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ORIGINAL RESEARCH

Developing expertise in gynecologic surgery: reflective perspectives of international experts on learning environments and processes

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Abstract: Research in medical education does not provide a clear understanding of how professional expertise develops among surgeons and what experiential factors contribute to that development. To address this gap, the researchers interviewed 16 international experts in female pelvic medicine and reconstructive surgery to assess their reflective perceptions of what specific opportunities and experiences initiated and supported their development toward expertise in their field. Characteristics and influences explaining the speed and quality of expertise development were sorted into the following themes: the dynamic process of expertise development, internal and personal characteristics, general aptitudes and preparatory skills, role modeling and interpersonal influences, opportunities to learn and practice, and roles and reference points. Across the narratives and perspectives of these expert surgeons, both individual characteristics and choices, and contextual activities and opportunities were necessary and important. Experiences with greatest impact on quality of expertise development included those provided by the environment and mentors, as well as those sought out by learners themselves, to elaborate and supplement existing opportunities. The ideal combination across experts was interaction and integration of individual characteristics with experiential opportunities. Grounded in theory and research in expertise development, these findings can support improvement of medical education, both for individual mentors and strategic program development. As surgery evolves at a continuously increasing pace, effective mentoring of promising surgical trainees will be critical to ensure that future generations of gynecologic surgeons will remain excellent. Effective, efficient surgical expertise development requires identifying trainees with the appropriate characteristics and providing them with the best development opportunities.

Keywords: expertise development, female pelvic surgery, learning environments

Introduction

For centuries, physicians have been trained on an apprenticeship model.[1] Some of these physicians have become good, solid practitioners, but with minimal recognition. Others have become widely recognized experts in their field specialties, those who peers contact when they encounter cases that require the highest level of expertise and professional judgment. Medical education can benefit from leveraging theory

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on expertise development into new research on what educational opportunities and experiences helped these more expert practitioners along the trajectory to their standard of excellence. Such opportunities could be replicated for the benefit of current physicians-in-training, and improve the field of medicine.[2]

In the US, many physicians are dissatisfied with the quality of their surgical training due to mandated changes in postgraduate medical education, such as the introduction of work hour restriction which limit trainee experience.[3,4] Public funding (such as through Medicare) pays for most of the cost of medical residencies, approximately a hundred thousand dollars per year per resident.[5] As a result, surgical training programs face accountability pressure to verify expertise development in postgraduate education that justifies that price tag. These pressures are likely to build (especially with implementation of the Affordable Care Act), so it will be increasingly critical to effectively identify suitable candidates for advanced gynecologic surgical training and employ effective strategies to train and mentor those individuals.[6] In Europe as well as the US, the quality of surgical training is threatened by increasing subspecialization, shortened periods of training due to duty hour restrictions, and rapidly emerging technological and surgical innovations.[7] Thus, identifying factors that promote surgical expertise development is an international need.

Background

The medical profession is changing rapidly. Demands of expertise and practice in medicine and surgery change continuously, making continuous learning and development necessary, both to become a good surgeon and to remain one.[8–10] Surgeons have to treat patients today with tools and methods that did not even exist when they were trained. Developing professional demands can be achieved not only by initial learning but also by continuous learning and effort to develop and innovate throughout their careers. With health and medical professions influenced by economics, culture, and technology, research cannot make assumptions that things are as they were even a decade ago.[5] The US is facing an extreme shortage of physicians across specializations, particularly surgeons and those serving older populations.[10,11]

Recent changes in medical education policy and practice require medical educators to rethink and redesign on new developmental frameworks.[11,12] Surgical educators and program developers need to understand what processes and influential factors produce recognized expertise, information they can use to redesign existing programs to facilitate similar development, amidst changes in practice and policy constraints.

Theoretical frameworks and research precedents

This study utilized a fully integrated conceptualization of expertise development based on the merging of cognitive and affective elements of learning and experience.[12,13] Frameworks for this study are the theories and research-based principles of expertise development[13–17] and situated and social cognition.[18–20]

Nature and development of expertise

Expertise in any domain or profession comprises cognitive knowledge and reasoning, cognitive and behavioral skills, and affective and perceptual elements, all of which together enable expert reasoning and performance.[8,9] Expertise is complex and often difficult to define or to assess decisively, apart from performance evidence.[21,22] As essentially an applied problem-solving profession, surgery expertise hinges on professional judgments and naturalistic decision-making, often done in response to unexpected events.[23]

Every skill and profession has a knowledge base comprising both basic and advanced knowledge, and a skill set comprising both general (cross-disciplinary) and field- or task-specific (domain) skills. General skills in surgery include things like acute observation, critical reasoning, analysis, problem-solving, and adaptive thinking.[9,10] Domain-specific skills in surgery include things like manual precision, surgical procedures and techniques, anatomical knowledge, and accurate tool-handling.[9,10] The body of knowledge and skills for a given field or domain of practice comprises its professional competencies.[22,24] However, expertise moves beyond core competencies to doing the job faster, better and more effectively, more fluently, and with fewer errors.[25] These are the characteristics that distinguish experts from novices in professional practice.

Adaptive expertise grows and endures over time, in response to developing relative expertise in a changing field. In contrast, unadaptive expertise deteriorates over time, relative to changing expectations (only enduring to the extent that it includes stable methods). Maintaining expertise in an ever-changing field requires being open to continuing development. Continuing medical education that supports expertise requires more than the individual trying new things solo because research has demonstrated that physicians often self-assess their developing competencies inaccurately and

require external expert assessment to effectively acquire new skills.[13,23]

The development of expertise is a multidimensional, multistage process, which may begin with formal education or experience, and continues over a career, based on needs, opportunity, additional input and modeling, and ongoing experiences.[13,14] Expertise development depends on exposure to, and practice with, a broad range of relevant situations, to develop adaptive skill range reaching across the domain, and including the development of professional identity.[15] The development of expertise and concurrent identity development across applied fields is supported by expert role modeling and mentoring,[26] characterized by robust tacit knowledge and practical intelligence,[24,27] and enriched by social support and encouragement.[16,17] Expertise development produces measurable neurological change, demonstrated in the physiology of the brain, as physical synaptic connections reflect the development of cognitive schema supplying rapid processing to support expert reasoning and intuitive linkages.[25,28]

The study of expertise development needs to acknowledge a set of psychological processes that promote or diminish it, such as initial learning and long-term retention, linkages between prior and new learning, schema development and problem-solving, and development of actual and perceived competence.[15,16] As expertise itself is context-specific, a number of contextual factors also influence its authenticity and rapidity of development.[19,20]

Situated and social cognition

Medicine (both clinical and academic) has social dimensions at the core of its skill set and work environment, making social learning and development a natural fit as a theoretical basis for understanding it. Senior mentors function as developing physicians' most important social and professional influences.[26,29,30] The learning and mentoring contexts of medical education are characterized by sequential training rotations under multiple models and in teams with various mentors, making them socially dynamic learning environments.[26] In addition, the performance contexts for surgery are innately social spaces, where collaborative action and communication with others determine success.[18–21] Thus, understanding the social and contextual nuances that enable physicians to develop exceptional skill and aspire to expertise is essential to achieving and maintaining excellence in medical teaching and practice.

In addition, the cognitive work of medicine is highly situated, contextualized in the requisites of specific demands, and of particular performance environments that cue trained actions and responses.[9,27] Expertise in complex problem-solving skills (like surgery) requires situated awareness of the need, possible solutions, and expert reasoning about best options for a particular case.[14,28] To develop expert physicians and surgeons, medical education must understand and build the situated cognition that supports and surrounds task knowledge and skills.

Motivation is closely related to expertise, as the reasons people choose careers, and the benefits they believe effort will yield, promote engagement, effort, and development.[29,31] Understanding the motivations that drive academics in medicine and health sciences to choose particular learning opportunities is a part of understanding their overall development as experts.[30,32]

Defining medical and surgical expertise

Based on its applied nature, surgery has been referred to as "a craft",[33,34] but expertise in highly technical professions is more complex than such a term communicates. Depending on the precise nature of the work, and its process and products, expertise is defined in a number of ways.[9,10] Expertise may be defined based on preparation or performance, on education (operationalized as degrees and certifications, specialty studies, or mentoring), or on past or current experience (operationalized as number of procedures done, or as number of years working in the field or specialty).[35] Depending on the nature (or existence) of field competencies, expertise may be defined objectively (such as by number or percentage of successful surgeries, or by years without complications) or subjectively (in terms such as "good hands" or "talented"), as judged by individuals or by a professional community. It may also be defined based on variety of contexts and tools or tasks so that a surgeon may be an expert in one surgical task but not others (eg, cardiac vs orthopedic surgery, abdominal vs vaginal hysterectomy), or with traditional tools but not with new ones (scalpel vs laparoscopic or robotics). New techniques and technologies add layers of technical skills on top of the original surgical task work and shift the nature (and definitions) of expertise. The challenge of this kind of complexity is that it presents no clear and generalizable criteria for "successful" or "expert" performance, which complicates efforts to codify it for educational and evaluation needs.[9,10]

Developing medical and surgical expertise

Becoming expert in a high-risk, applied profession such as surgery is marked by characteristics such as intuitive indicators that lead to problem diagnosis, automaticity of technical and procedural skills, and rapid adaptation when

confronted with unexpected circumstances or complications.[36,37] The initial development of advanced reasoning, field-specific intuition, deep knowledge, and adaptive thinking also support ongoing learning and innovation.[31,38] Medical training traditionally includes formal, classroom instruction, followed by the cognitive apprenticeship, with the goals of unpacking and instilling knowledge, skill, procedural understanding, and expert reasoning in authentic performance contexts.[32,39] The context of medical education begins with a high degree of constraint and controls, followed by gradual progression to more independence and autonomy.[40]

Historically, much of the existing research on medical expertise has been done primarily with a few "experts" (often defined as experts primarily by time-since-graduation).[34,41] They are often compared to convenience samples of medical students without authentic experience in practice.[42] To gain the advantage of later career perspectives including adapting through career changes, experiences requiring a range of professional judgments, and exposure to a broad range of expertise beyond their own, this study drew on expert senior scholars-practitioners and physicians already recognized as experts in their field and specializations.

To inform the establishment and improvement of standards and practices for medical education, research is needed that targets the nature and development of expertise for medicine generally and for particular specializations. This research needs to identify true experts based on more than time alone, taking into account the many dimensions of expertise in a field of high-stakes professional practice, and examining in detail the nuances of how expertise is defined and developed.

Synthesis of data on defining expertise

A recent study reported on how expert gynecologic surgeons described expertise in the specific task work of advanced gynecologic surgery.[42] Their perspectives were generally consistent with the general literature on medical expertise, operationalized for this particular specialty, and they illuminated a number of key components related to tensions in defining medical and surgical expertise. It is overall a complex psychomotor task involving problem-solution, based on the cognitive processing of situationally changing diagnosis from visual cues. The strategic and technical skills consist of applying that surgical vision to understand the problem and treatment options, and then using surgical tools (traditional, robotic, laparoscopic) to treat it. The strategic goal of surgery is to treat the existing health problem effectively, while maintaining the least pain and risk of injury to the patient. Success depends on adaptive tactical decision-making and motor responses in executing the problem-solution. Experts developed rapid reasoning and fluid skills that belie the effort they expend. Experts' most salient key elements of gynecologic surgical expertise were as follows:

- Cognitive information and knowledge (anatomy, task-based procedural skills, diagnostic indicators of use)
- Recognizing task cues (their nature, presentation, links to problem identification)
- Adaptive tactical decision-making (being able to plan, decide strategy, execute, adjust as needed when unexpected events arise)
- Visualization of the problem/task space (from knowledge recall plus tactile feedback, with emphasis on dimensionality and accuracy including all relevant structures)
- Skilled motor response (rapid, appropriate, facile, accurate, and safe)

Research focus

Building on recent work in defining surgical expertise, the present study examined how expertise in urogynecologic surgery is developed, from the perspective of recognized experts in the field. Key questions that framed data collection on developing expertise included the following:

1. How did these surgeons develop into experts in gynecologic surgery?
2. What were the critical junctures in their journeys toward expertise in this complex and changing subspecialty?
3. To what specific educational opportunities and activities do they attribute their success and high-quality skill development, and why?
4. What strategies do they use to mentor their own students toward expertise, and what indicators do they use to monitor and judge that development?

Methods

Design

In this descriptive design, the researchers used a reflective narrative technique facilitated through semi-structured interviews.[35,37,38,43–45] This method of gathering qualitative data prompts revelation of important life experiences illuminated by participants' reasoning.[39,40,46,47] The research initiated and supported the experts' sharing of unique insights and personal narratives featuring key points of learning and development, with attributions of internal (personal) and external (environmental) factors contributing to their professional knowledge and skill development, leading to expertise. Given the

interactions of cognition (thinking), emotions (feeling), and social (interpersonal) experiences in the authentic dynamic of career and professional development, the interviewers strove to capture all of these elements of the expert surgeons' experiences.

This study intentionally focused on the sample of internationally recognized expert senior surgeons, to identify the characteristics and experiences that had raised them to national expertise and sustained them in learning and excelling across periods of change. The goal was to obtain fine-grained data that supported a rich understanding of the complex developmental processes involved in defining expertise in a surgical specialty, and in becoming nationally known experts in such a specialty. Experts offered the dimensions of professional insight and experience that authentically reflect the full process of expertise development. Their reflective experiences can help to shape the development of learning environments to educate the next generation of expert physicians and surgeons.

Participants

All measures and activities included in this study were reviewed and approved by the University of Oklahoma's Human Subjects Research Institutional Review Board.

Selection and recruiting

This study investigated the perspectives of expert UroGyn surgeons. The researchers accessed participants at two prestigious professional conferences where these experts gathered annually. They were invited to participate by a peer, either just before or during the conference, and then scheduled and consented per human subjects requirements. Participants who initially agreed and came to scheduled appointments were presented by the researcher with the Institutional Review Board-approved consent document, allowed to read it, invited to ask any questions, and given free choice to accept or decline. They were aware of who would read their deidentified responses (the research team members' names were listed on the consent document). Those names included one coauthor who was a peer, an expert ObGyn surgeon in the professional community, and one who was a fellow in ObGyn surgery working under that peer. All 16 who came to appointments accepted, signed the consent document, and participated in the interviews. Twenty-one were invited, and 16 participated (71%).

Experts were identified a priori based on a set of characteristics consistent with established professional criteria of expertise: their specialized education (advanced education and residency in UroGyn surgery), experience (at least 5 additional years of active practice in UroGyn surgery, in a high-volume surgical center), scholarship (actively doing research, publishing in scholarly journals, and presenting at professional conferences in the specialty of UroGyn surgery), professional status (keeping current on developments in UroGyn surgical practice), and reputation in the professional community (frequently invited to speak at or keynote professional events, and consulted by colleagues on difficult cases).

Profile

Participants were 16 active consultant surgeons in UroGyn surgery. (Female pelvic medicine and reconstructive surgery is an American Board of Medical Specialties-certified subspecialty. Members of this group must first complete training in either obstetrics and gynecology or urology. Urogynecology is the study and treatment of pelvic floor disorders such as female urinary incontinence, fecal incontinence, and pelvic organ prolapse. "UroGyn" is an informal term that is frequently used to describe or self-describe surgeons who practice in female pelvic medicine and reconstructive surgery.)

All are practicing surgeons in high-volume medical colleges and surgical centers, who perform an average of over 100 procedures per month (compared to the national average of nine) and supervise surgical residents. All publish scholarly papers in top medical journals and present at prestigious medical conferences. The sample included nine (56%) males and seven (44%) females, aged 35–72 years (mean: 50), with 5–35 years in practice post-residency or fellowship training (mean: 19).

Data collection

The 16 expert surgeons individually participated, and had 30- to 50-minute semi-structured interviews conducted in a private room by an experienced interviewer (generating >12 hours of interview data). Interviews were conducted by the first author, a social science researcher skilled in qualitative research and interviewing. These elements of the design provided consistency in the way interviews were conducted. She had not previously met any of the participants and did not have a personal or professional relationship with them. This element of the design supported objectivity in data collection.

Guiding points of interest for the interviews are captured in the questions. The semi-structured format utilized more detailed questions to illuminate and follow-up participants' responses as interviews progressed. Beginning with these standard questions, the researcher adapted follow-up questions consistent with the direction of each participant's

personal narrative. Interviews were documented using digital audio recording and observation notes, which were professionally transcribed for coding and analysis.

Interview questions

1. How did you come to be an expert? What was your pathway to expertise?
2. Do you have a theory about what builds surgical expertise? If so, please explain it.
3. What methods and strategies do you use to teach people to be more expert surgeons in this specialty? Please give as much detail as possible.

Analysis

Procedures were consistent with systematic practice in qualitative research analysis.[41,42,48–50] The data were de-identified before analysis, with participant names converted to code numbers, and any potentially identifying information redacted from the transcripts. Two of the researchers (the social science researcher and the ObGyn fellow) conducted independent, hand-coded, thematic analysis of the interview transcripts. Then they met, compared notes, and distilled and synthesized their observations into convergent themes. They reached consensus on categories of themes, with minor overlap, as some comments could fit into several themes. In such cases, the researchers discussed and placed them based on dominance in meaning. The third researcher (the ObGyn peer) reviewed and checked findings as an objective expert.

Thematic analysis of rich qualitative data is a reciprocal, recursive process of coding by segmenting the data into dominant emergent categories, and then developing them into a coherent and meaningful set of examples illustrating those thematic response categories.[49] For this data set, a theme required at least six instances of evidence appearing across six different participants, along with triangulation and convergence from other contexts within the data. In other words, the theme needed to form a coherent and continuous thread through the data and across participants, rather than appearing once for a particular question or in just a few interviews. This standard of consistency and coherence is an important criterion of trustworthiness for qualitative data.[44,45] Due to their limited valuable time, no direct verification by participants was possible. However, the team of researchers were consistent and confident of findings, based on the multiple independent coders, high degree of consensus, triangulation of data from multiple participant interviews, and confirmation of the third expert. This systematic analysis generated multiple aspects of the process and influential factors in developing surgical expertise.

Findings

Developing expertise included how these experts and those they know developed to become recognized experts, what educational opportunities and activities they felt had contributed to their development most significantly, and what other influences they had found most important in refining and maintaining their surgical expertise. The following sections present the predominant response themes produced by the data, organized under the following categories: the dynamic process of expertise development, internal and personal characteristics, general aptitudes and preparatory skills, role modeling and interpersonal influences, opportunities to learn and practice, and roles and reference points. Each theme is divided into subcomponents, illustrated by exemplar quotes from the interviews. Numbers following the quotes indicate the code numbers of the participants quoted, included to illustrate the range of sources represented.

Dynamic process of expertise development

The process of expertise development involves a complex, reciprocal interaction between actual knowledge development, personal self-confidence, and trust from others (the supervisor, peers, patients):

> Repetitiveness of the training coupled with the knowledge […] as the person gains more knowledge, they gain more of your trust, and they are able to do more tasks […] it's a very slow progression. [8]

Signs of development toward expertise

Movement toward professional expertise is demonstrated by the dual skills to do and to teach the surgical specialty:

> Someone who, first and foremost, can demonstrate the proper knowledge of our field: anatomy, management, treatment. Now, granted, it's ever-changing, but definitely more than just the basics, a significant amount more than the basics, and able to communicate that to either trainees or colleagues. [9]

Internal and personal influences

Experts develop through complex interactions of internal and external factors as they control some of their experiences but receive others as opportunities or affordances through the supervisor or learning context.

Attitudes and habits of mind

These expert surgeons identified a set of attitudes and habits of mind which characterize those positioned to develop expertise. These characteristics consistently emerged in their own developmental narratives as well as in their descriptions of indicators that they use to signal which trainees are most likely to become expert.

Motivation and "hunger to learn"

A predominant theme was that those who became experts were motivated and hungry to learn, not just the basics but far more:

> There's got to be that inner drive that I want to be better […] you've done thousands of this. There's still opportunity to learn […] that self-desire to perform well […] I want the gold […] I want to do well for this patient. [6]

Passion and hard work

Caring and working hard were among the most repeated individual characteristics that prepared trainees to develop surgical expertise:

> Expertise is going to follow because you have passion for what you do and you want to work a little bit harder than everybody else. The only way I've gotten ahead is that I can physically outwork everybody else around me. But if you have a passion for it, then you don't really mind working the extra time, doing the extra things. [11]

Humility or teachability

A second commonly mentioned individual characteristic that positions surgeons for expertise development was humility:

> Humility is not a weakness; it's a strength. [10]

Humility was often coupled with willingness and ability to take criticism because that supported maximum learning and skill improvement. Teachability includes the willingness to receive and process critiques and debrief procedures, rather than become ego-involved and defensive. Nearly all of the experts described some components of this skill, in terms that converged on its pivotal importance, and agreed that the mentor needs to give feedback, and the trainee needs to process and learn from it. Supporting development is harder for mentors when learners are not humble:

> Debrief. It's hard to do because people sometimes get defensive. [5]

Critical thinking and quick, informed judgment

Until surgery occurs, the exact nature of the patient's problem may not be fully known, so the surgeon's expertise needs to include critical thinking and informed professional judgment. One expert described surgical judgment like this:

> Anatomy, knowledge of the procedure, but then there's the certain ability to put it all together, think on your feet […] because often you'll end up in situations where this wasn't in the textbook […] I always tell patients, "I don't know what's going to happen until I get in there," and you just have to take it as it comes. [12]

Metacognitive self-reflection

Related to development are caring and the individual's ability to self-process experience, self-evaluate performance, seek out help, additional perspective, or remediation as needed.

> We go home and we're thinking about that case that night, or you're waking up at night or you're seeing that patient back and there's an issue, and that ought to bother you. That's the sort of self-reflection or the personal burden that you ought to carry to some degree because then it matters. [6]

One expert framed this as the key to take surgical expertise to the highest level:

> Your ability to reflect and really be more introspective […] that ability to assess—especially when things don't go as planned, when you have a more complex case. One's ability to do that will ultimately help expand their horizons as a surgeon. [7]

Several of the experts explicitly linked self-reflection to feedback and critique, synergistically:

> To put in the effort, to be critical of yourself, let yourself be coached, willingness to learn, willingness to develop, look at new stuff and critique yourself. [16]

General aptitudes and preparatory skills

Surgical expertise development is based on mostly learned skills, but some preexisting capacities can support development. If it does not exist prior to surgical training, then it needs to be developed.

Three-dimensional visualization of the problem space

Given the nature of surgical skill, the aptitude to cognitively visualize a unique three-dimensional (3-d) problem space is critical:

> A 3-d vision for the important parts of the relevant anatomy. [1]
>
> This 3-d anatomy that I think people have a difficult time understanding. [10]

The visualization skill has to be adaptive enough to hold the basic anatomy in place but also take into account normal variations and abnormalities in each patient:

> You get difficult surgeries […] You start by going back to visual cues […] building a three-dimensional model in your mind. [but then] altering it a little bit to the presentation and the patient […] depending on how the anatomy is […] and so the expertise comes. [2]

Good hands

Surgery requires precise manual skill application, including the manipulation of sharp tools and other dangerous equipment, so it requires a high degree of manual dexterity, precision, and control:

> Some of it's cognitive. Some of it's motor skills. [5]
>
> There are concepts, things, techniques in surgery that are extremely simple when you really look at them and understand what it is that you're doing, but the simplicity belies how pivotal these things you're doing are, how much hinges on this. Appropriate technique, suturing, where you put that stitch. [3]
>
> Hand-eye coordination and the way people handle instruments. [4]

Good manual skill refined by quality training produces fluid motion in surgical practice:

> That's sort of the art of it. You watch someone that's a good surgeon and it just looks really easy because it's smooth. [12]

Some of this manual facility can be learned, and all agreed that it can be refined, but to some degree, it is extant before surgical training for most experts:

> There's an innate technical ability that's certainly helpful, then it's just dedication, willingness to do the work, the unpleasant stuff, accept failures and go back over those. [16]

Long-range, conditional, and systemic thinking

Long-range thinking refers to thinking many steps ahead. Conditional thinking means having "what-if" options in mind, in case of the unexpected. Systemic thinking is considering all of the potential needs, implications, risks, and issues surrounding a case or decision in surgical care. One mentor described the way he checks for and observes range of thinking with trainees:

> When you pose a question, how do they handle it? If they see a patient in the office, what options do they come up with for the management of that patient? Do they consider all of the potentials […] the nuances of surgery and of patient care? [12]

Another described his process for promoting these types of thinking around a surgical case, for surgical residents specifically:

> I would try to have them follow through the whole process, understand how the patient got there, how the decision-making occurred, and then in the OR […] the scrub team conversation […] "okay, so we are going to do this. What are you going to do if this happens? What are you going to do if that happens? […] so what is your plan if A, B or C happens," and make them verbalize it […] picture yourself going through the whole event see all of the pieces before it happens, so you've thought it through before it occurs, then follow through and do it--not just being there passively. [14]

Communication and interpersonal skills

Surgery does not end in the operating room (OR) and does not occur in a vacuum. It includes:

> Personal skills, getting along with patients, colleagues, team members […] calmness under stress. People skills are very important. [16]

Communicating with patients is important to ensure that they follow through on post surgical recommendations and just knowing how to protect their own health over time:

> It's communicating with the patient and also being able to translate things into terms patients can understand […] making sure your patients walk out of there educated as well as taking care of them. [2]

Communicating in the OR is developed through modeling and think alouds, similar to the processes described for developing thinking and judgment:

> A lot of the time, before we start a case, I like to draw out what we are doing […] my fellows are expected to read about a case before they come in, so they are usually familiar with the basic methodology […] I also try to explain to my surgical scrub techs, too […] just so everyone knows how things work […] I welcome questions, because I feel like that makes it a less adversarial environment and people are able to have kind of a free exchange of information. Continuously throughout the case I ask, "Are there any questions? Do you see what I mean?" [7]

Role modeling and interpersonal influences

The importance of expert mentoring endures in medical and surgical education, and most experts were influenced into their specialization and inspired toward expertise in it by their own expert mentors.

Respected expert mentors

One surgeon recalled the compelling value of striving for excellence to avoid disappointing mentors:

> I can think of training and not wanting to disappoint the person that was my mentor, the person I was assigned to or learning from. [13]

The respect and admiration that students have for their expert mentors open doors to teaching and development inaccessible to less-respected supervisors.

Admired role models fuel expert aspirations.

Another observed the power of modeling to fuel aspirations to be like those physicians he saw as expert:

> I can think of the gentleman that I rotated with on my third-year OB rotation for a month. [Name] had a great influence on me in terms of liking OB/Gyn., and I think there's something to that. Your exposure the charisma, the enthusiasm they have, that modeling that you can identify with. [3]

Mentoring with critical questions

Exposure to challenging cases as learning opportunities is foundational to developing surgical expertise, and it can be further enhanced by a mentor asking appropriately critical questions to promote the development of strategic reasoning and judgment. One expert described how he used challenging cases as opportunities to teach his surgical fellow reasoning and judgment in addition to technical skills:

> We'll have a complex patient that's multispecialty. What are you going to do about it? What's the goal? To fix what? […] It's a lot of judgment. You do have to teach them how to think. [13]

Meaningful and well-timed feedback

Feedback was critical in the experts' own development, and it is an essential part of the way they mentor their own surgical trainees. They recognize the utility and importance of appropriate feedback on less-than-expert performance:

> If you're not doing it right, you need feedback on that […] but to let people do stuff and not give them feedback isn't helping them ultimately. [6]

They recall the importance of positive, constructive feedback in their own development and make it a priority for their own students:

> I have very high expectations, but […] You've got to give some positive feedback. [13]

Opportunities to learn and practice

Plenty of regular, spaced practice across different examples is the key to learning any procedural or problem-solving skill well, and surgery is both a procedural and a problem-solving skill. Practice opportunities that support expertise development should be both abundant and varied, and include successes and failures, to result in optimal learning.

Multitude of opportunities

> Experience gives you expertise. [8]

Surgical experts shared stories of receiving or seeking out myriad opportunities to practice using their surgical knowledge and skills because:

> Volume and repetition become the key to becoming whatever an expert is. [6]

One expert shared his method of gaining a multitude of opportunities in medical school:

> My personal philosophy was to do every single procedure as many times as I could before I graduated because I was covered in case there was a problem. It's that mindset and willingness to get out of your comfort zone and just keep going. [11]

Diverse range of opportunities

The full range of opportunities to develop expertise includes many different types of cases, from simple and common to complex and rare:

> Having enough practice, enough exposure to cases and enough practice, and enough seeing the ones that go right, and the ones that go wrong also […] they have to see patients before and afterward […] put the time in, and have enough opportunity to practice. [14]

They recognized the importance of diverse experiences in their own development and considered it a function partly of context:

> With regard specifically to surgical practice, I think that the development of expertise has to involve not just a volume of patients, but a variety of patients within the populations […] Encountering and solving different surgical aspects that can

> come from a tertiary care center, for example, would probably develop expertise a lot faster than someone encountering uncomplicated issues out in the community. [15]

Throughout the career, experts acknowledged that diversity of practice promotes expertise growth and maintenance:

> In terms of surgical expertise, it's every day you learn something different. Every patient is different. Every patient teaches you something different […] I am learning how to improvise what I've learned in the past to make better surgery for the future. [7]

Authentic opportunities

An optimal range of real surgical cases are not always available during a given timeframe, wherever the surgeon is in training, so many depend on practice with simulators or cadavers. Some of these opportunities offer excellent authenticity, but others do not, and expertise depends on authentic – not trivial or artificial – practice. Different aspects of practice opportunities can authentically simulate true practice, each in its own way:

> I had exposure to fresh cadavers during residency, and started doing that monthly […] [because] a fresh tissue cadaver is where things feel like they feel in the OR and where you get to see the subtle varieties in anatomy that people have. [1]

Find or initiate opportunities not readily available

Some environments provide the key components for practice that supports expertise development, but when these are not readily available, those who became experts took initiative to seek out and make opportunities of their own. One expert explained that his self-assessment led him to do an extra training year:

> I felt like, "But I haven't done enough of this or enough of that." […] I was disillusioned that people thought that was good enough, so I did the extra year. [14]

Learning through error as well as success

Some of the most powerful learning occurs through error, and while errors refine expertise across novel situations, errors can also put patient lives at risk. For that reason, refining expertise through error while surgeons have the safety net of greater expertise alongside is an optimal balance. One expert described his own development as pivoting on errors made and lessons learned:

> Watching and learning from other people's mistakes and from your own mistakes […] know you're not immune to these things and to be humbled by those things and hopefully be thinking about how to do it better every single time. [10]

Several experts spoke of the importance of the protection during surgical training, and their own shifts from protected to protectors:

> Within fellowship, everything is protected […] you are in there with an expert in that type of surgery, and you feel like, "If anything starts going wrong, I'm going to be stopped and corrected […] So I'm confident and we are good." Yet when you are the expert, there is a paradigm shift in your mentality […] you have to keep ahead of the game and anticipate what the next step is, what you may need to correct in order for things not to go south rapidly. [15]

Expert feedback throughout opportunities

Expert feedback promotes learning at any phase, but is optimally effective in promoting development when it continues throughout the process, from expectations and preparation, through the follow-up debrief, self-critique and expert critique, and remediation.

> There is an art to constructive criticism and feedback […] I'm always at the side of my fellow or resident, to give them constant feedback, whether it's positive or not, so they know what they're doing. Tell them exactly what I expect beforehand. Give them a little bit of feedback after the procedure. If there's something that didn't go right, I might say, "What do you think you could've done differently? How could we have approached this in a different way? Would you have done it differently now? Why did you do it this way?" I'd try to get their feedback about how they thought things went. [8]

Roles and reference points in developing expertise

The experts' reflections included perspectives on the contexts, roles, and responsibilities in surgeons' expertise development, along with how they judge expertise development in their own surgical residents and fellows.

Reduction in accessible practice

A number of the experts pointed out realistically that changes in the field (policy, technologies) have constrained surgical trainees' access to opportunities:

> The actual case numbers that residents do are getting less and less […] so when they graduate, they're not qualified to operate on their own. [11]

> With limiting resident work hours […] There's barriers we're building in, which are leading to more of a narrow, or less of a broad base, of education. […] They don't have the tools to be able to practice to increase their skill set. [12]

They pointed out that this means mentors and trainees have to work harder to find opportunities to supplement.

Roles and responsibilities for expertise development

Narratives converged on the role of mentors in helping to provide opportunities, and the importance of learners taking personal responsibility to engage those opportunities:

> Providing them with confidence, a certain skill set and getting them to understand that they can become better and better and better with practice and their own due diligence, but it's ultimately on them, and they are not going to be expert at anything if they don't practice on their own. [7]

Performance indicators of expertise development

Observing and judging development toward expertise includes seeing mentees work toward refining skills, and determining who is not yet ready to do a procedure independently, and when to step in and take over if a trainee is not succeeding. Expert surgical mentors included both verbal (knowledge) and applied skill (performance) indicators of developing expertise:

> a lot of it is in our dialogue during the case and during planning […] When they're in the process of actually suturing and cutting and taking bits of tissue, a lot of times I can kind of discern who might be more tentative and rightly so, or who might be very bold, but sometimes those bold motions are not well-founded. The confidence of the hand is not directly correlated to the expertise of the surgeon. [9]

They also acknowledged the balance of giving opportunity and autonomy, while being vigilant about when to use their supervising "safety net" of assistance, also an implicit indicator of expertise development:

> I really set time limits on things. If they've tried something once or twice […] [I] take over a portion of the procedure to move thing along safely for the patient. If I do that very frequently, a lot of the times I judge that person as more novice. [2]

Surgical mentors pointed out the difference in judging developing (vs developed) expertise:

> There's a difference between teaching and evaluating a student's abilities and how you decide who is an established expert […] when you're teaching and trying to evaluate a resident or fellow, there's a bit more infrastructure there, be it bad or good […] there are benchmarks for deciding if they're competent. [8]

Synthesis of findings

1. Individual attitudes and habits of mind that help position learners to develop surgical expertise include: humility and teachability, passion and caring, motivation and hunger to learn, critical thinking and informed judgment, and metacognitive self-reflection.
2. Aptitudes and skills that support expertise development noted by experts are 3-d visualization of the problem space, manual dexterity and control, long-range thinking, and communication and interpersonal skills.
3. All of the experts were deeply influenced by expert mentors, and strive to mentor their own trainees with strategies like critical questions and well-timed feedback.
4. A key to optimal expertise development in this data is reciprocal interaction of individual characteristics and choices, with context affordances and opportunities, as either alone does not lead to expertise!
5. Continuous practice on a wide range of authentic cases is key to developing expertise, similar to other applied procedural and problem-solving skills. Such opportunities are largely contextual, but the dedicated learner will also reach out to find and capitalize on any others available. Gaining maximum practice in training takes advantage of the "protected" mentored practice space of the residency and fellowship.
6. Responsibility for optimizing critical practice opportunities is shared, by mentors challenged to find and provide productive opportunities for surgical trainees, and learners themselves responsible to engage available opportunities and also seek out others.
7. Gaining maximum learning benefit from practice and feedback is also result of shared contributions, with mentors setting expectations, and then giving coaching, guidance, critique, and feedback, and mentees being metacognitively self-aware and self-critical as well as open to receiving constructive feedback from the mentor and others.

Discussion

Expertise development is not just a cognitive process but also an affective and social one. The cognitive process of learning is partnered with the motivational process of recognizing the value of task outcomes, and the relevance of professional judgment. The cognitive process of competence development

(knowing what and how) works in concert with the affective process of efficacy development (feeling able), as individuals recognize and understand their own skills. The cognitive process of psychomotor skill development (anatomy recognition, instrument handling) works in concert with the motivational process of confidence development (trying new tasks and expecting success), as individuals refine their approaches, experience success, and dare to try new things. Competence and confidence are balanced by continuous learning goals and receptivity to feedback (timely, appropriate, clear), to keep ego in check and performance consistent, in the development of expertise.[21,22] Feedback was important at every juncture, and woven throughout experts' developmental experiences, supporting cognitive and skill development, as well as motivation to strive for continuous improvement. Thus, motivating students better supports them in learning more effectively, and developing greater career-long expertise, instead of being satisfied with basic competence and safe tasks.[27,43]

Strengths of this study include that it used experts with external credibility, those already recognized nationally by a specialized medical community. The sample of 16 international experts was a robust sample for a qualitative study of complex issues like these. The reflective interviews functioned to demonstrably generate recall of details on their most profound influential experiences in their journeys of learning and expertise development. While reflective responses present some potential bias in perspective (based on subsequent experience), that bias was not considered a negative effect for the goals of this study. The intent of the study was to recognize the relationships of past events to present status. Thus, the influence of current position on salience of past experience was not negative, but positive.

Experts agreed (interview responses converged) on defining the target expertise as both scholarly knowledge and skill across a broad range of applications and a high quality of execution. These experts' pathways to expertise were characterized by very different trajectories, but similarly punctuated by personally and professionally important influences, and conceptually guided by many of the same principles that are relevant to expertise development in other applied professions. They described personal attributes and habits of mind that drive learning and performance beyond expected competencies and toward true excellence. Passion and hard work with motivation to strive for excellence were balanced by humility, self-reflectiveness, and receptivity to critical feedback. They identified specific aptitudes and skills relevant to surgical performance that position learners for excellence and expertise development: manual dexterity and precision along with 3-d visualization of the problem space; and task-specific planning balanced with systemic and conditional (adaptive) reasoning. Their responses were consistent with the theoretical frameworks on expertise development generally,[8,9,13,14,27,43] and with the nature of problem-solving and procedural skill development.[44–46,49,50] However, this alignment had not previously been verified in this field through systematic data collection.

External opportunities were important for all of these experts, and some found those opportunities provided by their institutions, while others had to initiate and seek out supplemental opportunities, which is generally an expensive choice, negatively impacting short- and long-term earnings.[47] Experts who had taken both pathways reported striving to provide their own students with maximum external opportunities and supports. They also agreed that if those opportunities are inadequate, students should take responsibility to seek out additional ones. They emphasized not just a multitude of practice but also a diversity of authentic opportunities to practice the full range of professionally relevant tasks, while under the "safety net" of experts' watchful eye and intervention-if-needed. The way these experts articulated expertise and its development, as ever-changing, dynamic, and requiring adaptive monitoring and continuous learning, harkens back to the claim of Hippocrates that "life is short and the art long; the crisis fleeting; experience perilous, and decision difficult."[48]

Human factors were critical in surgical expertise and identity development for all, as each identified role modeling, mentoring, and interpersonal influences with profound influences on them. They intentionally carry forward that interpersonal connection in mentoring their own students. These experts underscored the critical roles of respected expert role models (who offered targets to aspire to be like) and expert mentors (who provide direct interactions, critical questioning, and meaningful feedback from credible sources). Expert and respected role models and mentors, interacting with skill range and competence development, also directly influenced these expert surgeons' professional identity development, including what specialties they chose and related career choices they made.

These findings also emphasized the importance of "soft skills" as critical for expertise among physicians, as the profound influence of interpersonal communication was emphasized in expert surgeons' own growth and development, the development they see in their own mentoring of

residents and fellows, and their collaboration with others on surgical teams. The characteristics of these relationships are consistent with the literature on excellence in mentoring in the health sciences. Their descriptions of how they developed and how they strive to support their own mentees' development are consistent with the principles of effectiveness in medical mentoring.[26] Additionally, they spotlight particular elements of both individual preparation and educational experience that help position students to develop surgical expertise more specifically.

Implications

This study responds to the call for more systematic research that assesses the match of anecdotal and theoretical frameworks of medical expertise with the authentic demands of specialty fields.[9,10] Understanding expertise development supports design and facilitation of learning environments that afford opportunities making expertise development more likely for learners. Medicine attracts some of the most gifted minds in the US, and medical educators need all possible strategies to develop them into experts across diverse specialties. Medical professionals determine life and death, and attention to expertise development can tip the scale toward success. Now, with reduced time to achieve expertise (due to reduced work hours in residency training) and more complex and ever-changing skills and technologies to master, surgery needs strategies for expertise development more than ever. Researchers, curriculum designers, and medical educators need to know clearly what makes experts, and that comes most authentically from the experts themselves, who are also currently training the next generation of surgical experts.

Disclosure

The authors report no conflicts of interest in this work.

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