Learning and Creativity: Ideas from Montessori and Neuroscience

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"…creativity – the process of having original ideas that have value – comes about through the interaction of different disciplinary ways of seeing things"

"Creativity is as important in education as literacy and we should treat it with the same importance."

Sir Kenneth Robinson, TED Talks, June 2006

In the wake of Sir Kenneth Robinson's groundbreaking talk in 2006, many in the field of education have been inspired to take a closer look at creativity in education and how to foster it. In this paper, we will examine the learning process in Montessori together with research from neuroscience and look for implications for fostering creativity in the education of young children.

What is Montessori?

It has been 100 years since Montessori opened her first *casa* classroom in Rome and began lecturing and writing about her discoveries relating to child development and learning. At the core of her theories was the idea that children under the age of 6 learn effortlessly from their environment – coining the term *the absorbent mind* to describe their process of learning. She postulated that there were sensitive periods for development in the areas of movement, sensorial exploration, language, and mathematics and that providing enriched environments for young children brought about rapid development in the children's cognitive abilities in these areas.

In this context, the Montessori curriculum and practices as defined by the Association Montessori Internationale (AMI) – which oversees teacher training and recommended materials – are used as the Montessori benchmark. AMI was founded in 1929 by Maria Montessori and currently operates 39 training programs for *casa* teachers across five continents. Both Maria Montessori and Jean Piaget viewed the child as an active learner, and there are similarities in their approach to educating children.

Angeline Stoll Lillard identified 8 principles of Montessori education:

(1) that movement and cognition are closely entwined, and movement can enhance thinking and learning;
(2) that learning and well-being are improved when people have a sense of control over their lives;
(3) that people learn better when they are interested in what they are learning;
(4) that tying extrinsic rewards to an activity, like money for reading or high grades for tests, negatively impacts motivation to engage in that activity when the reward is withdrawn;
(5) that collaborative arrangements can be very conducive to learning;
(6) that learning situated in meaningful contexts is often deeper and richer than learning in abstract contexts;
(7) that particular forms of adult interaction are associated with more optimal child outcomes; and
(8) that order in the environment is beneficial to children. (Lillard, p. 29)

In addition, a number of differences in the setup, schedule and curriculum of a Montessori versus a traditional classroom merit further note. Montessori includes a mixed age range – from ages 2 ½ to 6 for *casa* – and children interact often with others of similar and different ages. The Montessori curriculum is set in terms of the potential work that each child could do over time instead of being set as the work that every child will do during the same time period. Each child follows his own schedule and path, but the order of lessons within each area is roughly the same for each child, since lessons increase in complexity as the child moves through the program. The four areas of the classroom are Practical Life (i.e., pouring, buttoning, polishing), Sensorial (i.e., matching, grading by shape, size or other characteristics), Language (oral, writing, reading) and Mathematics (from concrete to abstract). The Montessori classroom uses child-sized shelves for materials, child-sized furniture and the children choose their work space, either at a table or on a mat on the floor. Each material is designed to work on or isolate a particular feature (such as size), set of movements (such as tying a bow), or process (such as building a hexagon from 6 equilateral triangles). Many of the activities are materialized abstractions – that is, a hands-on way to learn an abstract concept. Each child is free to work with each material that he[1] has been shown and work for as long as chooses. From the time that children walk in, they are free to choose work and associate with others provided that they are not disrupting others' work. Lessons are given to each child at the discretion of the teacher. If there is a story read out loud or some other group activity, it is usually optional for the children rather than required. The teacher's role in the Montessori classroom is less that of a teacher than that of a guide. Once the child has been given a lesson, the teacher invites the child to work on his own with that material. Every activity in the classroom is called work, but it could equally be called play. There is no distinction in terms of the value of one activity over another.

One could describe the education process in Montessori as follows: independent, hands-on learning and exploration. Independent refers to the self-directed learning, the materials are hands-on, and there is an opportunity for the child to explore in his own way with the materials.

Creativity in Montessori

Some would view the idea of creativity in Montessori as an oxymoron. In their defense, the structure and order within the classroom could be seen as constraining, and the teachers' strict adherence to Montessori pedagogy (rather than experimentation within the classroom) could be seen as stifling to the creative process. What is not apparent without a closer look at the lessons and the work done in the Montessori environment is that the structure in the classroom provides the scaffolding for the children to explore in a creative way in their everyday work. Examples include but are not limited to metal insets, the graded colour tablets, the fractions, the pink tower,

[1] The convention here is to use *he* to refer to the child, and *she* to refer to the teacher

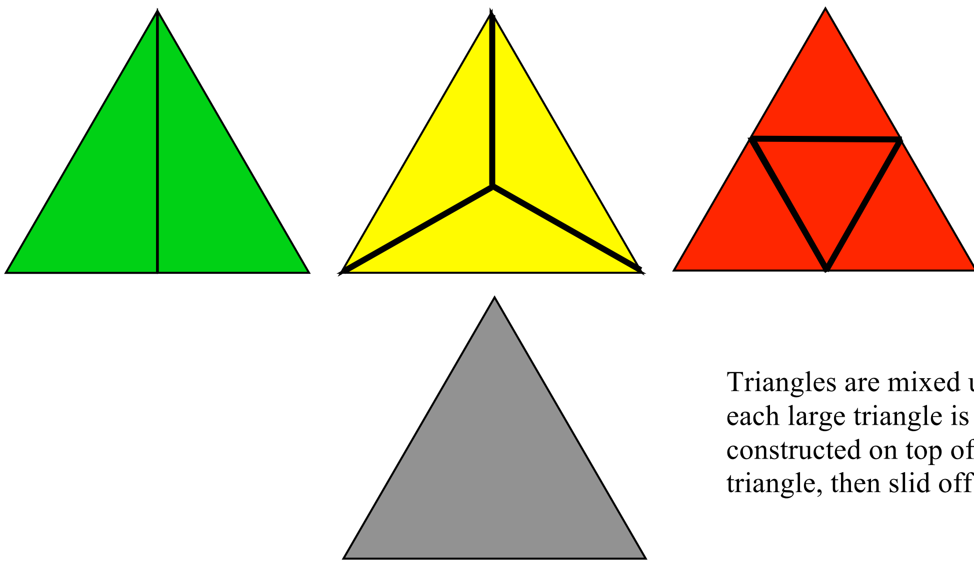
geometric solids and the constructive triangles. Not only are materials provided that enable children to express themselves creatively in various ways, but the fact that there are some consistent colours, sizes and relationships (based on the metric system) across the materials invite the children to envision and create links between completely different activities. A prime example of such a link is the building of the pyramid of squares in the decanomial square activity (sensorial) and the squares used in skip counting (math).

Constructive triangles

The constructive triangles from the sensorial area will be used here to illustrate how creativity is encouraged and scaffolded in a Montessori classroom. Each of the lessons is given one-on-one, with the teacher showing a series of movements and combinations and then inviting the child to follow, a process central to the Montessori method of teaching. There are 6 activities in the constructive triangles series, each of which is outlined below. These lessons would be given to a child aged 5-6.

1. Rectangular box A: building 7 shapes, each consisting of two triangles
2. Rectangular box B: flipping and sliding one triangle around the other for 5 different quadrilaterals (each quadrilateral consisting of 2 triangles)
3. Triangular box: building an equilateral triangle in 3 ways, using 2 right-angled scalene triangles, using 3 obtuse isosceles triangles, and using 4 equilateral triangles (Shown in Exhibit 1)
4. Large hexagonal box: building parallelograms, equilateral triangles and a hexagon using only obtuse-angled isosceles triangles
5. Small hexagonal box: building a rhombus, trapezium and a hexagon using only equilateral triangles
6. Design box: creating a design using 12 identical blue right-angled scalene triangles

Exhibit 1: Constructive Triangles (#3): Triangular Box



Triangles are mixed up, then each large triangle is constructed on top of the grey triangle, then slid off.

Before linking these processes to neuroscience, we will step back and cover some basic ideas and research in the area of neuroscience.

A primer on neuroscience

Technology has enabled researchers to make incredible discoveries about the learning powers of the brain, and particularly, the windows of learning that are open in early childhood. We will take a closer look at the development of the child's brain and recent research that has unveiled new information about the processes underway during the early years that are relevant to education.

Key areas of the brain:

- The prefrontal cortex is responsible for executive function.
- The temporal lobe is responsible for language, reading and for auditory stimulus.
- The parietal lobe is associated with mathematics, spatial representation, and creativity.
- The occipital lobe is linked to sight.

- The hippocampus is responsible for memory.
- The motor cortex is involved with movement.
- The cerebellum is linked to numerous functions, including balance, movement coordination, emotion regulation and higher executive function.

Neuroscientific research has identified that children facing deprivation or a lack of stimulation in particular areas during sensitive periods for development will have a deficit in that particular area of brain function. However, research has also supported the idea of plasticity in the brain. Given that the human brain can adapt and even produce new neurons over its lifespan, learning and a strengthening of connections within the human brain occur throughout one's lifespan (Blakemore & Frith, 2005).

The question for early childhood educators of which type of environment is ideal for children may seem simple, but the answers are not yet clear. Research on rats revealed that an enriched environment (which for rats includes spinning wheels, ladders and rat playmates) boosted rats' cognitive development, with these rats showing up to 25 percent more synapses per neuron than rats in a non-enriched environment (Blakemore & Frith, p. 32). As Blakemore and Frith note, "it is unlikely that children brought up in any "normal" child-oriented environment could be deprived of sensory input (p. 33).

Implicit versus explicit learning

Maria Montessori proposed that children up to the age of about 6 possess what she called an absorbent mind, learning effortlessly from the environment around them. In contrast, Montessori viewed the child over 6 as more of an abstract learner, one who is open to direct instruction. Education systems around the world also view the age of about 6 as the cut-off between a type of pre-school or Kindergarten and the formal learning that occurs in grade 1.

Looking through the lens of neuroscience at this differentiation, we can name these two learning styles as implicit and explicit. Montessori *casa* classrooms make use of implicit learning for the most part, while Kindergarten or pre-school programs tend to offer a more play-based approach, which may contain elements of both implicit and explicit learning.

Returning to the constructive triangles exercises, for activities 1 through 5, the child is shown then invited to undertake the sequence of steps used to build and/or move the created shapes. The activities call for inhibition of movement (when the child watches the teacher working directly in front of him), the activation of mirror neurons (as the child observes the actions), working memory (storing the created shapes and movements shown), and movement (the wooden shapes are mixed up, then matched and manipulated). The creative process is initiated after experience with activities 1 through 5, when the child is shown the 6th lesson – design. The design lesson involves the teacher demonstrating design by building a particular shape of her choosing and inviting the child to build whatever he wishes using the triangles. The experience with exercises 1 through 5 builds the child's competence and prepares him to work with the triangles creatively.

Executive function: inhibition of movement

It has been proven in recent years that executive function (EF) in preschool children is a good predictor of cognitive development and of school readiness. "School readiness and learning achievement across the content areas and grades rely on EF processes, which is why EF skills should be promoted and trained in early childhood programs and schools" (Kubesch et al, p. 236).

Although there is no explicit lesson or area of the Montessori *casa* designed to work on executive function, the program does foster the development of executive function in the way the children interact with each other and with the materials. In particular, the fact that there is only one of every activity means that children have to wait their turn. Placing the material back on the shelf ready for the next child to use brings to the child's attention the impact of one's actions on the others in the room. Understanding of others' needs is learned from the environment as children realize that they do not wish to be disturbed in their work (and children do not hesitate to tell other children that they do not wish to be disturbed!).

Within the brain, the frontal lobes are involved with inhibition of movement. As Blakemore and Frith note, "abilities that require inhibition, such as advanced social etiquette and rational decision making, tend to emerge gradually parallel with the development of the frontal cortex" (p. 163). The inhibition of movement involved when a child is observing a lesson, whether when being taught directly, or when observing another child's lesson, is one of the key aspects of the child's behavior that is observed and monitored by the Montessori teacher. For the younger child (aged 2 ½ to 3), lessons are of extremely sort duration – sometimes only 30 seconds – partly as a result of the simplicity of the exercise, but also as a result of the young child's as yet limited capacity for inhibition of movement. For the older child (aged 5-6), the duration of lessons is generally much longer, requiring a much higher degree of inhibition of movement as well as a greater capacity for focused attention. For the child, this gradual increase in the amount of inhibitory control requested from his environment over time is one way that the development of the child's executive function is supported and strengthened in the Montessori classroom.

Mirror neurons

When a child is receiving a lesson, not only must the child inhibit movement, the child must also observe the teacher's actions with the object of enacting them soon afterward. The activity of watching is not passive in the brain, as mirror neurons in the premotor cortex are at hard at work. Brain scanning has shown that when one observes another person performing a movement or series of movements, the observer's brain goes through many of the motions that it would if the observer were performing the action. The brain is effectively preparing itself to replicate the movements. In research with monkeys, it was found that viewing of a goal-oriented action was required to get the mirror neurons to fire, not the viewing of the objects themselves. This neuron activity may help the monkeys to understand the goal of the observed action (Blakemore & Frith, 2005).

Working memory

When a child undertakes an activity requiring a sequence of movements or a series of steps to follow, the child uses his working memory. As Kubesch notes, "working memory allows operating with short-term stored information. This is the precondition for the development of complex cognitive functions, including language (p. 235). There are many examples of demands placed on working memory in the Montessori classroom, ranging from matching colour tablets at a distance by keeping the requested colour in memory, to retrieving a specified quantity of beads from across the room based on only verbal instructions. For the example of the constructive triangles, there is a complex sequence of movements to be followed, particularly in the case of the large hexagonal box, which can provide a challenge to a child without a strong working memory. If the child is unable to carry out the entire task, or asks for help, the teacher would repeat the lesson with the child. In this way, the child is supported in the building of his working memory.

How is working memory different from long-term memory? Working memory and long-term memory involve different systems in the brain. Research with monkeys revealed that the prefrontal cortex was activated when monkeys were holding an idea or plan of action in working memory (Blakemore & Frith, 2005). Long-term memory, in contrast, is located in the hippocampus. There are implicit and explicit components to long-term memory, with the former including episodic and semantic information, and the latter including procedural and emotional information. For the example of the constructive triangles, the types of memory activated would likely be procedural, which would include skills such as building shapes using triangles, and semantic, to the extent that the child learns the names of the triangles and shapes he is creating.

The types of learning and memory activated by the constructive triangle exercises are undoubtedly complex. These Montessori activities, although not researched directly, can be linked to the following research findings in the area of geometry: "Highlighting perceptually different types of triangles may bolster children's comprehension of what a real triangle is. Showing these kinds of shapes supports learning that triangles are any closed figure formed by three intersecting lines, rather than believing that a triangle is a particular perceptually arresting instance…Active exploration, in combination with dialogic enquiry…has been found to be especially beneficial for learning geometric shapes—even more so than direct instruction (Newcombe and Frick, 2010, p. 107).

Movement

In the example of the constructive triangles, the parietal cortex, which is involved with spatial representation, as well as the motor cortex, which covers movement, would be activated when the child undertakes this activity. Not only do all Montessori activities require movement, they also require hands-on manipulation of the materials as an aid to learning concepts. Research has revealed that many more systems in the brain are involved in movement than was previously thought. "In addition to the motor cortex, movement control involves the interaction of many other brain regions, including the basal ganglia, thalamus, cerebellum, and a large number of neuron groups located within the midbrain and brainstem — regions that send axons to the spinal cord. Scientists know that the basal ganglia and thalamus have widespread connections with motor and sensory areas of the cerebral cortex" (Society for Neuroscience, 2008). Montessori claimed that, "we may put it like this: the child's intelligence can develop to a certain level without the help of his hand. But if it develops with his hand, then the level that it reaches is higher, and the child's character is stronger (Montessori, p. 152). With the current emphasis on play-based learning, the idea of learning as an active (and enjoyable) task is now widespread. As Blakemore and Frith note, "it is through play and direct physical experience that children gather most of their knowledge about the laws and rules of the world they live in" (p. 108).

Implications for creativity in education

Bringing the discussion back to fostering creativity, how do we combine the ideas from neuroscience and Montessori to help us understand the creative process? Sir Kenneth Robinson emphasizes the coming together of ideas from different disciplines in his view of creativity. Blakemore and Frith note that: "creativity is required for the flexibility and originality to go beyond imitation. On the other hand, creativity without imitation may generate many novel ideas, but these would often be wasteful because they may not take into account what is already known, tried and tested" (p. 163). Combining these ideas, one might conclude that creativity would be fostered in an environment where there is not only learning from others' and one's own experience, but also a freedom to explore ideas and relationships between different areas of learning or disciplines. The above examples show that such an environment is possible in a Montessori classroom, and can also be created in many other educational settings.

The axiom: "use it or lose it" is often applied when talking about the synapses in the brain. Repeated activity forges stronger synapses, or connections between neurons, and enhanced capabilities. Our examination of one set (from among dozens of sets) of exercises in the Montessori curriculum demonstrates that it is possible to design activities for children that invite them to use a broad range of systems for learning, thereby strengthening the connections within the brain. If we can incorporate this variety into children's learning environments, and give the children the chance to be creative, we are likely to be on the path towards meeting Sir Kenneth Robinson's challenge of the uncertain future:

"the only way we will do it is by seeing our creative capacities for the richness that they are and for seeing our children for the hope that they are and our task is to educate their whole being so that they can face this future" (Sir Kenneth Robinson, TED Talks, 2006)

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