CASA Montessori

S: Physical and Social SCIENCES
T: Incorporation of TECHNOLOGY
E: Principles of ENGINEERING and Design
A: English Language ARTS
M: Application of MATHEMATICS

What is the History of STEM?

Since the launch of Sputnik in 1957, the US has called for an increase in scientific and mathematical education.

President Barack Obama put out the call in his 2011 State of the Union Address, igniting a movement to teach students 21st-century skills to become more competitive with other nations in the fields of STEM. Millions in funding from public and private sectors flooded in for teacher training, grants, research, and school programs that promote STEM study. In the last decade, there has been an increase in math and science course offerings, higher expectations for testing, and an evolution of project-based learning using STEM as a framework for exploration. The increased emphasis has been embraced by policy makers, corporations, educators, and parents; all of which understand the importance of STEM education in the 21st Century as the global economy becomes more dependent upon innovation, science, and technology.

This approach emphasizes how all fields relate to each other and that project based learning on real life situations is a better approach to learning than segmented subjects with hypothetical questions. Educators have been charged to be creative and engaging rather than just teaching from a textbook.

Furthermore, this movement in education circles moved forward even further to include Arts and became STEAM.

Technology

Technology is more than just computers and abstraction. If we define technology in its rawest state, it's really about using *tools, both simple and complex*, to improve people's lives.

Before moving on to complex tools like computers, let the children master simple tools first. Even a spoon is a tool. Practical Life around the home abounds in opportunities for children to use tools: cleaning tools, kitchen tools, and so forth. In the elementary the children are loading dishwashers, using microscopes, drills, cooking and all that entails, and much more.

Why the "A" in STEAM is important in education?

"The arts can no longer be treated as frill. Arts education is essential to stimulating the creativity and innovation that will prove critical to young Americans competing in a global economy."
- Arne Duncan(U.S. Secretary of Education 2009-2015)

Professionally, there is a STEM shortage in our country. We need the "A"—not just because real STEM professionals need artistic and design skills to be better STEM professionals, but because the arts are a way to recruit students to the wonders of STEM.

Every engineer who comes up with a new innovation practices far more than math, engineering, and technological prowess. They also use design-thinking, creativity, communication, and artistic skills to bring those innovations to fruition. The antiquated idea that scientists are isolated workers huddled away in laboratories is a falsehood.

Today's innovators are creative, working collaboratively in open work environments, sharing ideas globally with other thinkers, and combining their STEM powers with incredible STEAM talents.

Today's trailblazers are communicators who design, craft, experiment, and pioneer. To make STEM truly work, we must include the arts.

How Does Montessori Relate to STEAM?

Often things that are reported as new "discoveries" or trends in education are things that Maria Montessori observed 100 years ago and incorporated into the time tested, scientifically proven approach we use at Casa. As with many other areas where Dr. Montessori was an innovative leader in education, it is possible that her *Casa dei Bambini* was among the first to bring forth at least some minor level of relevant Science content to the Preschool environment. Maybe it was Dr. Montessori's background as a medical doctor that helped her see that Science belongs in preschool, when other educators didn't? Activities such as Land and Water are powerful STEM activities already, in common use among Montessorians way before STEM was "invented"?

Three important Montessori ideas are: the importance of movement in learning, the benefit of developing internal motivation rather than being given external rewards, and how to have all subject material including STEAM (Science, Technology, Engineering, Arts, and Mathematics) in education in an integrated, concrete, real-world way. These are all important components of the curriculum and experience that students have at our school from toddlers through Upper Elementary.

In traditional education the sequestration of knowledge into categories that don't connect is ultimately detrimental to our students because in the real world, all of it blends together. The scientists who can use science and math to create a new treatment for disease must also incorporate design-thinking to

imagine and visualize their work. They must also express themselves using impressive communication skills in order to secure funding and support. They must work collaboratively with their colleagues and investors to improve and expand ideas, and then publicly speak about their progress and discoveries with eloquence and ease. These multi-skilled individuals are a representation of a student who understands how academic subjects are meant to be a genuine symphony and not a collection of discordant solos.

The current STEM movement is calling for innovation, collaboration, and hands-on learning and problem solving. To the Montessori community, this is nothing new. This is what Montessori is based on and what happens every day at Casa Montessori School. At Casa Montessori School we do STEAM!

Since inception, our school has focused on fostering a love for learning and to create well-rounded global citizens. Applying this interdisciplinary approach, we are able to make numerous connections between science, engineering, math, technology, and art.

This approach is a natural extension of the Montessori Cosmic Curriculum which provides both inspiration and instruction. Children then engage in hands-on inquiry-based activities which allow them to build on the concepts and skills they have learned.

<u>The connection of the Hand to the Mind:</u>

The human mind is wired to learn through moving and experiencing, not through sedentary rote memorization. The classroom and outside environments at Casa, encourage concentration, movement and experiential learning.

When students use their bodies in the learning process, it can have a big effect, even if it seems silly or unconnected to the learning goal at hand.

The Body and the Brain

Scholarly study goes back a long time in history, but in terms of human evolution, many of the academic skills now required for successful functioning in the world are fairly new to the human brain. As neuroscientists investigate how humans learn, they often find that newer skills and aptitudes are mapped onto areas of the brain that also control basic body functions. Increasingly, this work is helping to illuminate neurological connections between the human body, its environment and the process of learning.

This area of study, called "embodied learning," is not new to many educators. Learning that involves a mix of kinesthetic, mathematical, mechanical, collaborative, intellectual, emotional, physical and social components. Where the children aren't just thinking about a solution, they're *living* the solution. What they learn is wired into their neural net at every level. It's not just an intellectual experience. It's *embodied*. This is also known as *optimal* or *robust* learning.

Maria Montessori highlighted the connection between minds and bodies in her 1936 book The Secret of Childhood: "Movement, or physical activity, is thus an essential factor in intellectual growth, which depends upon the impressions received from outside. Through movement we come in contact with external reality, and it is through these contacts that we eventually acquire even abstract ideas."

Increasingly scientists are proving Montessori correct. Researchers are studying the body movements of children as young as four-to-six months old and have found earlier and more frequent movement correlates with academic learning down the road. Kids who could sit up, sustain “tummy time” longer and walk extensively were all correlated with future academic success, even when researchers controlled for socioeconomics, family education and type of future education, among other mitigating factors.

Children in the first plane of development (0-6 years old) are sensorimotor explorers, meaning they learn best by moving and using all their senses. In *The Absorbent Mind*, Dr Maria Montessori herself called it “**one of the greatest mistakes of our day… to think of movement as something apart from the higher functions. The child uses his movements to extend his understanding. Movement helps the development of mind**.” (p125-6)

As young children move and explore their worlds, they are learning through touch. Early bimanual training correlates with the robustness of the corpus callosum, a part of the brain that facilitates quick communication between the left and right brain hemispheres. Thus this connection between using ones hands and swift communication in the brain may be part of the reason that learning to play music is often correlated with math ability. Math is a very recent cultural invention and the part of the brain responsible for numerical representation also controls finger motion. Many children first learn to count on their fingers, a physical manifestation of this connection.

Environment Matters

Just as body movement and involvement can have a huge impact on learning, so too can the spaces where we learn. While

neuroscientists are starting to be able to prove this link with their experiments, this concept is nothing new. Philosophers, writers and practitioners of Eastern religions have long made the same connection between the power of nature to relax the mind and readiness to take on the world.
Visual distractions also apply to the classroom. Carnegie Mellon researchers recently found that when students learn in highly decorated classrooms, their gazes tend to wander, they get off task and their test scores suffer. Limiting visual stimulus is particularly important for very young learners who are still learning how to focus, and yet some kindergarten classrooms are often the most brightly and densely decorated in an effort to make institutional buildings feel more cheerful.

Internal Motivation, Not External Rewards:

Social scientists, such as Daniel Pink, have studied motivation in the business world for a long time and concluded that traditional ways of motivating employees with financial incentives doesn't work. In study after study, social scientists have found that external rewards narrow the focus and restrict possibilities, making it difficult for people to come up with creative solutions to complex problems. The only time incentives worked, in fact, was when the problem was mechanical and the path to the solution was straightforward.

Instead, companies around the world have shown that employee motivation increases when people have autonomy, a driving purpose and the desire to perfect their craft.

Teachers are preparing students for a world in which the jobs increasingly require problem solving, critical thinking and creativity. Many schools are trying to mirror that sort of thinking in the classroom to give students practice confronting messy

problems, but many students have very little autonomy, mastery or purpose with which to develop intrinsic motivation. So using tests and grades and other external motivators are not beneficial to children. To foster intrinsic motivation students should be given opportunities to do real-life problem solving and feel a sense of purpose from doing real tasks where they can develop a sense of skill, pride and accomplishment. This can be:

- serving a friend snack, our toddlers do this with great enjoyment and pride
- washing a table, a classic Montessori activity often accomplished in our Primary classrooms
- choosing a menu for, planning, shopping and creating a lunch in Lower El. (Taco Day, Sub Day)
- building bird boxes in the Upper Elementary, using precise measurements, calculations, and skilled craftsmanship
- running a monthly lunch business for staff, used book sale and bake sales to raise money for the Upper Elementary trips

<u>The Benefits of Cultivating Curiosity in Kids</u>

Despite the centrality of curiosity to all scientific endeavors, there's a relative dearth of studies on the subject itself. Scientists are currently actively unraveling this concept and, in the process, making a convincing case that we can and should teach young minds to embrace their inquisitive nature.

Curiosity comes with many benefits. Studies suggest it's linked to joy on the job, social skills and even a happy disposition. In an academic context, greater curiosity generally predicts greater success.

Prachi Shah, an associate professor of pediatrics at the University of Michigan, published findings from a study of 6,200 children and found that elevated curiosity was linked to higher math and literacy skills among kindergarteners. That effect remained strong even when researchers compared kids with similar levels of "effortful control," or the ability to concentrate and pay attention. Even more surprising, she discovered that students from impoverished backgrounds with a strong thirst for knowledge performed as well as those from affluent homes.

Neuroscience is starting to explain curiosity's power. A hunger for answers changes our brain activity in ways that help us retain new information. For one, the curious mind engages processes and brain regions associated with anticipating a reward. We want to learn more because the answers are satisfying. In addition, the hippocampus, a memory hub, increases in activity, preparing to store information. The more we want to know an answer, research suggests, the more memorable it becomes.

"Curiosity is automatic, it's in our DNA … We're born curious about so many things," said psychologist, author and researcher Scott Barry Kaufman. However, we are not equally curious about everything. Instead we each have special interests and natural proclivities. Thus, allowing children to follow their interests will increase their curiosity. Students, in a Montessori environment, are given looser curriculum guidelines and allowed the leniency to follow their own natural interests.

STEAM in the Toddler Program

Students in Casa's toddler practice and explore in the areas of science, technology, engineering, arts and mathematics in their daily exploration of both the indoor and outdoor environments.

Goals of the Toddler STEAM Program:

- Cultivate communication.
- Encourage the child's natural curiosity, creativity and innovation.

Sample Toddler Activities:

- Exploring the use of tools, such as droppers and spoons
- Participating in and observing scientific experiments
- Creating materials or products such as bread
- Building with age-appropriate engineering materials such as natural blocks

STEAM in the Primary (3-6) Program

The Primary environment provides an age-appropriate environment for preschool and kindergarten-age students to continue to develop their understanding of STEAM concepts. While the materials and environment become more complex at each level, the main goal of the program remains the same: to encourage each child's natural curiosity, creativity and innovation. Students learn the fundamental rules of math and science through the discovery of natural laws through manipulation of didactic materials and problem-solving with peers. The work engages the senses and insures the *internalization* of concepts, not just memorization of disjointed facts and figures.

STEAM and Montessori are highly complementary, with their emphasis on the child determining what he learns through hands-on experimentation. Movement is not separate from cognition but connected in a feedback loop; movement *is* cognition. Dr Montessori presses her point: "**The more delicate the work, the more it needs the care and attention of an intelligent mind to guide it.**" (134)

Thus, jumping straight into abstract algorithms and coding betrays a fundamental misconception about how first-plane children learn, which is through concrete, hands-on experiences.

In fact, all aspects of STEAM overlap, but art and math seem especially inseparable. If math is about recognizing patterns of numbers and shapes, art is about creatively expressing one's concept of those patterns. Look no further than the sensorial materials, especially the color tablets, to witness color theory in a Montessori classroom.

Goals of the Primary (3-6) STEAM Program:

- Promote flexible and adaptive thinking.
- Develop higher order thinking skills (critical, logical, reflective, metacognitive and creative thinking).
- Cultivate communication skills and collaboration.
- Stimulate cooperation and fellowship between children and their peers.

Sample Primary (3-6) Activities:

- Experiencing sensory lessons to promote cognitive, linguistic, social and emotional skills
- The metal insets combine art, with geometry, and are a preparation for writing.
- Participating in scientific experiments and experiences
- Follow the child's interest, especially in the study of nature. Nature provides one of the biggest driving forces of curiosity and exploration while offering rich sensorial experiences for children.

STEAM in the Lower Elementary Program

Students in the Lower Elementary utilize more advanced, state-of-the-art equipment while also continuing to explore some of the materials they have seen in the Primary environment with a deeper understanding. It is at this level that many children begin to truly develop a "Maker Mindset" that allows them to believe that they can build, create, plan, design or learn anything. In both Elementary levels the Montessori concept of Cosmic Education, gives a curriculum emphasizing that everything is interrelated; students see how math and science work harmoniously in nature, like in the Fibonacci sequence.

Math and science work harmoniously in nature.

Goals of the Lower Elementary STEAM Program:

- Allow children the freedom and space to practice and explore in the areas of science, technology, engineering, the arts and mathematics.
- Stimulate cooperation and fellowship between children and their peers.
- Create a safe learning environment where children can make mistakes, learn and recreate from their mistakes.
- Develop a community in which the arts are appreciated, valued and seen as a critical component of all of the sciences.

Sample Lower Elementary Activities:

- The “timeline of life” is a lesson in history, biology, geology, and can be beautifully rendered in colored pencils, or felted wool!
- Participating in scientific experiments and presenting data and findings from those experiments
- Researching scientists, mathematicians and artists
- Participating in group projects, often creating visual representations of lessons. For example : posters, dioramas, skits or clay objects

STEAM in the Upper Elementary (9-12) Program

The classroom in the 9-12 Program, is a space to get to know themselves better as learners, advance their understanding of science, technology, engineering, the arts and mathematics, and make connections with other curricular areas. It calls for an increase in hands-on discovery and the use of outside resources such as museums, science centers, and other 'real-life' activities that engage and focus student's attention in the areas of science, technology, engineering and math. Again, Montessori teachers have been using "going-out" opportunities to pique student interest and foster real-life connections for over 100 years.

Goals of the Upper Elementary STEAM Program

- Support children in becoming advocates in their learning.
- Promote a global understanding of others and their cultures by sharing and creating works of art from different nations around the world.
- Create a safe learning environment where children can make mistakes, learn and recreate from their mistakes.
- Promote an integrated curriculum throughout Casa Montessori School through experiences in the classroom and allow that to extend beyond the classroom.

- Encourage the children to identify their own affinities in learning and appreciate the intelligences, interests and abilities of others.

Sample Upper Elementary Activities:

- Developing projects in Upper Elementary requires combining disciplines to prepare a written and physical illustration to communicate a complex concept.
- Presenting information in a variety of platforms such as speaking, composing, illustrating or using a presentation application such as PowerPoint.
- Participating in scientific experiments and presenting their results
- Collaborating with classmates on STEAM projects
- Learning about and sharing their own personal intelligences

Montessori “Products”

Larry Page and Sergey Brin, Co-founders of Google, have said that Montessori education allowed them to think for themselves. They credit Montessori with allowing them to question what was going on around them and to discover the answers for themselves. Former Montessori students, Jeff Bezos, founder of Amazon.com, and Will Wright, inventor of “The Sims” video game series, also credit Montessori for allowing them to ask questions, discover, and learn on their own terms. The Wikipedia page on founder, Jimmy Wales touts his childhood private school as a "Montessori influenced philosophy of education." The massive impact these innovators have had on modern society, in many ways, can be traced to fundamental skills and thinking philosophies developed in learning environments designed by Maria Montessori, a woman of science. While a typical Montessori learning environment will not feature the latest technological gadget, the foundational skills required to problem solve and the most important of all educational tools, the ability to learn and how to learn, will prominently be on display.

Dr Chong, a scientist researching the immune system, had this to say:

To me a good scientist needs to have

1) a curious mind

2) the thirst for new knowledge

3) perseverance to finish their discovery

4) to not be discouraged from multiple failures

To encourage young children to have a scientific mindset, I think it's important that children

1) question often what is taught to them

2) accept failure as part of learning and achieving success

3) think out of the box and ask themselves how can I improve what I have at the moment. For eg, how can I make a car move faster; is there any other method to approach the same solution that is better?

4) to love learning and creating new knowledge.
And I would add perseverance and patience. Being in this industry can be depressing as you are faced with failures 80% of the time. So I think it's important that kids don't give up!

Intellectual curiosity. Integrity. Resilience. Perseverance. And above all, a sense of awe and wonder.

Any moderately clever person can be taught math, science, and tech as an adult in college. It's much, much harder to learn perseverance and the ability to self-direct your problem solving. It's also very hard to untrain the habits of competing for grades and gold stars and to retrain yourself into intrinsic motivation for the joy of discovery and accomplishment.

Long before girls were openly encouraged to pursue careers in STEM industries and did not have the benefits of Race to the Top initiatives, a pioneer carved a legacy often overlooked in the modern landscape of science and technology - Dr. Maria Montessori. In 1896 Montessori graduated from the University of Rome's medical school and was among the first of Italy's female physicians. She had a keen interest in education and became

well-versed in the teaching methods of her time. After being appointed co-director of a special education teacher training institute, she spent a number of years carefully observing children and their learning methods. These clinical, scientific observations of children led directly to the development of her educational philosophy and pedagogy that fostered independence, encouraged the development of critical thinking skills and cultivated a natural desire to learn. A century later, Montessori's impact on the educational landscape can be seen throughout the world as tens of thousands of schools follow the Montessori Method of education.

It should be noted that some reports show that the racial and gender gaps are actually widening for science and math and STEM schools often do not show expected results. For example a study published in 2014 of STEM versus non-STEM schools in Florida and North Carolina showed that there was no difference in the math scores between the programs. Educational statistics are often flawed due to the wide number of variables that must be considered. However, some studies have been done using Montessori students such as one that was published in the journal *Science* in 2006. It found that students with a Montessori education tended to be more socially adaptive and creative. The same study found that the Montessori students, who were divided into groups of youth aged 3-6 and 6-12, fared just as well as traditional students on tests across a number of subjects. Of course, the reliability of such results are questionable since many Montessori schools are private and somewhat selective.

In a nutshell, Montessori education aims to engage young learners by allowing them to develop academically in a more **personalized** manner.