Welcome to this session on experts, novices, development, learning and memory. As novices gain expertise in a domain, their factual knowledge base expands, new schema develop, and there are also changes in the efficiency of processing, acquiring, and approaching new information within that domain. In this session, we explore differences between experts and novices to better understand a few different ideas. These include, how memory and expertise can intersect and some differences in the ways in which experts and novices approach challenging tasks. We also consider a set of Algebra materials that are designed to scaffold relative novices to adopt some expert-like behaviors.
What characterizes experts vs. novices? First, let’s think about how we can most easily study these differences. Differences between experts and novices are clearer when the domain to be studied has well characterized skill levels and straightforward ways to measure performance. For example, in chess it’s easier to establish clear boundaries between different levels of expertise than in creative aspects of the visual arts. It’s no accident, therefore, that seminal work in the 1970s on differences in memory performances between expert and novices was done in the domain of chess. In well-characterized domains, like chess, physics problem solving, reading x-rays, or in the technical aspects of performing arts, etc . . . we can measure the ways that experts have a heightened capacity to recognize, encode, and make use of meaningful patterns. Such patterns are sometimes described in terms of “deep structure”. Novices are more likely to attend to, encode and try to make use of surface features that are easily evident but which do not represent unique information about central underlying properties. When the deep structure is accessible it facilitates the running of a mental model that considers primary causal connections. Quick movement through successive, linked aspects of such a mental model contributes to the rapid, flexible, somewhat automatized processing that characterizes expert performance within their domain.
Glaser articulated 6 partially overlapping generalizations about performance and knowledge – note that the functional performance of experts is a result of the interaction between their skill and the structure of the domain specific information or challenge.

1. **Specific proficiency**: Expertise is based in specialized knowledge within specific content areas and that knowledge is best used when the problem they address reflects the underlying structure of the domain.
2. **Perception of patterns**: Experts have mental models that make use of meaningful patterns of domain information that reflects underlying causal structures. One of the effects of such patterns is that experts can easily encode large “chunks” of information from within their domain, so long as the elements within those chunks correspond to meaningful patterns. Novices tend to encode individual and superficially evident aspects of the information available.
3. **Problem solving relies on pattern recognition**: The ability to quickly recognize and make use of meaningful patterns speeds experts’ problem solving. Their efficiency is driven in part simply by their ability to make use of a larger total amount of information since it is organized within coherent chunks.
4. **Patterns are not just structural**: The patterns experts recognize include information about the dynamic relationships among elements within the pattern. Knowledge of the function-structure relationships among interacting aspects of domain content is further connected to a larger goal structure. The function-

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### Six Generalizations

- Specificity of expert proficiency
- Experts’ perception of patterns
- Experts’ use of patterns
- Patterns reflect structure *and* function
- Resources available for self-regulation
- Proficiency can be automatic or flexible

(Glaser, 1992)
structure relationships are not just of importance unto themselves, but also to understanding the inherent causal structures. Experts recognize and make use of the ways that sub-patterns interconnect and how their manipulation can advance problem-specific goals. When novices attend to less meaningful surface elements of a problem it means that they do not have the resources left to attend to more important function-structure relationships.

5. Domain specific meta-cognition supports self-regulation: Perhaps because manipulation of domain specific information is somewhat automatized, experts have mental resources left over which can be used to self-regulate. Initial task performance may appear slower as experts use these self-regulatory approaches to cycle through and reflect on different approaches to solving a problem. However, arriving more quickly on a good overall strategy wins in the end and contributes to experts’ greater speed and efficiency. In contrast, novices are more likely to begin manipulating surface information and applying problem solving approaches that they know well or which are suggested by the surface information. Since these approaches aren’t necessarily appropriate for the deeper demands of the challenge their progress is slower and less effective.

6. Proficiency can be both automatic and flexible: Expert knowledge can be manifested in routinized or adaptive ways. This depends in part on the nature of the task at hand and whether the training that led to expert status emphasized opportunistic planning skills.
The generalizations described in the previous slide might leave one with the picture that expert knowledge and the patterns that characterize it are available always at the flip of a switch. That can be true when the circumstances and task are familiar. However, when the task is a novel one for a given expert their initial performance can plummet to novice-like levels. For example, in a study conducted for a graduate class, a theoretical physicist whose expertise was in magnetism was asked to construct an electro-magnet. He was supplied with all the needed materials: battery, nail, copper wire, alligator clips and paper clips to test the strength of the electro-magnet he made. If you were to look at his performance transcript after sometime you would be impressed at the facility with which he described the equations that could be used to predict which assembly approach would work best. However, if you looked at the first few minutes of his performance you would see little or no evidence that he was an expert. The first time he was faced with this novel task within his domain of expertise his performance looked very similar to a non-expert. This reflects another aspect of expert knowledge. It needs to be reconstructed in order to be of use and to map on to the demands of a novel task. Glaser discussed this in terms of ill-structured challenges, and the phenomenon is similar, but the conditions that generate the drop in experts’ ability to make use of their stored knowledge of patterns are distinct. In the scenario described, the challenge is well structured, but because it is novel experts must first map on their existing knowledge to task demands and then they can make use of the stored patterns.
We have spent some time thinking about how an expert’s ability to recognize patterns facilitates problem-solving endeavors. Here, we hone in on the ways that expert and novice memory capacities do and do not differ. In general this can be summed up in this statement: Experts’ memories are better than novices within specific domains of expertise – but not more generally. So, for example, chess experts are much better than novices at recalling presentations of chess positions, but only when the presented information is meaningful. If a subset of chess pieces are placed on a board at random, experts do about the same as novices. However, if the presented pieces are holding positions that make sense in the context of how a chess game would likely have progressed, experts are significantly better than novices. If you compare their performance on a typical test of how many presented digits (numbers) can be recalled, chess experts do not show an advantage compared to novices. In other words, the mnemonic advantage of experts is generally limited to domain specific information.
Interesting work pioneered by Chi and some of her colleagues further explore the question of how expertise interacts with memory performances by adding in the variable of age. Generally speaking our ability to perform well on memory tasks increases with age and also with expertise. Note that developmental factors and the acquisition of expert knowledge bases each contribute uniquely to improvements in memory. For example, it is possible for children to have better memory performances than adults within domains where the child has expertise. However, for areas where both child and adult are novices, the adult will be able to remember more than the child, although, to be sure since adults generally employ strategies such as rehearsal or grouping it can be difficult to tease apart whether it is strategy or capacity that drives those differences. Unless studies carefully control for each, in fact, it is not possible to be certain of what portion of adult/child memory differences are due to strategy or capacity. As a general rule, somewhere during the primary school years, data suggest that when adults are prevented from using memory-supporting strategies, their basic capacity seems similar to that of children.
A set of unique, strategically designed Algebra assignments, called “AlgebraByExample” may work in part by supplementing students’ working memory – a form of memory that is active, somewhat transient and is used in service of specific goal directed activities. This assignment format is unique because it provides an equal number of Your Turn items where students solve a problem on their own, and worked examples with companion probing questions. These paired items provide students with opportunities to practice expert-like behaviors including attending to the deep structures of mathematical problems. In this sample set, you can see that students are prompted to attend to specific aspects of a fictional student’s work. The features that are pointed out reflect important aspects of the deep, rather than surface structures of the problem. In doing so, they highlight relationships that would be immediately evident to experts but which novices are less likely to appreciate. To the extent that materials can be designed to specifically scaffold expert-like recognition of deep structure, they may help novices practice some of the same strategies experts use.
In addition, experts are more likely than novices to evaluate their strategic approaches in real-time. Further, these materials ask prompting questions that draw attention to aspects of the problem solving approach or the problem itself which frequently contribute to mistakes. In this sense too, it scaffolds novices to adopt expert-like behaviors which include self-regulation in the form of evaluating a particular approach to decide if it is appropriate or reflects the deeper structure of the problem.
In Closing

The creation of instructional tools should reflect what we know about:

1. the targeted domain,
2. expert performance in the domain and
3. the developmental and acquired characteristics of the students who will use those tools.

Studies of expertise allow us an opportunity to consider the interacting effects of domain and task characteristics, age, memory capacity, knowledge levels, and strategic approaches. When we consider the development of pedagogical tools or approaches it makes sense also to consider ways to harness what we know about the strategies experts use in the domain so we can help novices employ them. In addition, if our students or intervention targets already have expertise in some other domain there may be ways to help them leverage strategies they are comfortable with in that domain in order to better encode or recall the new types of information in an unfamiliar domain. Remember though, that expertise in one domain is not easily transferred to new areas so while careful scaffolding can facilitate this progress the process of building new expertise or applying old expertise in a new area will always take time and concerted, intentional effort.