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A Learning-Process Model

Sensory Input
- 5 senses, each continually receiving many sensory images
- Translated into electrical impulses

RAS
- Reticular Activating System
- Acts like a filter – a very important function!
- Chooses the most relevant images and passes them through to working memory (table)
- Discards the rest
- Holds the image for between ½ second and 4-5 seconds
  - Visual images held for a short time (½ second): iconic memory
  - Auditory images held for as much as 4-5 seconds: echoic memory
    - Some believe that the reason for the difference is that echoic memories need to remain as a sequence of sounds to make sense, whereas iconic memory can be more like a snapshot.

Working Memory
- Working memory, “What do I already know about this new idea? What is like this?”
- Searches existing memory (filing cabinet).
- Criteria is “match” or “don’t match” – very digital
- Memories that are determined to match the new idea are brought “to the table”
- New idea is manipulated and integrated to existing knowledge

Encoding & Storage
- Modified knowledge is stored in the same file-folder and replaced in storage
- New knowledge may get a new file folder and be stored
Brain Geographies and Responsibilities

**Brainstem (Reptilian Brain)** — (gray). Connects the brain to the spinal cord. It controls breathing, heart rate, swallowing, alertness, sleep, balance, blood pressure, digestion, temperature, and sweating. This is where “fight or flight” resides.

**Cerebellum** — (purple) Behind the brainstem and below the occipital lobe, it controls coordination of movements, balance, and equilibrium.

**Cerebrum** — outer layers of the brain, largest and most complex part of the brain made up of lobes. The lobes have different job.

- **Frontal lobe** — (green) movement, planning, reasoning, responses to our surroundings, emotions, word meanings
- **Parietal lobe** (red) — sense of touch, focusing on and understanding our surroundings, naming things, writing words, drawing, reading
- **Occipital lobe** (blue) — vision
- **Temporal lobes** — hearing, memory, understanding speech, recognizing faces,
Anatomy of a Neuron

**Neurons** - both transmit and receive messages

- average brain has 86 billion neurons
- highly differentiated function
  - programmed to send and receive only on type of information; e.g. within the occipital lobe, a neuron might respond only to the color black, for example
  - when not activated, remains at rest
  - when multiple neurons fire simultaneously, they wire together to make a neural network.
Types of Memory

Semantic Memory
- Facts and Generalized knowledge (content)
- “I know that...” or “I know what ... is.”
- Requires conscious processing (awareness that you are thinking about the information or calling up the memory).

Episodic Memory
- Personal experience with events
- “I remember when ...” or “I know where ...”
- Requires conscious processing (awareness that you are thinking about the information or calling up the memory).

Procedural Memory
- Skills, habits, and procedures
- The ability to do things without thinking of each individual step, like driving a car (for an experienced adult) or taking a shower
- Is done automatically, with lots of input from the sub-conscious brain, because it is automatic; no conscious thought needed.

Semantic memory is the content, Episodic Memory is the context, and Procedural Memory is the application, the doing.

*Deep content and rich context enables us to do the doing things!*

All memories begin as Episodic Memories. Multiple exposures to the same concept convert memory from the gossamer thread of Episodic Memories to the more durable twine or stout rope of Semantic Memory. When the process of accessing Semantic Memory becomes automated, the memory becomes internalized as a Procedural Memory.
Often used strategies that don’t work

Telling and testing

Rote memorization

Mindless manipulation of ideas

Work and encourages mindlessly following a protocol or algorithm

Work that encourages guessing

Implications for Montessorians:
- Check children’s paperwork – is there “heavy lifting” or is it copy work / mindless reproduction?
- Check classroom 3-part / 4-part cards – do definition cards reveal too much so that children don’t need to read or process the information?
- Similarly, check other materials that involve placing information in certain positions (like Timeline and Classification materials) to ensure that children are processing information through the work.

Effective strategies that file information into long-term memory for retrieval

Authentically activate prior learning through effortful retrieval.

Interleave / integrate the new concept with prior learning in context.

Mindfully store the new learning.

Four Views of the 3-Period Lesson / Stages of Learning

<table>
<thead>
<tr>
<th>This is…</th>
<th>Show me…</th>
<th>What is…?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decoding</td>
<td>Manipulating</td>
<td>Encoding</td>
</tr>
<tr>
<td></td>
<td>Integrating</td>
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<tr>
<td>Naming</td>
<td>Recognition</td>
<td>Recall</td>
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<tr>
<td>Analyze</td>
<td>Synthesize</td>
<td>Utilize</td>
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Teaching Strategies Applied to Lessons and Follow-Ups

Initiate Lessons with Authentically Activating Prior Learning and Effortful Retrieval

Through the conversations initiated in the opening moments of a lesson and through “warm-up” activities given to children, provide the context and insure that necessary prerequisite skills are in place.

- Provides the opportunity to “bail out” if children are not prepared sufficiently to be successful with the new lesson.
- Gets the brain warmed up for new heavy lifting that is coming.
- Opens the context folder so that new learning is stored relationally.

The nature of the warm up depends on the type of lesson being given. Here are a few ideas:

- math: give a problem or two that utilizes the previous isolated difficulty. Examples:
  - If introducing dynamic stamp game addition, have the children do a static division problem with stamps (even if previously abstracted) to check for flow with the basic addition with stamps process.
  - If moving to abstraction with long division, have the children do a dynamic division problem with racks and tubes to reconnect with the physical meaning of each step of the long division problem.
  - If working with non-common denominator fraction addition, either have the children find the LCD of a problem or two using their preferred material, of simply give the children an abstract long division problem to keep those skill alive while working with fractions (practicing division, multiplication, and subtraction skills).

- language/grammar: give a task exercising the prerequisite isolated difficulty. Examples:
  - If introducing a new part of speech, engage the children in activities that exercise the parts of speech that we hope have been internalized. This might include symbolizing or working with a previous grammar box.
  - Exercise the 3rd period of learning (utilize) by having children write to a pattern illustrating the previous isolated difficulty. This pattern might be a parts of speech pattern (traditional Montessori) or a sentence analysis pattern (less traditional).
  - If introducing a new type of syllable, spelling pattern, reading difficulty, etc., identify isolated difficulty of the previous lesson and start with that.

- cultural:
  - If initiating a new study, the very traditional KWL charts are very effective. Listing what one Knows about a particular topic pulls prior learning from memory to ready it for integration. It also sets up the proverbial folder to integrate and store the new learning.
    Brainstorming what the children Want to know, the first point of curiosity, opens the doors to “Wonder and Wander”, which opens the neural pathways to new learning.
  - If continuing a study in progress, ask questions that encourage children to do the “heavy lifting” to pull out prior learning. This will be particularly effective if the questions go from broad to specific so that children can elaborate on previously answered questions. Another powerful technique is asking children to retrieve facts that will be used to compare the new learning to prior learning. Recall that we retrieve prior learning by similarities and store new learning by differences.
Teaching Strategies Applied to Lessons and Follow-Ups

Wrapping Activation of Prior Learning, Effortful Retrieval, and Interleaving into lessons.

Throughout the lesson, prompt children to provide facts or processes from prior lessons, and to elaborate on those process and concepts. This can be done through dialog or even silently through the manipulation of materials. The nature of this depends on the type of lesson being given. Here are a few ideas:

- math: if the lesson is one within a Montessori-provided sequence according to the systematic progression of isolated difficulties, this is nearly guaranteed because of the linear nature of math and the brilliance of Montessori's scope and sequence.

- geometry: consider how the new concept relates to previously presented concepts. For example, if presenting area of a pentagon, once the new algorithm (to find area of a pentagon) is discovered, direct the children towards considering how this algorithm is similar to or different from those previously discovered (rectangle, triangle, parallelogram...)

- language: circles and arrows. Integrate parts of speech with the syntax study, to see how the subject and objects (black pieces) consist of a noun family; the predicate (red piece) is made up of the verb and its modifiers, and the adverbial modifiers (orange pieces) are either adverbs or prepositional phrases.

- language: reading discussion. This is the place to intentionally integrate questions that cause children to relate the text that they have read to self, the world, or other text. It is also a great opportunity to compare characters from one book to another, and to create opportunities for empathy.

- cultural: consider how lessons can be tailored to reflect prior learning. Examples given in the talk include relating parts of a mammal to parts of a bird, and relating tree of life studies to the Timeline of Life.

Wrapping up lessons with Effortful Retrieval and Interleaving.

Finish each lesson in a way that causes children to mindfully reflect on the material just presented. Asking them to summarize, prioritize, or demonstrate the new concept before leaving the lesson initiates the second period of learning. Here are a few ideas for children’s “ticket to go” from a lesson:

- ask a children at the conclusion of a math or grammar lesson to identify the isolated difficulty of the lesson and, if appropriate, how it relates to prior lesson(s).

- ask children to recall a fact from the presentation. Those children who have had a hard time maintaining focus through the lesson will benefit from hearing the other children’s answers.

- ask the children (especially older children ) to write a summary or a list 3 most important facts from the lesson.

- ask children questions that compare and contrast information from the lesson to prior learning, for example: comparing what children just learned about the governing system of Ancient Greece to that of Ancient Egypt or to their understanding of modern systems of government; comparing and contrasting flatworms and roundworms; comparing and contrasting, comparing and contrasting tornadoes to hurricanes, etc.
Effortful Retrieval and Interleaving in children’s follow-up activities

The specific activity being asked of the child is highly dependent upon the child’s level of exposure, understanding and mastery. Does the child recognize or recall the concepts from the lesson?

1st Period of Knowledge: At the most basic level, follow-ups should require effortful retrieval of the isolated difficulty of the lesson. Children repeat what was learned – repeat the activity of the lesson just the way that they were shown, developing knowledge, flow, and, where appropriate, muscle memory that helps working memory. (Most appropriate for math, geometry, grammar, and some cultural lessons).

2nd Period of Knowledge: Learning will be aided when it is possible to interleave new and prior learning during the follow-up activity. For example, when the lesson is on the adjective, initially we follow the principle of isolation of difficulty with follow-up activities, focusing exclusively on the adjective. But when this knowledge of the adjective is sufficiently well developed to allow a follow-up activity that integrates the article, adjective, and noun, the child’s understanding of the adjective is contextualized.

3rd Period of Knowledge: When the children’s understanding of the concept is fairly well established, follow-up activities cannot merely practice the isolated difficulty, but extend that knowledge through, application of the new skill, research, or compare and contrast activities.

By tailoring the follow-up to forward the child’s progress from one level of understanding / knowledge to the next furthers the child’s ability to mentally manipulate the concepts. This is abstraction, and tending to the stepwise movement towards independent manipulation of concepts is the highest form of Minding the Gap.
Scope and Sequence: Division of Whole Numbers, 1-Digit Divisor

- **Stamp Game**
  - Record only complete quotient.

- **Stamps or Racks & Tubes: Distributive Division**
  - Record partial quotient at each step.
  - Record partial quotient and remainder at each step.
  - Record partial quotient, quantity shared out, and remainder at each step.

- **Racks & Tubes: Group Division**
  - Confirming concrete manipulations with abstract recording
  - Confirming abstract calculations with materials

Scope and Sequence: Parts of Speech Leading to Circles and Arrows

1st Period Learning
- Function of the _______
- Name the part of speech
- Introduce the Grammar Symbol

2nd Period Learning
- Grammar Box
  - Read and decompose (sequence)
  - Act it out
  - Transpose
  - Symbolize
  - Write
- Grammar Box Command Cards

3rd Period Learning
- Pattern Cards
- From Parts of Speech into Reading/Sentence Analysis! (example: preposition)

<table>
<thead>
<tr>
<th>1st: Naming / Analyze</th>
<th>2nd: Recognize / Synthesize</th>
<th>3rd: Recall / Utilize</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function of preposition:</strong> a bridge from the main part of the sentence to a modifier that specifies when, where, by means of what, etc. Isolated Difficulty: function and name of preposition, symbol</td>
<td>Preposition Grammar Box and perhaps command cards.</td>
<td>Parts of Speech Pattern Cards</td>
</tr>
<tr>
<td><strong>Name the circle and arrow part that relates to that grammatical part of speech (integrated with previous circles and arrows)</strong> Isolated Difficulty: the orange circles and arrows (adverbial modifiers)</td>
<td>Repeated use of circles and arrows with sentences containing prepositional phrases that answer different “orange” questions, all integrated with parts of speech.</td>
<td>Circles and Arrows Pattern Cards, Improve My Sentence Editing during children’s writing process Application in creative ways</td>
</tr>
</tbody>
</table>
Scope and Sequence: Cultural Lessons
The scope and sequence for cultural lessons allows for flexibility and innovation on the part of the Montessori teacher. The classic materials, which include timelines and three-part cards, are best presented not in isolation, but as part of a larger picture. When teaching cultural lessons, it is helpful to be mindful of two things:

- What truths about the real world are being revealed to the child through this work?
- What is the arc of the story that can be shared and re-told through work which establishes a relationship between concepts?

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<td>3-period lesson (nomenclature) OR Teacher presentation on timeline</td>
<td>Student work with materials. Follow-up work should include effortful retrieval and some heavy lifting.</td>
<td>Teacher or student refers back to the relationship established through work with timeline/nomenclature for future lessons and/or further study. Great opportunity for cross-curricular work!</td>
</tr>
</tbody>
</table>

Spontaneous Thoughts from Children Regarding Materials Leading to Abstraction:
“Wait, wait, wait, is this the pink tower we were building in primary? All this time, I never knew what I was working on. Totally epic!” (5th-grader working on bead decanomial)

“I like that if I don’t get something, I can work on the materials and no one can see that I don’t get it.” (4th-grader)

“I don’t know why, but touching these glass 10 beads just makes me so happy!” (6th-grader)

“I love the feeling when I work really hard on something and I finally get it! It makes me feel giddy like I want to jump around and celebrate!” (6th-grader).

“I was afraid of the materials because I didn’t understand them. I didn’t get any lessons with them and so I didn’t want to work with them. Now that I am getting lessons with them, I would rather use the materials than do worksheets!” (6th-grader at conferences).

“This is way more fun than doing a worksheet!” (5th-grader, after a grammar lesson).

“We just realized that we are math nerds!” (3 6th-grade boys working with the pegboard).

Thoughts from Other Wise People Regarding Materials Leading to Abstraction:
“To make it clear whether or not a child has understood, we should see whether he has gone beyond the level of mere understanding”

Maria Montessori, To Educate the Human Potential, p.10

“Our teaching must only answer the mental needs of the child, never dictate them.”

Maria Montessori, To Educate the Human Potential, p.5

“Our aim therefore is not merely to make the child understand, and still less to force him to memorize, but so to touch his imagination as to enthuse him to his innermost core”

Maria Montessori, To Educate the Human Potential, p.11

“Growth comes from activity, not from intellectual understanding”

Maria Montessori, The Montessori Reader, p.526

“We don’t learn from experience, we learn by reflecting on it.” John Dewey
Annotated Bibliography

**More about Neuroscience:**

**Videos / Digital Courses**


This is a series of 24 lectures focusing exclusive on memory: types of memory, how memories are built and rebuilt, and how and why memory fails. Neuroscience vocabulary is introduced with examples and analogies to make these advanced concepts readily understandable.


This is a series of 24 lectures focusing on how the brain functions. It touches on memory, but also addresses neuroplasticity, sensory experiences, emotions, and how the brain pleasure, attention, stress, and grief, among others.

**Lectures**


Lecture sharing research about longitudinal studies following Montessori students in math, language, and science. The study found that Montessori students do better at tasks that require divergent thinking than peers in non-Montessori settings.


Lecture presenting a summary of current research on the neuroscience of learning, including the office model as an analogy for the learning process used in this presentation.

**Publications (Books and Articles)**


This book traces brain development from prenatal time to maturity. Research, story, and insights fully develop the story of how we learn and the limitations that largely we place upon ourselves.


Peer reviewed article about the function of the hippocampus.
Katrina Schwartz outlines “thinking maps” and the importance of children having a “hands on” experience with materials and topics to strengthen learning. This article provides indirect support for Montessori education as a cutting edge brain based educational philosophy.

This article includes an in-depth look at the role math materials play in the strengthening of working memory and the importance of concrete representations of math concepts in children up to 6th grade. It also looks at the neurochemicals in the brain that play a part in motivation and strengthening neural networks. If you need neuroscience inspire you to use more materials in math, this is a good article to start with.

Linda Stade examines observable characteristics of deep learning. The smc education blog contains relevant topics for curricular areas as well as social issues, and parenting tips for teachers.

“STEM schools teach concepts that children are not developmentally ready for. They need a solid foundation that is based on human development, not founded in the economic development of the nation,” This article makes a strong argument against setting standards in education which are inappropriate for developmental levels and the consequences of those actions.

His article explains the processes of building memory and knowledge within the brain. He pays special attention to the role of the hippocampus in forming new memories and the connection between emotion and learning. Brain World Magazine is a publication dedicated to the nature of the brain, consciousness, and behavior. It is a reliable source of information as well for further brain studies.
More about Math:
Videos / Digital Courses
This Ted Talk discusses causes of math anxiety in children, including not enough time to complete tasks, anxiety from teachers, and unintentional gender stereotyping. This video also offers strategies for parents, teachers, and administrators to help relieve this anxiety.

Publications (Books and Articles)
This article includes an in-depth look at the role math materials play in the strengthening of working memory and the importance of concrete representations of math concepts in children up to 6th grade. It also looks at the neurochemicals in the brain that play a part in motivation and strengthening neural networks. Additional information on encoding information as part of learning math is included.

More about Language:
Publications (Books and Articles)
An album of Montessori Language lessons and activities with a scope and sequence that integrates Parts of Speech and Circles and Arrows work. Each lesson has suggested follow-up activities scaffolded by the stage of learning: analyze, synthesize, or utilize.

This article, referenced in the presentation, describes the identification of issues in NYC high school students’ writing as being a lack of fundamental understanding of the structure of writing at the sentence level, and what the school did in response. It lends support to teaching grammar as a means to strengthen children’s reading and writing.

Short article about the history of diagramming sentences, but can lead to a further discussion about the importance of creating a picture of language.
More about Cultural:
Publications (Books and Articles)
Michael Dorer’s utilizes the Montessori principle of storytelling and the power of children’s imaginations to provides interactive stories to use with materials with in almost every curricular area. Stories for EI and EII components are contained in this collection as well as The Great Lessons. Very useful if you are looking to bring the materials to life and enchant children with stories that they will relate to concrete materials.

Priscilla Spears provides an in-depth curriculum into the phylogenetic relationships of all living things through the five kingdoms and the tree of life. Her curriculum provides a chart for study as well as detailed picture cards. Each section contains teacher reading materials as well as lessons and follow-up work for children. This is a fantastic resource for those wanting to go further in-depth with Living World studies.