by stating: "When I'm not sure, I occasionally remove ...." In 19 cases, supervisors added specific lexical items (e.g., "my preference" and "what I do") categorising if/then as a personal rule to the resident.

Additionally, supervisors add information about the prevalence of the rule (28 cases). In case example 1, the supervisor added "occasionally" to the rule to highlight that the if/then rule is applicable in some instances. The supervisor in case example 2 however used "in most cases" to express that it is general practice (though also providing for possible exceptions). Supervisors encode the prevalence of the rule using adverbs that denote frequency, like *always*, *normally*, *often*, *sometimes* or *never* (Table 2).

Besides the prevalence of the rule's applicability, supervisors can also provide information about the necessity (epistemological status) of the rule (this was done in 14 cases). In case example 4 application of the rule is framed as a necessity.

Case example 4: If/then rule + information about the implication.

The resident was preparing the acetabulum by reaming stepwise until the right shape and angle was realised. During this process the supervisor stated: "*You must choose the definitive angle of reaming early on in the reaming process when you insert an uncemented prosthesis.*"
This information is constructed following an if/then format:
if you use an uncemented prosthesis, *then* you have to determine the correct angle early in the process. However, by adding "you must" the supervisor upgrades the implication to *without exception*. The rule is applicable now and every time the resident will be inserting an uncemented total hip prosthesis in the future.

Supervisors encode the epistemological status of the rule using different types of modal verbs. In the majority they used *you must* to emphasise the crucial status of the rule. In other cases, residents were taught that the rule is a serious option (*you can*) or an alternative that could be considered by the resident in the future (*you might*) (Table 3).

3.2 | Strategies of supervisors to introduce if/then rules

Up to this point, we have focused on the specific interactional practices supervisors use to formulate heuristics (if/then rules). In the following, we will analyse how these practices are occasioned by these activities: How do supervisors provide the opportunity for explicit teaching in the course of a procedure? We identified two contexts for informing residents about the scope of their expertise. In the first

context (25 cases), supervisors responded to specific verbal actions of residents about a situation in the present. In the other context (34 cases) the supervisors initiated if/then rules without a request of the resident, but in reaction to what residents are doing or are about to do in the present patient.

3.2.1 | If/then rules as a reaction to what residents verbalise in the present

Residents express assessments about their actions during surgical procedures. These assessments make residents' thoughts about the present situation public and controllable to supervisors.[29,30] Although assessments do not explicitly invite supervisors to react and supply expert information, they do provide an opportunity for the supervisor to think along and respond, and as such may trigger supervisors to provide an if/then rule. Case example 2 (repeated below) shows how the supervisor supplied expertise in a reaction to the resident's assessment about the present situation.

Case example 2, reprise. Supervisor reacts to resident's assessment with if/then rule.

1. *4.7 sec. silence*
2. *Resident: Is not sufficient*
3. *Supervisor: Yes, it is a tulip, so you must widen the entry of the acetabulum*
4. *Resident: Yes*
5. *2.1 sec. silence*
6. *Resident: A tulip?*
7. *Supervisor: Yes a tulip, instead of a regular sphere*
8. *Resident: I understand.*

The resident expressed an assessment about the current situation (line 2). By doing so, the resident made his private thoughts accessible to the supervisor. However, he did not explicitly invite the resident to react. In this case, the resident was executing a point-of-no-return task and evaluated the result of his previous action as insufficient. The supervisor could limit herself to a simple confirmation or give information that is exclusive to this particular case. However, she shared expert information (line 3) that is relevant now and in similar future cases. The timing and type of information has a threefold function for the supervisor in this case: (1) It confirms the resident's evaluation; (2) it gives the resident insight into what the problem is now (and in similar future cases); and (3) it implicitly guides the resident to what his next action should be: redo the reaming until the contour of the acetabulum is correct.

TABLE 2 Adding prevalence to an if/then rule

Utterance	Always	Normally	Often	Sometimes	Never	Total marked	Total unmarked	Total
Frequency	10	2	11	4	1	28	31	59

TABLE 3 Modal verbs used to mark the epistemic status of the if/then rule

Utterance	You must	You can	You might	Total marked	Total unmarked	Total
Frequency	6	3	5	14	45	59

Residents can also explicitly invite their supervisors to provide expertise to solve problems in the present. This also provides an opportunity to teach residents the scope of expertise (case example 5).

Case example 5. Supervisor reacts to a resident's request for assistance with an if/then rule.

In the next case example, the resident was preparing the acetabulum, using a reamer to mechanically remove bone to establish a shape similar to the implant. Reaming is a repetition of actions with reamer heads that increase in size until the right shape and angle is realised. In this case, the resident requested a confirmation about the size of the reamer (line 1).

1. Resident: The 45? Because you need to continue in odd reamer sizes now?
2. Supervisor: Yes
3. Resident: Yes
4. Supervisor: Yes, normally the odd-sized reamer is your last step in the reaming process. However, it is alright to switch to odd-sized reamers now.
5. Resident: Alright, then I continue in this direction (R demonstrates to the supervisor the angle at which she inserts the reamer)

The resident expresses a request for confirmation after providing the supervisor insights into her thoughts on how to continue. The supervisor confirms, then follows up with what is usually the procedure: If you ream stepwise to prepare the acetabulum, then you normally use the odd-sized reamer in the final step. The supervisor is explicitly invited to react. He could limit his response to a confirmation. However, in this case, he expands with an if/then rule, likely provoked by the resident's intention to ream in a different order than is commonly done.

Case example 6. Supervisor follows up with an if/then rule after suggesting how the resident should continue.

In the next case example, the resident was exposing the acetabulum before the reaming process can start. He dissected tissue with the electrosurgical knife but stopped and retrieved the instrument from the wound. Then the supervisor made a suggestion as to how to continue in the here and now (lines 1 and 3).

1. Supervisor: I would
2. 5.6 sec. silence
3. Supervisor: Try to clear up the edge at the top
4. 1.6 sec. silence
5. Resident: You mean here?
6. Supervisor: Yes (hands over the electrosurgical knife)
7. Resident: Right, with the electrosurgical knife
8. 2.9 sec. silence
9. Supervisor: I always prefer to clear all the edges of the acetabulum with the electrosurgical knife
10. Supervisor: It is just what you are used to
11. Resident: Then we have a much better view later on
12. Supervisor: Yes

The supervisor's if/then rule is: When you clear the acetabulum, you must be sure to clear all edges (although it may look as if use of the electrosurgical knife is the subject of the rule, the suggestion [lines 1–3] when the resident stops clearing the edge at the top as well, indicates that the resident did not complete the task of clearing the acetabulum completely, and that the subject of the rule is: complete all edges at once). The if/then rule is produced by the supervisor (line 9) after they discuss the local situation for this patient (lines 1–7). The supervisor already directed the resident with the suggestion: I would clear the edge at the top too. However, he expands on his suggestion to ensure optimal care for this patient, and provides expert information that is useful for future procedures.

In both examples, supervisors react to insights the residents provide in their thinking. In the next contexts, supervisors do not react to the residents' verbal actions, but introduce rules to follow up on their own initiatives to guide residents in the present first.

3.2.2 | Introducing if/then rules as a reaction to what residents do or are about to do in the present

Supervisors also incorporate heuristics (if/then rules) in larger contributions initiated by themselves (e.g., as part of an assessment, instruction or correction). In these cases, the if/then rule closes that particular sequence and function as the culmination of their contribution. Case example 6 shows a prototypical example.

Expert information to inform residents how to use their expertise was commonly embedded in longer sequences of supervisor–resident interactions. All sequences started with a verbal action by either residents or supervisors indicating a (potential) urgency in the present patient surfaced. These actions started a sequence of interactions in which the supervisors created the *if*-part of the if/then rules by explicitly attending the urgency itself. Then, as the interactions proceeded, supervisors followed up with the solution to solve the urgency, the *then*-part. This expert solution addressed both the urgency in the present patient as potential similar urgencies in future patients. Furthermore, supervisors could introduce adjuncts to the instruction to teach residents the degree of individual freedom and variation of their professional standards of that action in future occasions.

4 | DISCUSSION

The aim of this study was a structural analysis of one specific phenomenon: how supervisor inform residents to use expertise in future occasions. We were interested what practices supervisors used and how they introduce these practices during supervisor-resident interactions in the real time of surgical procedures.

We identified and analysed 59 instances in more than 11 h of supervisor–resident interactions, each dyad was included in the final collection showing that this is a general supervision strategy. All the interactional practices, were instances of the if/then rule, discussed in the literature. The *if*-part highlighted a particular situation or action of the procedure and in the *then*-part supervisors introduced the instruction, which they regularly customised by adding metaphors, arguments, information about preference, prevalence and/or consequence.

Supervisors unambiguously switched to their role as teachers when they informed residents how to use expertise in future occasions in this study. What stands out is the scale and regulation of this teaching behaviour. First, supervisors informed residents about the smallest possible action of surgical procedures: a decision, motor action or evaluation. Second, teaching was almost always part of larger contributions between residents and supervisors, and consistently in reaction to potential flaws in the care for the present patient.[4–6] Previous studies showed potential flaws in residents' performances cannot pass unnoticed or unrepaired by supervisors.[4–6] In most cases supervisors provide expertise to solve the problem now, without any information to guide residents in future patients.[10,13,14]

Supervisors seem to decide after the identification of a problem in the present patient if they just supply expertise to ensure optimal care (default mode) or construct their expertise according an if/then template. The if/then template has a twofold effect on the residents' learning: The *then*-part, the experts' instruction, informs residents how to provide expert care now and in the future. The *if*-part displays the relevance of that particular situation at that moment for supervisors. By emphasising the relevance of a particular moment of the procedure supervisors give accounts of their *professional vision* to residents. Professional vision is the unique expert's perception and understanding of objects *within* a particular situation and as part of a given professional task.[31] The use of metaphors in the if-part of the heuristic provides trainees an insight in the expert perception of the situation. In incorporating their professional vision in a heuristic available for future use, supervisors also give insight in their procedural knowledge.

Professional vision is one aspect of experts, insight in the procedure itself (procedural rules) is another hallmark. This may be best explained by how experienced chess players read a given position on the board as patterns (professional vision) and understand the advantages of their actions in the next in three or four moves (professional rules).[32] Novices lack professional vision and procedural knowledge, as was demonstrated in a study in which supervisors indicated they think ahead during complex tasks of an uncemented total hip replacement procedure, in contrast to residents, who tend to think now when

faced with those complex tasks.[33,34] By using and customising if-then rules supervisors encourage residents to understand the procedural rules of a specific procedure.

Procedural rules give residents insights in the degree of individual freedom of professional action and the variation of professional standards that exists among supervisors. When supervisors construct their expertise as: *if/then- because*, they allow residents explicit insight into their expert reasoning: residents learn why supervisors perceive and understand features of the operation as relevant and important. Adding information about personal preferences (personal rules) helps residents to understand alternatives exists in a particular situation, just as adding *you can*, or *you might* to their rules does, while no exceptions to a rule exists when supervisors use more absolute modalities (e.g., always, *you must*).

5 | PRACTICAL RELEVANCE

Now that we have identified the specific interactional practices that supervisors use for explicit teaching, these can be used to reflect on the teaching behaviour and teaching styles of supervisors. What type of expertise is provided (professional vision, procedural knowledge), how is it presented (as standard professional behaviour, a personal rule) and how is it occasioned in the actual procedure (assumed or invited)?

The results also allow identification of explicit teaching in real-time to evaluate individual supervisors' teaching in one procedure, or in multiple encounters. Such information may be useful for feedback on teaching or monitor supervisors' development as teacher over time.

However what remains unknown are the qualitative aspects of explicit teaching behaviour: why do supervisors decide to turn from default supervision, and just provide expertise for the here and now, to explicit teaching at a specific moment during the procedure? How are these supervision strategies evaluated by trainees? These questions cannot be answered by CA, however different methods (e.g., video-stimulated recall) could provide new avenues of studying those questions.

6 | IMPROVING LEARNING IN THE OR

Explicit teaching adds the *why* to the *what*. It informs residents about what actions experts apply (what) and about the underlying expert principles of those actions (why). Teaching the underlying principles is one of the crucial components in four component instructional design, or 4C/ID-model.[35,36] The 4C/ID could be a promising lead to improve residents learning of surgical procedures by offering a template that supervisors can use to construct training programs to improve learning of complex procedures. The four components 4C/ID-model relies on supervisors providing procedural information and supportive information, in a structure that can be divided for sub-task practice and learning tasks are relevant and recognisable.[35,36]

All components of the 4C/ID-instructional design model can also be applied to OR teaching. Surgical procedures can be broken down into steps, tasks and actions, which vary in complexity and are all relevant for the residents' learning.[34,37] Supervisors scaffold their residents' learning by default throughout the procedures (regulation of autonomy) and direct their teaching on simple and low risk parts before turning to more complex tasks.[4-6,12] Furthermore supervisors provide residents information that is context-specific and helps them to automate their actions.[4,7,12-14] Finally, supervisors stimulate problem-solving and residents' understanding of how actions relate within tasks and between tasks, as this study demonstrates.

However, there are constraints that decrease the efficacy of the OR as an teaching environment. Firstly, residents cannot repeat actions of subtasks to improve their learning. Secondly, learning-needs of residents are difficult to anticipate because learning-needs commonly surface spontaneously and rather unpredictable as procedures unfold.[4,10,12] Thirdly, and probably most importantly, learning and teaching is tacit and implicit.[38,39] Because supervisors are often unaware of their teaching behaviour we cannot expect them to deliberate tailor their behaviour to the learning needs in a time and outcome pressured learning environment. However, this study exposed the actual interactional practices of explicit teaching used by supervisors. Turning these insights of explicit teaching into a trainable for supervisors may be beneficial for residents' learning in each procedure.

7 | LIMITATIONS

This study is not without limitations. We analysed interactions in one teaching hospital and one specific procedure in one teaching culture. Other practices may exist and transferability of our findings should be explored by validating supervisors' behaviours in other procedures and settings.

8 | CONCLUSION

Supervisors add the *why* to the *what* when they inform residents how to use their expertise now and beyond the here and now. They introduced their explicit teaching in reaction of a (potential) problem in the present patient, directed at the smallest possible actions that define the surgical procedure, provided expertise to secure outcome in the present patient,, and has a specific design (if/then $+/-$ adjuncts) to teach residents professional vision and the degree of individual freedom and variation of their professional standards in problem-solving in future occasions.

AUTHOR CONTRIBUTIONS
PN (surgeon) and MH (linguist) led all aspects of the project. PN wrote the manuscript. FH (cognitive science), DJ (medical education), MS (qualitative and quantitative research), SK (orthopedic surgery and post graduate training) contributed to the analysis and interpretation of the data, each from their field of expertise. All authors made substantial contribution to all parts of the manuscript and its revision. They all approved of the final version to be published and agreed to be accountable for all parts of the work.

ETHICS STATEMENT

This research was reviewed by our medical ethical committee and they confirmed that the Medical Research Involving Human Subjects Act (WMO) did not apply. We followed the Helsinki declaration of medical research for all participants in this study.

ORCID
Patrick Nieboer https://orcid.org/0000-0001-7516-3072

REFERENCES

1. Svensson MS, Luff P, Heath C. Embedding instruction in practice: contingency and collaboration during surgical training. *Sociol Health Illn*. 2009;31(6):889-806.
2. Collin K, Paloniemi S, Mecklin J-P. Promoting inter-professional teamwork and learning—the case of a surgical operating theatre. *J Educ Work*. 2010;23(1):43-63.
3. Ong CCP, Dodds A, Nestel D. Beliefs and values about intra-operative teaching and learning: a case study of surgical teachers and trainees. *Adv Health Sci Educ*. 2016;21(3):587-607.
4. Nieboer P, Huiskes M, Stevens M, Cnossen F, Bulstra SK, Jaarsma DACD. The supervisor's toolkit: strategies of supervisors to entrust and regulate autonomy of residents in the operating room. *Ann Surg*. 2020; Publish Ahead of Print. https://doi.org/10.1097/SLA.0000000000003887
5. Chen X (Phoenix), Sullican AM, Smink DS et al. Resident autonomy in the operating room. *Ann sur* 2019;269(6):1080–1086
6. Moulton CA, Regehr G, Lingard L, Merritt C, MacRae H. Operating from the other side of the table: Control dynamics and the surgeon educator. *J am Coll Surg*. 2010;210(1):79-86.
7. Cope AC, Bezemer J, Kneebone R, Lingard L. 'You see?' Teaching and learning how to interpret visual cues during surgery. *Med Educ*. 2015; 49(11):1103-1116.
8. Arora S, Hull L, Sevdalis N, Tierney T, Nestel D, Woloshynowych M. Factors compromising safety in surgery: stressful events in the operating room. *Am J Surg*. 2010;199(1):60-65.
9. Cristancho SM, Apramian T, Vanstone M, et al. Thinking like an expert: surgical decision making as a cyclical process of being aware. *Am J Surg*. 2016;211(1):64-69.
10. Nieboer P, Huiskes M, Cnossen F, Stevens M, Bulstra SK, Jaarsma DADC. Recruiting expertise: how surgical trainees engage supervisors for learning in the operating room. *Med Educ*. 2019;53(6):616-627.
11. Torbeck L, Wilson A, Choi J, Dunnington GL. Identification of behaviors and techniques for promoting autonomy in the operating room. *Surgery*. 2015;158(4):1102-1112.
12. Sutkin G, Littleton EB, Arnold L, Kanter SL. Micro-relational interdependencies are the essence of teaching and learning in the OR. *Med Educ*. 2020;54(12):1137-1147.

13. Chen X (Phoenix), Williams RG, Sanfey HA, Smink DS. A taxonomy of surgeons' guiding behaviors in the operating room. *Am J Surg* 2015; 209(1):15–20

14. Roberts NK, Brenner MJ, Williams RG, Kim MJ, Dunnington GL. Capturing the teachable moment: A grounded theory study of verbal teaching interactions in the operating room. *Surgery*. 2012;151(5): 643-650.

15. Flin R, Youngson G, Yule S. How do surgeons make intraoperative decisions? *BMJ Qual Saf*. 2007;16(3):235-239.

16. Bell RHJ, Biester TW, Tabuenca A, Rhodes RS, Cofer JB, Britt LD. Operative experience of residents in US general surgery programs: a gap between expectation and experience. *Ann Surg*. 2009;249(5): 719-725.

17. George BC, Bohnen JD, Williams RG, Meyerson SL, Schuller MC, Clark MJ. Readiness of US general surgery residents for independent practice. *Ann Surg*. 2017;266(4):582-594.

18. Mir HR, Cannada LK, Murray JN, Black KP, Wolf JM. Orthopaedic resident and program director opinions of resident duty hours: a national survey. *J Bone Joint Surg am*. 2011;93(23):1421-1429.

19. Kairys JC, McGuire K, Crawford AG, Yeo CJ. Cumulative operative experience is decreasing during general surgery residency: a worrisome trend for surgical trainees? *J am Coll Surg*. 2008;206(5): 804-811.

20. Federatie medische specialisten. Verkorting opleidingsduur naar beneden bijgesteld. Beschikbaar via: https://www. demedischspecialist.nl/nieuws/verkorting-opleidingsduur-naar-beneden-bijgesteld Retrieved 2021 September 11.

21. Patkin M. Surgical heuristics. *ANZ J of Surg*. 2008;78(12):1065-1069.

22. Hughes TM, Dossett LA, Hawley ST, Telem DA. Recognizing heuristics and bias in clinical decision-making. *Ann Surg*. 2020;271(5): 813-814.

23. Cnossen F. Cognitive skill in medicine: an introduction. In: *PanVascular Medicine*. Berlin, Heidelberg: Springer; 2014:1-41.

24. Anderson JR, Bothell D, Byrne MD, Douglass S, Lebiere C, Qin Y. An integrated theory of the mind. *Psych Rev*. 2004;111(4):1036-1060.

25. van Wijmen FCB. De Wet medisch–wetenschappelijk onderzoek met mensen. *Tijdschr Voor Gezondheidsrecht*. 1998;22(2):21-32.

26. World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *Bull World Health Organ*. 2001;79(4):373-374.

27. Hepburn A, Bolden GB. The conversation analytic approach to transcription. In: Sidnell J, Stivers T, eds. *The Handbook of Conversation Analysis*. Chichester, UK: John Wiley & Sons, Ltd; 2012:57-76.

28. Schegloff E. *Sequence Organization in Interaction: A Primer in Conversation Analysis*. Cambridge: Cambridge University Press; 2007.

29. Heritage J. Online commentary in primary care and emergency room settings. *Acute Med Surg*. 2017;4(1):12-18.

30. Heritage J, Stivers T. Online commentary in acute medical visits: a method of shaping patient expectations. *Soc Sci Med*. 1999;49(11): 1501-1517.

31. Goodwin C. Professional vision. *Am Anthropol*. 1994;96(3):606-633.

32. Ericsson KA. Expertise in interpreting: an expert-performance perspective. *Interpreting*. 2000;5(2):187-220.

33. De Groot AD. *Thought and Choice in Chess*. The Hague: Mouton & Co; 1965.

34. Nieboer P, Cnossen F, Stevens M, Huiskes M, Bulstra SK, Jaarsma DACD. Residents think in the "now" and supervisors think ahead in the operating room. *J Surg Edu* 2020. https://doi.org/10. 1016/j.jsurg.2020.06.010, 78, 1, 104, 112

35. Van Merriënboer JJ, Clark RE, De Croock MB. Blueprints for complex learning: the 4C/ID-model. *Edu Tech Res Devl*. 2002;50(2):39-61.

36. Vandewaetere M, Manhaeve D, Aertgeerts B, Clarebout G, Van Merriënboer JJ. Roex, A.4C/ID in medical education: how to design an educational program based on whole-task learning: AMEE Guide No. 93. *Med Teach*. 2015;37(1):4-20.

37. Nieboer P, Huiskes M, Cnossen F, Stevens M, Bulstra SK, Jaarsma DA. Fingerprints of teaching interactions: capturing and quantifying how supervisor regulate autonomy of residents in the operating room. *J Surg Edu*. 2021;8(4):1197-1208.

38. Eraut M. How professionals learn through work. 2008; Retrieved from http://learningtobeprofessional.pbworks.com/Michael-Eraut, September 2021.

39. Teunissen PW, Wilkinson TJ. Learning and teaching in workplaces. In: Dornan T, Mann KV, Scherpbier AJJA, Spencer JA, eds. *Medical Education: Theory and Practice*. Edingburgh UK: Elsevier Health Sciences; 2011:193-111.