

## How the Neurobiology of Learning Informs Teaching and Learning

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## Goals of Learning

What do we want students to do with the knowledge, skills, and attitudes they learn?

- 1) Remember → Retention
- 2) Solve problems (reasoning) → Application
- 3) Apply in new situations → Transfer



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## Evidence-Based Education

We should integrate existing knowledge from the neurobiology and science of learning into the design of learning experiences and the curriculum

Acad Med 2011;86:415-420



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## Learning – Construction of Meaning

- Learning involves the active construction of meaning
- Meaning is constructed by making multiple connections between the information being acquired and prior knowledge and experience
- Meaning cannot be transmitted by instruction
- Meaning and knowledge structures organized for future application can be created by engaging the learner in effective learning activities



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## Prior Knowledge and Experience

Consists of an amalgam of facts, concepts, models, perceptions, beliefs, values, and attitudes that influence how students filter and interpret new information

Learning is hindered if prior knowledge is:

- Insufficient
- Inaccurate
- Not activated



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## Learning – Construction of Meaning

- There is limited capacity for cognitive processing in working memory
- Learners need adequate time to process and connect new information to prior knowledge
- Complexity (interrelated concepts) requires more time – rote learning if not learner paced
- Reflection helps learners organize knowledge for future application and transfer



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### Implications for Curriculum Design Meaning - Prior Knowledge and Experience

- Assign readings, questions or critical thinking exercises that activate relevant prior knowledge before class
- Review relevant prior knowledge in class
- Explicitly link new material to relevant prior knowledge and experience
- Explain the application of new material to practice and / or research



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### Active Learning and Retention

The more actively involved a learner is in learning activities:

- the greater the sensory input
- more processing is required
- larger knowledge representation (storage)



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### Implications for Curriculum Design Active Learning Methods

- Problem-Based Learning
- Team-Based Learning
- Case Method Teaching – Discussion
- Application of Knowledge Exercises
- Simulations
- “Debriefing”



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### Implications for Curriculum Design Active Learning Strategies

Engage the learner in “higher order” thinking

- Application
- Analysis
- Synthesis
- Evaluation
- Creation



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### Knowledge Structures

Novices have sparsely connected, superficial knowledge structures

Experts have densely interconnected facts, concepts, skills and understandings in richly meaningful knowledge structures

When learners are provided with a structure in which to organize new knowledge, they learn more effectively and efficiently



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### Implications for Curriculum Design Organizing Learners Knowledge

- Use exercises, problems or cases that compare and contrast key concepts
- Provide the “big picture” or framework of key concepts and relationships
- Ask students to categorize or organize knowledge for different purposes



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### Knowledge Structures and Problem Solving

- Novices attempt to make connections and consider a wide range of random options
- Experts quickly recognize features and patterns and assess the pros and cons of a very select set of high quality options
- Experts can very flexibly use multiple knowledge structures

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### Implications for Curriculum Design Problem Solving

- When learners are given solved problems and asked to explain the solutions, they learn the principles that guide the solution
- Guiding learners through analogical reasoning helps them make connections and see relationships
- Analyzing contrasting cases develops more elaborate and flexible knowledge structures

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### Retrieval Practice

**“Retrieval Practice” – Long term memory is improved if some of the learning time is devoted to recalling information**

- Information that is frequently retrieved becomes more easily retrievable
- Practice at retrieval is the single most important variable in promoting long term retention, application and transfer

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### Spacing Effect

**Practice that is distributed over time (spaced practice or distributed practice rather than massed practice) improves learning**

**Learners are more comfortable with massed practice as they have the illusion that they have achieved the desired learning**

**Forgetting occurs over time**

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### Interleaving Effect

**Interleaving - presenting information in a non-contiguous manner (mixing with other information) results in improved learning**

**Learners are less comfortable with interleaving**

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### Testing Effect

- **“Testing effect” – Tests improve retrieval of information but only for information that was recalled for the test, not for all information studied for the test**

- **Studying and testing is more effective than studying alone**

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### Effect of Context

- Transfer is application of learning in a new situation or context
- Altering the context for retrieval increases the transfer of learning across multiple contexts



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### Implications for Curriculum Design Effect of Spacing and Interleaving

- Important concepts should be integrated into the learning experiences repetitively over time to provide distributed practice and interleaving
- “Spiral curriculum” – learners revisit important material and build on it



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### Implications for Curriculum Design Testing Effect

- Provide “key concept” review questions to guide studying and exam preparation
- “Key concept” questions should be used in self assessments or quizzes over time to provide practice at retrieval
- Examinations should be constructed with “key concept questions”



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### Implications for Curriculum Design Effect of Context

- Cases are simulations of real patients and should be used as often as possible
- Use multiple and varied contexts for learning experiences
- Mix different types of problems and solutions in the same learning experience
- Integrate basic and clinical sciences, and societal issues that impact on health and health care delivery



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### Outcome-based Education Assessment

“Assessment drives learning” and ensures that learning outcomes have been achieved

- Formative assessment – feedback that “forms” the development of the learner
- Summative evaluation – summarizes the achievement of the learner – grading



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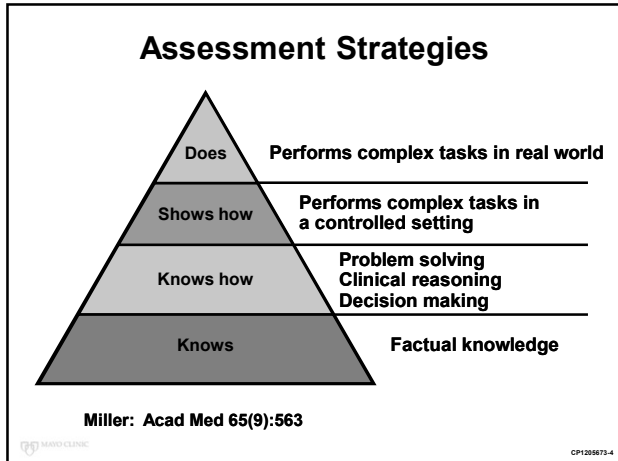
### Formative Assessment

3 components of Formative Assessment

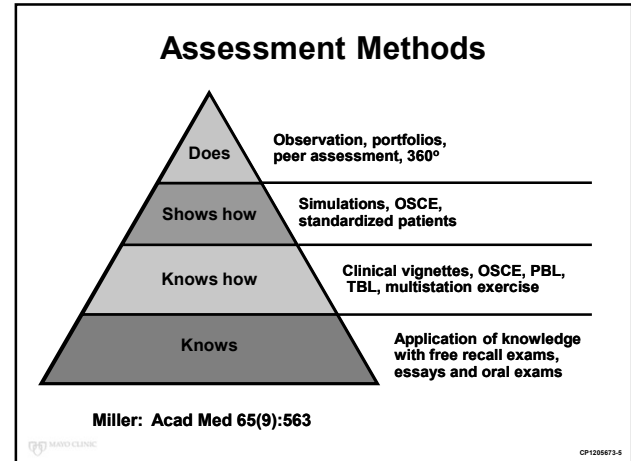
- Constructive feedback
- Direction to facilitate desired learning
- Encouragement to create a supportive learning environment



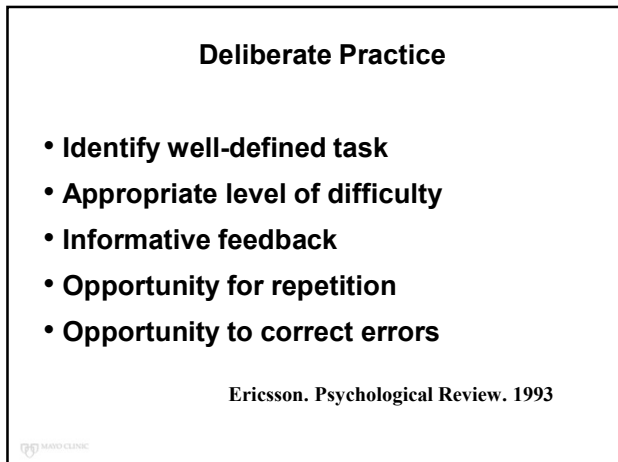
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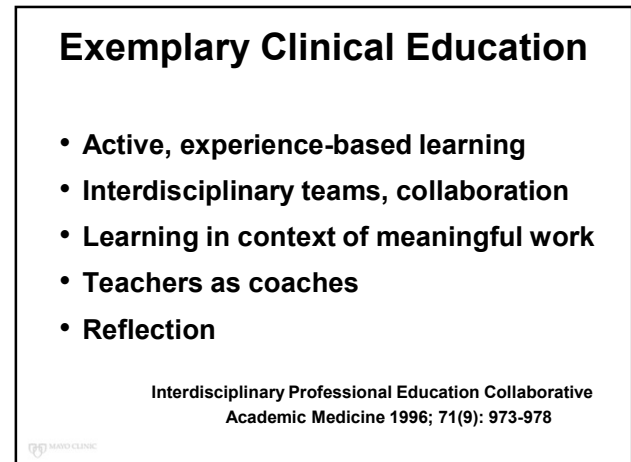
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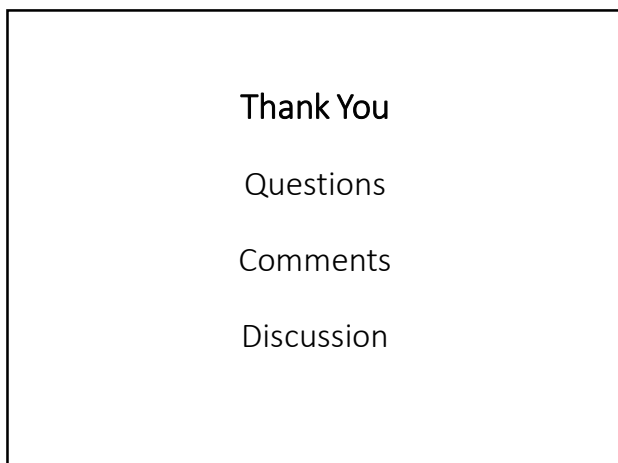
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