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Title: Adaptive Expertise: The Optimal Outcome of Emergency Medicine Training

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Introduction

The breadth of practice in emergency medicine (EM) is daunting. Emergency physicians are expected to be resuscitation experts who competently manage all acutely ill and injured patients, no matter the source of their pathology. In reality, it is impossible to expose emergency medicine residents to every possible case presentation during training to develop comprehensive expertise. Physicians must be capable of *adapting* their practice to variations in presenting complaints, conditions in the emergency departments, and their own unique prior experiences. Truly *expert* emergency physicians can apply their knowledge and skills to manage both common and uncommon cases effectively and efficiently. The emergency physician must be an *adaptive expert*.

In this paper we describe adaptive expertise, explain why it is central to the practice of emergency medicine, and describe how educators can best train residents to become adaptive experts.

What is Adaptive Expertise?

Expertise is defined by elite, peak, or exceptionally high levels of performance on a particular task or within a given domain.[1] It can be divided into two types based on whether skills are applied to perform common or uncommon tasks. *Routine expertise* is the efficient and effective use of mastered skills to consistently perform a complex task at a high level of

competency. *Adaptive expertise,* by comparison, is the effective application of existing knowledge and skills to create innovative solutions for tasks or problems that are novel to the expert.

Routine expertise can be likened to the automatic, reflexive, pattern-recognizing "System 1" thinking described by Kahneman.[2] The ability to apply skills to commonly performed tasks becomes second nature and requires little active thought.[3] In EM, routine expertise is demonstrated in a myriad of clinical tasks such as quickly screening electrocardiograms for critical concerns, reflexively ordering the timely antibiotics and fluids when resuscitating a patient with suspected sepsis, or inserting a central venous catheter. Each circumstance requires near instantaneous analysis of available information, pattern recognition, decision-making, and skillful performance of complex actions to ensure optimal patient outcomes.

But what happens when a clinical case doesn't fit a commonly-recognized pattern? What should an emergency physician do when an electrocardiogram suggests a myocardial infarction but the patient complains primarily of back pain? How should they manage a 'septic' patient who recently started taking a new serotonergic medication? What actions are necessary when their guidewire kinks during the insertion of a central venous catheter? Once unusual circumstances are recognized, the provider must engage in active critical thinking to call upon their foundational knowledge and flexibly adapt previous mental models to the novel situation.[4] This kind of thinking, akin to Kahneman's "System 2" thinking, is effortful and intensive, and requires an understanding of the *why* behind decisions and not just the *what* of the action.[2,3] To demonstrate adaptive expertise, the provider must *adapt* their previous knowledge or skills to *transfer* them to the novel situation.

Why is Adaptive Expertise Important to Emergency Medicine Training?

Adaptive expertise was originally described in educational psychology literature to explain why some experts are able to easily apply their existing knowledge to thrive in novel situations.[3] Adaptive expertise has garnered significant attention from medical educators in the last decade, with links demonstrated between it and self-regulated learning,[5] long-term learning,[6] and medical decision making.[7] At the same time, studies of clinical diagnostic failure reinforce that reliance on rote performance of existing skills is insufficient.[7] It is clear that physicians must

be able to identify gaps in their expertise, select, appraise, and apply relevant information to address those gaps, and adjust their practice accordingly.[8,9]

One can quickly see how adaptive expertise is central to the practice of EM. The rapid pace of scientific discoveries, expansion of medical knowledge, evolution of treatment strategies, introduction of new technologies, and appearance of novel disorders mandates that all physicians adapt their practices throughout their careers; this is especially true for a generalist specialty tasked with the acute management of any presenting condition. At the same time, the clinical care environment is evolving to have less opportunities for learners to acquire routine expertise for essential and once-common EM procedures, such as tube thoracostomies or central venous catheterizations.[10] Thus, EM educators must prepare learners to be adaptive experts that can successfully navigate novel clinical challenges. But how?

How can we Teach Adaptive Expertise?

A general consensus in the literature highlights four educational approaches central to the development of adaptive expertise: (1) emphasizes conceptual understanding, (2) allow for struggle and discovery in learning, (3) incorporating meaningful task variation, and (4) developing self-regulated learning skills.[3,11-16] **Table 1** provides actionable recommendations for emergency medicine educators to address each of these domains.

Emphasize conceptual understanding

A conceptual understanding of a given task is central to a learner's ability to transfer knowledge from their accrued experience when solving a novel problem. By understanding the deeper *why* and not merely the superficial *what* of a task, learners can form the necessary abstractions, heuristics, and interconnections necessary to achieve effective knowledge transfer. These higher-order cognitive processes parallel those originally articulated by Bloom's taxonomy,[17] and this ability to effectively integrate knowledge and competencies may be what makes a physician an "expert" in their craft.[18] Thus, it is incumbent upon educational programs not to simply deliver clinical content to learners, but to push them to connect the dots by integrating knowledge between learning experiences whenever possible.

This focus on conceptual understanding addresses important flaws in our existing educational system. For instance, multiple-choice question exams test recall of facts and do not

routinely assess conceptual understanding; they offer little predictive value about future clinical performance.[19] Similarly, competency-focused assessments for specific procedures risk a "procedural fluency trap," wherein learners focus on performing a routine skill more efficiently, but struggle when faced with task variability.[6] Both forms of assessment implicitly measure routine expertise but fail to capture adaptive expertise; deliberate practice with expert feedback and cognitive apprenticeships are useful methods to address this gap.[5,20] For example, instead of simply relying on a minimum score on a thoracostomy tube insertion station, the assessor can use their own expertise to further probe the learner's thinking and decision making and then teach nuanced or advanced concepts. Similarly, a program can develop a culture that views assessments as diagnostic learning opportunities and positively embraces lifelong learning.[21]

Allow for struggle and discovery in learning

Fundamentally, the learning experience is a journey of the learner with teachers as guides. This learner-centric mindset helps us understand the centrality of *struggle* to the learning process. Bransford, a leader in adaptive expertise, captured this sentiment well: "*Students also need to experience processes of inquiry and innovation—including the struggles and doubts. . . These changes can evoke strong emotions and take us away from our momentary efficiencies and comfort zones by forcing us to unlearn old skills, tolerate momentary chaos and ambiguity in order to move forward, and—at least occasionally (and perhaps frequently)—be in positions where we must take risks and be wrong"* (p.2).[13] As educators, it is imperative that we allow learners to experience struggle when facing new ideas or tasks, but also normalize this as a positive marker of learning.[22]

One practical issue for teaching adaptive expertise is the sequence of teaching. Shall we model and teach efficiency first, and then encourage innovation? Or vice versa? Evidence consistently favors the latter.[3,12] In fact, "early innovation yields better adaptability in the short term and efficiency in the long run."[12] This has profound implications for emergency medicine training, as educators are tasked with the challenge of balancing teaching efficiency with innovation.[23] Problem-based learning, team-based learning, and simulation seem to be ideal methods for safe learner struggle and discovery without any associated threat to patients. Furthermore, these methods provide an opportunity for "guided discovery," wherein a learning experience is followed by targeted feedback or instruction.[24] As an example of this sequencing,

learners could first participate in a simulation of cardiac arrest, and *then* be taught the teaching principles of advanced cardiac life support. This order strips them from being able to simply parrot back a recent lesson, and instead requires them to innovate - even if incorrectly - to navigate through the case. This kind of instruction has been associated with better learner efficacy with future novel problems.[25,26]

Incorporate meaningful task variation

Task variability is essential to developing adaptive expertise.[3,27] Emergency medicine training, and the broader culture of medicine, often teaches learners to manage expected case variability with rigid, algorithmic approaches rather than allow for deliberate variations in task performance and innovative management.[28] Such sociocultural structures that prioritize efficiency have been shown to inhibit innovation,[3] posing a challenge for educators seeking to teach adaptive expertise. Still, there are existing methods to introduce meaningful task variability into the learning environment. Simulation offers educators the opportunity to adapt cases to the specific learner's experience and skills, and has been associated with development of adaptive expertise.[29] In the clinical space, supervisors can skillfully deploy "*what if…"* questions that safely build hypothetical variability into actual patient cases to help residents analyze their clinical decisions.[14] Tasks with built-in variability - such as managing difficult patient encounters or having goals of care discussions - require learners to consistently adapt their approach and lend themselves to development of adaptive expertise.[3] Educators must create opportunities for task variation when the task lacks implicit variability, such as a simple laceration repair. The traditional suturing workshop could be modified with models that demonstrate atypical lacerations or require learners to compare and contrast different repair materials and develop usage heuristics.

Develop self-regulated learning skills

Adaptability requires learners to engage in critical thinking, reflection, and assessment of biases.[7,16] Such metacognitive abilities fall within the realm of self-regulated learning (SRL), which includes cognitive, metacognitive, and affective skills necessary for engagement and monitoring learning.[30] After medical school, external support mechanisms for learning progressively dissipate;[31] thus, the capacity to self-regulate learning is essential for physicians.[32]

Educators should use residency training as a time to ensure residents acquire SRL skills, as evidence suggests they struggle to do this on their own.[33]

Cutrer et al. proposed the Master Adaptive Learner conceptual model to describe how learners acquire the metacognitive skills of adaptive expertise.[15] Similar to the PDSA cycle,[34] this 4-phase model conceptualizes learning as a cyclic, recursive process within learners. Regan et al. investigated the initial *planning* phase of learning within a population of Master Adaptive Learners and identified a number of skills and strategies that high-performing learners use to plan learning.[22] Optimizations in the learning environment, such as coaching,[35] can make these skills explicit to developing learners. A SRL-focused learning science curriculum that operates in parallel with more traditional content-centered curricula may also be beneficial.

Conclusion

The inherent breadth of EM, accelerating pace of advancement of medicine, and limited duration of training make it impossible to expose learners to every possible future situation encountered in the emergency department. Residency training programs are thus challenged to create the *adaptive experts* that have the skills to meet these future needs. We provide a series of recommendations (Table 1) to assist EM educators in enhancing their programs to meet this challenge.

Table 1: Recommendations for Teaching Adaptive Expertise in Emergency Medicine Training Programs

Adaptive Expertise Developmental Principle	**Recommendation for EM Educators**
Emphasize conceptual understanding	**Program reflection**: *Does your teaching curriculum emphasize understanding over memorization? Does it push learners to connect the dots and build their own unique cognitive scaffolds such as illness scripts, diagnostic schemas and heuristics?* - **Emphasize learning *why* over *what*:** Encourage both residents and faculty to be inquisitive and receptive to questioning. - **Invest in long-term learning**: Teach learners about the need to make connections (e.g., between basic science, clinical care, and social determinants of health, etc.)[6,14,36] - **Avoid overreliance on superficial markers of knowledge** (e.g. in-training exams)[14] - **Increase opportunities for the externalization of learner thought**: Use deliberate practice and cognitive apprenticeships within teaching experiences to make learners externalize their knowledge, decisions, etc.[5,20]
Allow for struggle and discovery in learning	**Program reflection**: *What is the learning culture of the program? Are learners rewarded for giving the right answer, or for acknowledging and addressing their knowledge gaps?* - **Prepare learners:** Anticipate the emotional discomfort of productive struggle and address it directly with learners - **Start early:** Provide opportunities for learners to innovate early in training (e.g., during orientation).[3,12] - **Protect learner autonomy**: Maximize learner autonomy commensurate with their ability; conversely, avoid attending-only tasks that sideline learners from direct patient care[22] - **Always get a commitment**: Solicit a decision or rationale from the learner *before* giving answers or feedback - **Encourage guided discovery**: Build teaching experiences wherein learners *first* experience struggle with new content and *then* receive direct instruction/feedback[24]

Incorporate meaningful task variation	**Program reflection**: *Which learner tasks, roles, and skills lack intrinsic variability and need supplemental task variation?* - **Ask 'What if…?'**: Encourage "what if..." questions that build hypothetical case variability (e.g., variations in age, comorbid conditions, access to consultants, etc.)[14] - **Embrace simulation**: Adaptable simulations allow for nearly-limitless case variability and adaptability to specific learner needs and abilities[23]
Develop self-regulated learning skills	**Program reflection**: *Does your program prepare learners to be self-directed by providing opportunities to "practice" self-regulated learning skills?* - **Prioritize the development of self-regulated learning:** Implement a curriculum and/or coaching program focused on cultivating and role-modeling self-regulated learning skills [22,35,37-39]

Abbreviations:

E.g. = for example

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