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From Magnetic Compass to Learning Styles: Logic Machines

VOLKAN DURAN [a] GÜLAY EKİCİ [b]

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Abstract: A logic machine is a device, electrical or mechanical, designed specifically for solving problems in formal logic. A logic diagram is a geometrical method for doing the same thing. Many ancient machines such as a compass, a clock can be an example of those logic machines. However, logic machines were not restricted to concrete objects but abstract models since ancient times. When many models especially models about learning, teaching styles are investigated, it can be easily seen that they were built on the structure of logic machines such as Kolb's learning Styles, Gregorc Learning Styles, etc. Therefore, it is important to understand the structure of those logic machines to evaluate the epistemological foundations of those models. In this regard, this paper aims to investigate logic machines in the context of learning styles models in comparison with their historical usage and to discuss the epistemological boundaries of logic machines in terms of those educational models.

Keywords: Logic machines, logic diagrams, learning styles, educational models.

[a] Iğdır Üniversitesi, Fen Edebiyat Fakültesi, Psikoloji Bölümü
volkan.duran8@gmail.com
[b] Gazi Üniversitesi, Gazi Eğitim Fakültesi, Eğitim Bilimleri Bölümü

Pusuladan Öğrenme Stillerine: Mantık Makineleri

Öz: Bir mantık makinesi, elektriksel ya da mekanik bir cihazdır, özellikle formel mantıktaki sorunları çözmek için özel olarak tasarlanmıştır. Mantık şeması aynı şeyi yapmak için geometrik bir yöntemdir. Aslında pusula, saat gibi pek çok eski makine bu mantık makinelerine örnek olabilir. Bununla beraber, mantık makineleri, eski zamanlardan beri somut nesnelerle değil, soyut modellerle de kullanılmıştır. Birçok model özellikle öğrenme ile ilgili modeller, öğretme stilleri incelendiğinde, Kolb'un öğrenme stilleri, Gregorc öğrenme stilleri vb. Gibi mantık makinelerinin yapısı üzerine kurgulandıkları kolayca görülebilir. Bu modellerin epistemolojik temellerini değerlendirmek için bu mantık makinelerinin incelenmesi önem arz etmektedir. Bu bağlamda, bu makale, mantık makinelerini tarihsel kullanımlarına göre öğrenme stilleri modelleri bağlamında incelemeyi ve mantık makinelerinin epistemolojik sınırlarını bu eğitim modelleri açısından tartışmayı amaçlamaktadır.

Anahtar Kelimeler: Mantık makineleri, mantık diagramları, öğrenme stilleri, eğitsel modeller.

Introduction

A logic machine is a device, electrical or mechanical, designed specifically for solving problems in formal logic. A logic diagram is a geometrical method for doing the same thing (Gardner, 1958). The most famous and simple logic machine is Magnetic compass showing directions relative to Earth's magnetic field. The logic behind the compass is actually very simple. There are four direction as North, South, West and East and the crosssections of those directions as well. The compass needle, which is the most significant part of the magnetic compass is mounted on the compass body so that it can move freely. The compass needle always shows the same direction when it ecounters with only the magnetic field of the Earth. The pin always pointing in the same direction is due to the fact that there is a magnetic force of the earth that attracts the needle. The earth is like a giant magnet with one end extending north and the other end south. Magnetism of the world causes the compass needle to rotate to magnetic north (north pole of the magnetic field).

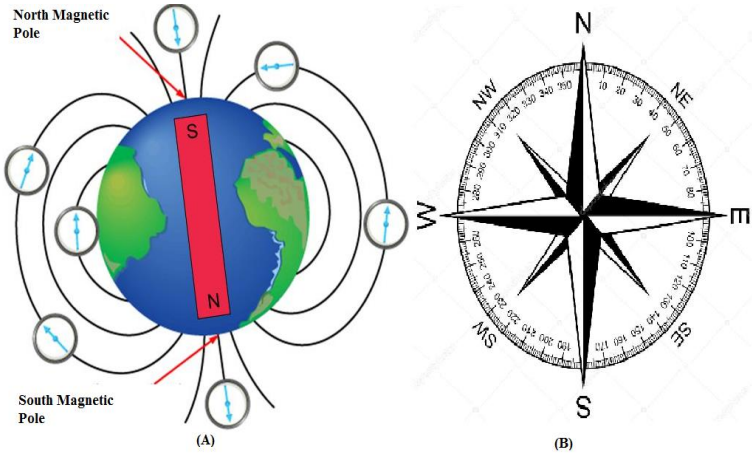

Figure 1. A magnetic compass always pointing North just because the magnetic lines of the earth point toward North away from South (A) A magnetic compass can be given as an example of a simple logic machine.

In terms of their connection with logic machines and diagrams, Aristotle's square of opposition could be regarded as

significant example and prototype of the most primitive form of them. The square of opposition expresses another kind of logical 'laws', in relation with basic propositions with the four quantifiers contradict or 'oppose' each other. In this schema, the A and E are called universal quantifiers, whereas the I and O are defined as particular quantifiers. Furthermore, both A and I quantifiers are remarked as affirmative quantifiers although and the E and O are called as negative quantifiers (Westerståhl, 2005). Through square of opposition, one easily might infer four different interpretation based just on a single proposition or information. For instance, let our informations is "all cats are mammals" and it is a true proposition, this immediately brings three different informations as "no cats are mammals", "some cats are mammals", "some cats are not mammals" and they can be attributed and arranged as false, true, false in an order.

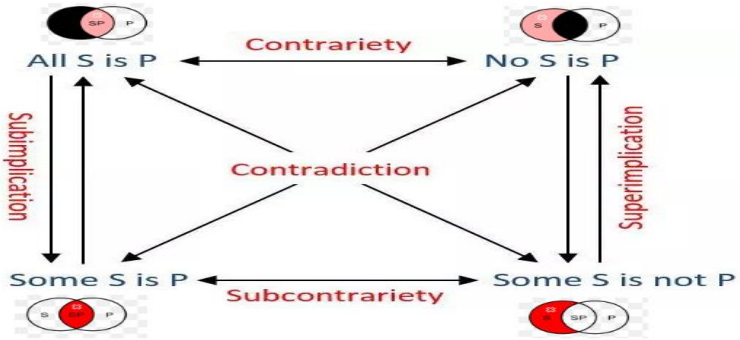

Figure 2. Square of opposition

Therefore, in this study it is aimed to investigate the samples of logical diagrams and machines in the context of square of opposition and to discuss the common characteristics of logical diagrams and to propose a thought experiment based on these characteristics.

Methodoloy and Findings

In this sections different examples of logic diagrams will be given from primary sources in the context of square of opposition and logical diagrams. The data collection method is document analysis which is a form of qualitative research in which

documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009). Hence documents are collected and analyzed based on the prototype as Square of opposition. The sample of documents have to parts as the logical diagrams in the history of science and logic diagrams in the context of learning styles. In the findings section, the descriptive method was used, hence the data was given as it is in the literature to enable to reader to see the connections of the data in the context of logic diagrams.

Findings in the History of Natural Science

Based on the square of opposition, Aristotle's physics were conceptualized based on the idea that four elements can be differentiated on the basis of properties as hot versus cold and wet versus dry. Elements are the combination of two opposite pairs as hot versus cold and wet versus dry. Therefore, Fire is made from the combination of hot and dry. Water is the result of the combination of cold and wet as well. Air is made of hot and wet whereas Earth is the result of the intersection of cold and dry. In this respect, air and earth are opposite elements and should be located in opposite corners, similarly, water and fire are also opposite elements and should be put in opposite directions. This logical chart was used fort he explanation of many phenomena for thousand of years. These 'elements correspond to modern concepts of solid (earth), liquid (water), gas (air) and heat (fire). On the one hand, Aristotle uses the four basic elements for explaining cosmological phenomena where the light and the heavy are instrumental in drafting an architectural plan of the cosmos. On the other hand, Aristotle uses them in the service of chemistry to explain the elemental transformation and the generation of composite bodies (Berman, 2018). As for Aristotle hard and soft were passive properties, because they determined the malleability of materials, whereas hot and cold were active properties in that they could act on other materials. For instance, water expands if it is heated by fire and shrinks if it is cooled (Schummer, 2006).

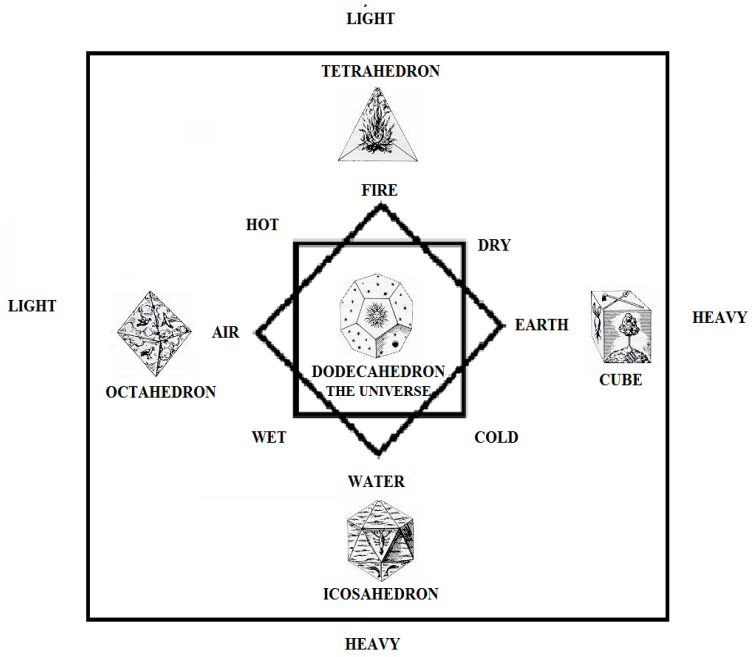

Figure 3. Conceptualization of four elements.

Those elements are also represented by platonic solids where the tetrahedron corresponds to fire, the octahedron to air, the cube to earth, the icosahedron to water, and the dodecahedron to the cosmos or ether. The Platonic solids have several intriguing properties, some of which turn out to be equivalent ways of describing them. For each type of solid, the same number of faces meet at each of the corner points, or vertices. Platonic solids are of significant geometrical tools even today, they are used in group theory, quantum theory and investigation for the crystal structure of molecules. They are important also in terms of inspiring Kepler to support Coppernican astronomy that is a model of the solar system centred on the Sun, with Earth and other planets moving around it, formulated by Nicolaus Copernicus. So conceptualization of four elements lead us the fact that all elements are observed to be composed of minuscule versions of the Platonic solids if it is examined these elements in fine detail like Earth would thus consist of

tiny cubes, the air of octahedrons, fire of tetrahedrons, and water of icosahedrons (Yau, Nadis, 2010).

Another example for logic machines in mathematics are magic squares. A *magic square* is a square matrix drawn as a checkerboard filled with numbers or letters in particular arrangements so that the sums of the numbers in the horizontal rows, vertical columns, and main diagonals are all equal. Magic squares has beed famous since the ancient times and their samples can be seen various locations from China to Europe. Yu magic (Figure 4a) square used in China can be regarded as the typical example of this summing up 15 in the horizontal rows, vertical columns, and main diagonals where the central 5 represented the earth, surrounded by evenly balanced four elements in yin and yang: 4 and 9 represented metal, 2 and 7 fire, 1 and 6 water, and 3 and 8 wood. It can be seen also in İslamic culture where an Islamic magic square expresses the number 66 in every direction in which the grid is formed by the letters in the word "Allah," whose numerical value is also 66 given as in figüre 4 (b). In Europe, the templar magic square that is a particular arrangement of the words in the Latin sentence "*Sator Arepo tenet opera rotas*," continued to be used during the nineteenth century in Europe and the United States for protection against fire, sickness, and other disasters. Templat magic square is claimed to have a hidden message as ""Our Father, Our Father" ,n which the four remaining letters may represent alpha and omega—the beginning and the end (Pickover, 2002).

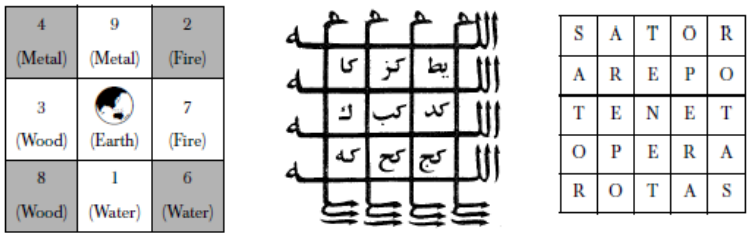

Figure 4. Chinese magic square (a) Arabic magic square (b) the templar magic square (c)

Just as magnetic compass, magic squares are used to direct same number or meaning for any direction. Best example can be given as Dürer magic square for explaining the nature of magic square which is drawn in the upper right-hand column of his work of Albrecht Dürer's *Melencolia I* (Figure 5 a) where the two central numbers in the bottom row read "1514," the year Dürer made the etching. The Dürer square (Figure 5 b) yields a magic sum in an amazing number of ways in addition to the traditional ways (Figure 5 c). The patterns, although reminiscent of the symmetries of certain crystals, tell us a good deal about the properties of this square (Pickover, 2002).

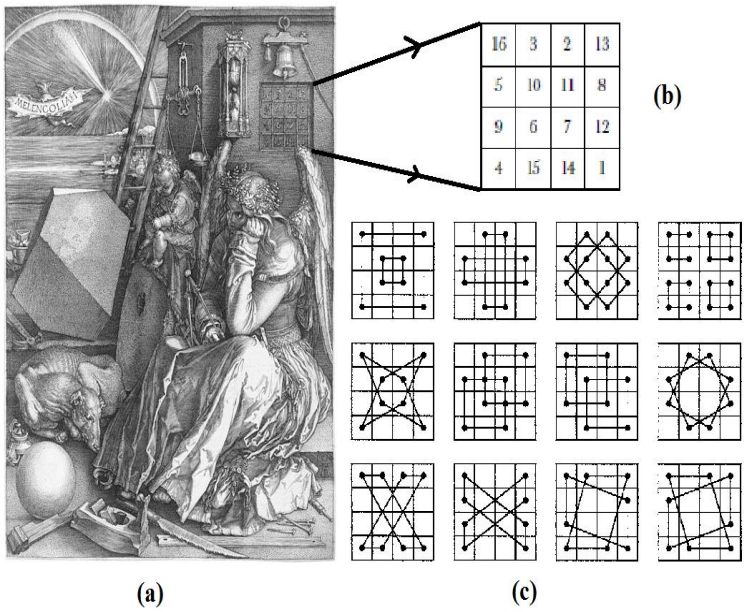

Figure 5. Albrecht Dürer's Melencolia I (a) The Dürer square (b) a magic sum in different number of ways (c)

Interestingly, the beauty of magic squares were so overwhelmingly important, they are used as talismans. For instance, many talismanic shirts containing magic squares were prepared to protect important figures in the goverment in Ottoman from evil spirits and bad fortune (Aytekin, 2015).

Another famous example of a logic machine is Spanish

theologian and visionary Ramon Lull's Great Art which was created after many days of fasting and contemplation and his experience of divine illumination in which God revealed to him the Great Art by which he might confound infidels and establish with certainty the dogmas of his faith. According to Lull's views, in every branch of knowledge, there should be a small number of simple basic principles or categories that must be assumed without question. In this context, it is possible to investigate and explore all the information through simple rules and diagrams such as diagrams or rotating circles. For example, two sets of categories can be listed in two vertical columns then exhaust all combinations simply by drawing connecting lines as shown (Figure 6 a). A set of terms in a circle (Figure 6 b) can be arranged so as to draw connecting lines as indicated, hereby obtaining a table of two-term permutations (Gardner, 1958).

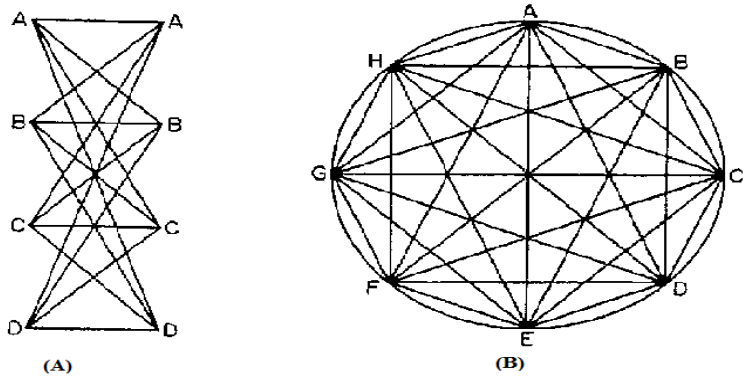

Figure 6. Different combinations of the informations could be arranged so that different permutations could be obtained in which possible combinations counted so easily (Gardner, 1958).

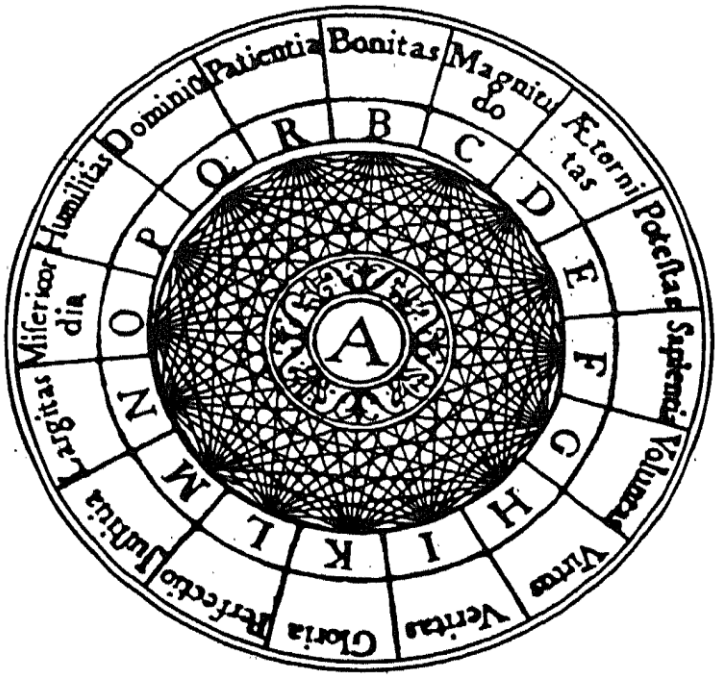

Figure 7. Concentric circles of Lull (Gardner, 1958).

The third method proposed by Lull is to place two or more sets of terms on concentric circles as shown in Figure 7 where it can be easily obtained a table of combinations by rotating the inner circle. In Lull's method, the letter "A," representing God, is placed in the center of a circle. Around the circumference, inside sixteen compartments the sixteen letters from B through R could be arranged. These letters stand for sixteen divine attributes B for goodness (bonitas), C for greatness (magnitude), D for eternity (eternitas), and so on. By drawing connecting lines (Figure 7) 240 two-term permutations of the letters could be obtained or 120 different combinations that can be arranged in a neat triangular table as shown below. Each of the above combinations gives additional truth regarding God. Therefore it can be inferred that His goodness is great (BC) and also eternal (BD), or to take reverse forms of the same pairs of letters, Reflection about these combinations could result in toward the solution of many theological difficulties. For example, it can be

realized that predestination and free will must be combined in some mysterious way so that God is both infinitely wise and infinitely just; hence he is both omniscient but also be incapable of withholding from any sinner the privilege of choosing the way of salvation. Lull's ideas can be arranged through putting different letters in circles such as where circle was designed based on the letter S and or a circle was designed based on the letter V (Gardner, 1958).

Logic machines and logical diagrams are not only used for theological issues or preparing talismans but they can be used for scietific purposes. One famous example for this, Kepler's logic diagram for the conjunction of the planets Jupiter and Saturn which is called as 'Great Conjunction' in which he mentioned this phenomena in his famous De Stella Nova based upon the eight-century motion of the Jupiter-Saturn conjunctions as moving through the zodiac elements Kepler realized that every three conjunctions (a trigon) Jupiter and Saturn meet approximately at the same location of the zodiac, which happens every ~ 60 yr. He also found that the trigon slightly rotates and the configuration repeats every 800–1000 yr (Scafetta, 2014). According to this, the precise start of the Trigon had occurred on 1603. This diagram explain the conjunction that is seen from the Earth every twenty years, each time moving eight zodiacal signs with respect to the previous time. So it composes a trigon, and falls always in the same three signs, disposed as the vertices of an equilateral triangle. Its position is translated about 9^{o} every. time it appears in the same sign, so that, after 200 years, it falls in other three signs and we say that it changed trigon. Once every 800 years, a new cycle began and the conjunction fell again in the trigon of the signs of fire: Aries, Sagittarius and Leo (Lombardi, 2005).

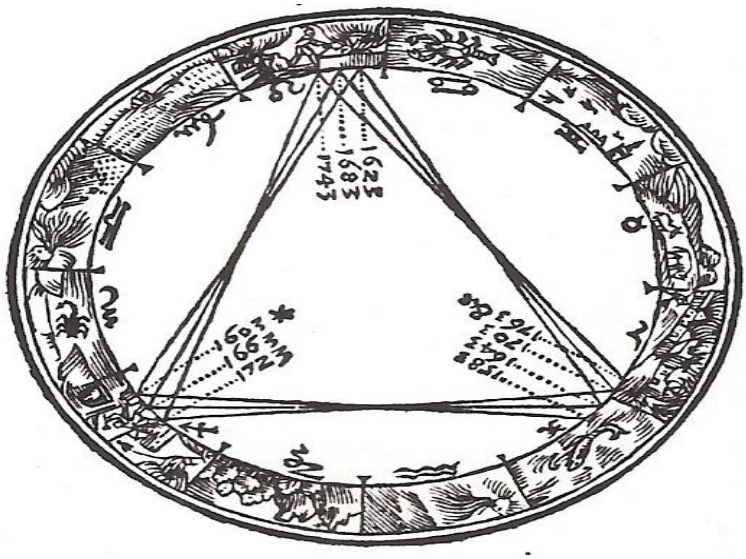

Figure 8. Kepler's original diagram (trigon) of the great conjunctions of Saturn and Jupiter, which occur every ~ 20 yr, from 1583 to 1723.

With this first diagram, Kepler thought that he had discovered the key to unlocking a geometrical secret about the creation of the universe in relation with the Copernican system. Therefore, he was trying to explain the relationship among the distances of the planets from the sun and the length of their revolutionaround the sun. In his diagram in Figure 8, the stars are represented by the signs of the zodiac around the rim of the 'drum'. The successive points on the rim represent successive conjunctions of Jupiter and Saturn. The lines within the rim highlight the way in which metrical geometry is used within an ultimate frame of reference provided by the stars (Barbour, 2001). The diagram came to Kepler as a revelation in which the crossing points of the triangles formed another circle, half the size of the first one where their proportion was the same as the proportion between the orbits of Saturn and Jupiter (https://calisphere.org/item/ba48c55bd3f3a182a4381e704bb9a3b1). This diagram later encouraged him to develop the idea that all the proportions in the heavens could be explained by using aesthetically interesting combinations of geometrical fi-

gures to construct the circular motions found in the heavens (Martern, 2000). Through those diagrams, Kepler showed his true strength and his belief in the power of precise observations and rational reasoning (Lombardi, 2005).

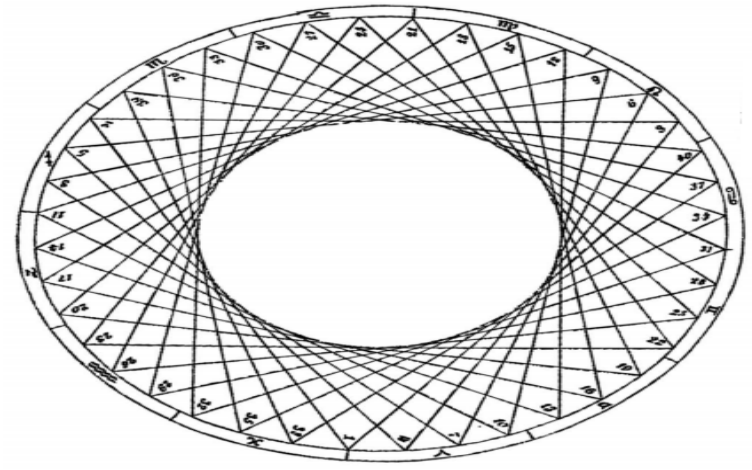

Figure 9. Kepler's preliminary diagram relating to the orbits of Saturn and Jupiter

Later he later used his ideas that it was not numerical relationships but the successive circumscribing and inscribing of circles to geometrical figures which provided the key to the successive planetary distances. Putting a square between Jupiter and Mars seemed to lead to a reasonable fit for those two planets, and so did a pentagon between Mars and the earth. But the problem with this was that polygons with successively increasing numbers of sides form an infinite sequence but the planets were just six in number. Finally he use his 'Platonic inspiration', the idea that the five perfectly regular Platonic solids (rather than plane figures) are inscribed and circumscribed between the spheres of the planets (Barbour, 2001). He explained this as follows (Barbour, 2001) :

"The [sphere of the] earth is the measure for all the other spheres. Let it be circumscribed by a dodecahedron; the sphere that circumscribes this is Mars's; let the sphere of Mars be circumscribed by a tetrahedron; the sphere that circumscribes

this is Jupiter's. Let the sphere of Jupiter be circumscribed by a cube; the sphere which circumscribes this is Saturn's. Now place an icosahedron within the earth's sphere; the sphere which is inscribed to it is Venus's. In Venus's sphere place an octahedron; the sphere inscribed to it is Mercury's. You have there the reason for the number of planets"

So he claimed that platonic solids could be used to explain a superstructure for the heavens, as well as its dynamics regarding the motion of the paths of the planets. Kepler's cosmological theory, based on the Copernican system could be regarded the first attempt since Copernicus in order to claim that the theory of heliocentrism is physically true. This also shows the poer of logic machines and diagrams for scientific inquiry.

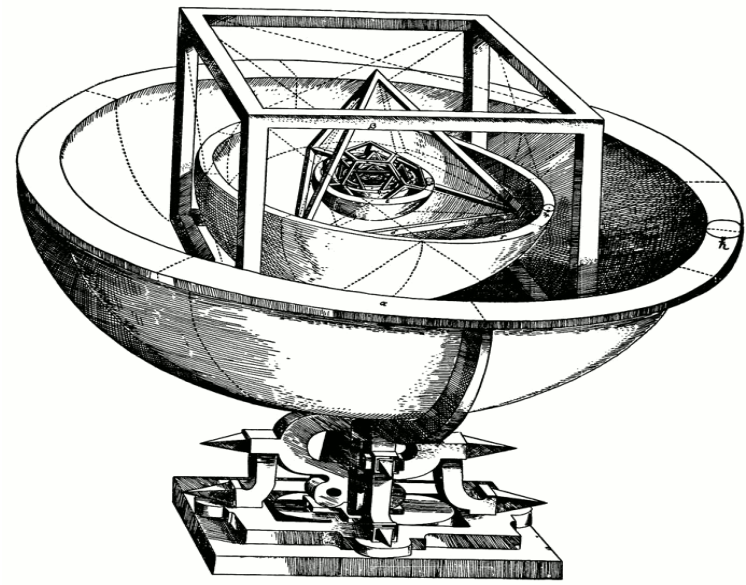

Figure 10. Kepler's Platonic solid model of the Solar System

The usage of logic machines or diagrams even today are used for many scientific purposes. As mentioned above, platonic solids are used in very wide range area from chemistry to physics or magic squares are today studies to show peculiar characteristics of phenomena such as Mermin-Peres "magic square" . Furthermore, they are used in psychology and educa-

tion where those theories are investigated in the second part of the research. Lastly, Hydrogen-Bond Codon-Anticodon Magic Square can be used as a modern example of the power of logic machines and diagrams even todays' scientific thought.

It is known in every high school biology course that DNA contains the basic hereditary information of living cells and is expressed as a four-letter code symbolized by the letters G, C, A, and T. These letters stand for the chemical bases guanine, cytosine, adenine, and thymine. Amino acid as the basic building blocks of proteins, are coded for by specific consecutive triplets of theese bases that are called codons. For example, GGG codes for the amino acid glycine. Researcher Gary Adamson from San Diego, California, has discovered that the set of three-letter codons in the genetic code corresponds to a magic square where the number of hydrogen bonds for each codon-anticodon pair can be computed by assigning two numbers to each base as given in Figure 11 (a). Hence for instance, codon CUG can be converted as given Figure 11 (b) (Pickover, 2002).

Base:	C	G	A	T/U
Two-digit	0	1	0	1
code:	0	1	1	0

(a)

C	U	G
0	1	1
0	0	1

(b)

Figure 11. Codon-anticodon pair values (a) conversion of CUG (b) (Pickover, 2002).

Finally based on the Hamming distance, Adamson constructs an *H-bond codon-anticodon magic square* with magic constant 60 (Pickover, 2002).

	000	**001**	**011**	**010**	**110**	**111**	**101**	**100**
000	000 000 CCC 9	001 000 CCU 8	011 000 CUU 7	010 000 CUC 8	110 000 UUC 7	111 000 UUU 6	101 000 UCU 7	100 000 UCC 8
001	000 001 CCA 8	001 001 CCG 9	011 001 CUG 8	010 001 CUA 7	110 001 UUA 6	111 001 UUG 7	101 001 UCG 8	100 001 UCA 7
011	000 011 CAA 7	001 011 CAG 8	011 011 CGG 9	010 011 CGA 8	110 011 UGA 7	111 011 UGG 8	101 011 UAG 7	100 011 UAA 6
010	000 010 CAC 8	001 010 CAU 7	011 010 CGU 8	010 010 CGC 9	110 010 UGC 8	111 010 UGU 7	101 010 UAU 6	100 010 UAC 7
110	000 110 AAC 7	001 110 AAU 6	011 110 AGU 7	010 110 AGC 8	110 110 GGC 9	111 110 GGU 8	101 110 GAU 7	100 110 GAC 8
111	000 111 AAA 6	001 111 AAG 7	011 111 AGG 8	010 111 AGA 7	110 111 GGA 8	111 111 GGG 9	101 111 GAG 8	100 111 GAA 7
101	000 101 ACA 7	001 101 ACG 8	011 101 AUG 7	010 101 AUA 6	110 101 GUA 7	111 101 GUG 8	101 101 GCG 9	100 101 GCA 8
100	000 100 ACC 8	001 100 ACU 7	011 100 AUU 6	010 100 AUC 7	110 100 GUC 8	111 100 GUU 7	101 100 GCU 8	100 100 GCC 9

Figure 12. Codons mapped to gray code (Pickover, 2002).

This mysterios semimagic square has many hidden symmetries like all hydrogen-bond numbers will be identical on both sides of the mirror plane. There is also a one-unit difference between adjacent cells (up, down, right, and left, including wrap-arounds) and a one-letter difference between adjacent codons (Pickover, 2002).

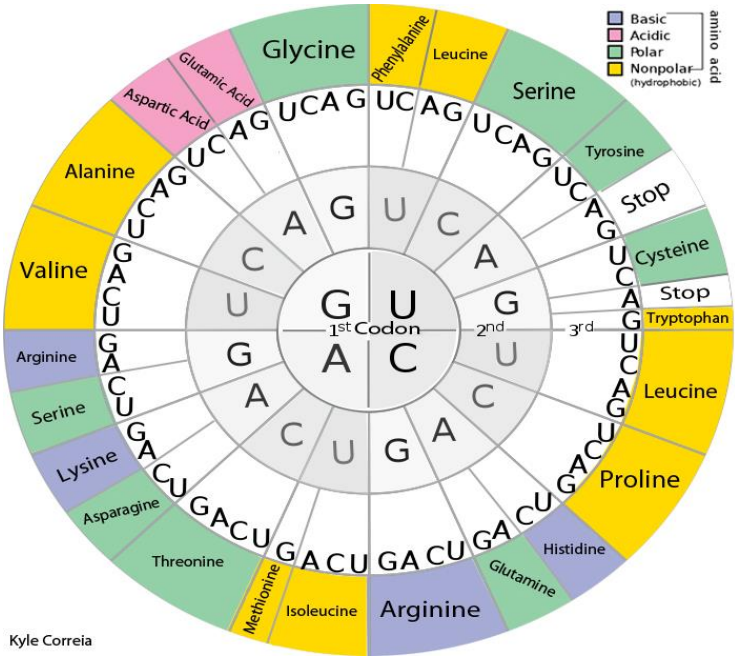

Figure 13. Codon wheel.

More interesting thing about codons in the context of logic machines is the codon wheel. In this type of codon wheel nucleotide bases are arranged (from center outward) in the order of 1st, 2nd, and 3rd codon positions. The "Wheel" shows how to determine which amino acid goes with which m-RNA codon sequence. To decode a codon, it should be started at the middle of the circle and move outward. Within each of these three rings, the four bases are repeated clockwise in the order of "AGCT" to minimize the number of transversions, which has a greater evolutionary distance than transitions. Base cycling is the fastest at the 3rd and the slowest at the 2nd codon positions, reflecting the decreasing evolutionary rates in the order of the 3rd, the 1st, and the 2nd positions. With these rules, the codon wheel represents the shortest mutation path and is analogous to the time dimension in a Traveling Salesman Problem (TSP) (Attie, Sulkow, Di, Qiu, 2018).

Table 1. Summarization of the functions of some logic machines in the history of natural science

Name of the logic machine	**Characteristics**	**Function**
Conceptualization of four elements	Componenents	Solid (earth), liquid (water), gas (air) and heat (fire) or platonic solids
	Rule	Opposition of the elements in terms of their characteristics
	Main Aim	Explaining the natural phenomena
Magic Squares	Componenents	Numbers (Especially Natural numbers)
	Rule	Opposition of the numbers where numbers compansate each other in order that total sum of any line equals a constant
	Main Aim	Enciphering
Concentric circles of Lull	Componenents	Adjectives of God
	Rule	Matching
	Main Aim	Understanding the adjectives of God
Kepler's diagram (trigon)	Componenents	Signs of the zodiac
	Rule	Matching and Correlating
	Main Aim	Understanding the correlation among the movements of planets
Codon magic square and codon wheel	Componenents	Codons-anticodons
	Rule	Transformation codons into into integers and opposition of those codes where codes compansate each other in order that total sum of any line equals a constant. As fort he codon wheel, matching codons in order to achieve the amino acids

	Main Aim	Exploration the pattern through the codons and amino acids

As it can be seen that logic machines have be used for many purposes ranging from mathematical games to creating talisman to genetic code. What is more beautiful about logic machines and diagrams is their strenght in the usage of computation of many different tasks. They could be regarded as the simple computers for scientists for centuries.

Findings Regarding Logic Diagrams in the Context of Learning Styles

Interestingly in many contemporary theories and models of psychology and education, the structure of logic machines and diagrams can be traced. The ideas of Carl Jung as one of the founders of modern psychology who also studied mystical literature and alchemy conceptualizating intuition, sensation, thinking and feeling as the four basic archetypes or components of personality is clearly related with logic machines and diagrams. His theory consists from concepts of attitude and function. Attitude dimension referrs to the individuals particular attitude towards objects either as extra verted or introverted. The extravert is habitually orientated towards the external object whereas the introvert is better focusing on his own psychic processes, hence s/he is reflective and occupied with his own reaction to external object. The function types define ways in which people operate in relation to objects whether 'internal' or 'external'. Accordingly, there are rational fuctions that are opposed to each other as thinking and feeling. Thinking is a mode of evaluation that is concerned with the truth or falsity of experience that is based on the conceptual interrelationships of the things in a rational manner. Feeling involves judging the value of things or having an opinion about them on the basis of our likes and dislikes. Similarly, there are irrational functions as sensation and intuition. Sensation defines things and situations as they are in the present whereas intuition seeks out possibilities of a situation and so is essentially speculative. These can be

classified as perceiving (or, non-rational) functions of Sensation and Intuition as well as judging (or, rational) functions of Thinking and Feeling. After creating those dimensions based on a logical order, there are eight personality types emerged as The Extraverted Sensation Type, The Introverted Sensation Type, The Extraverted Intuition Type, The Introverted Intuition Type, The Extraverted Thinking Type, The Introverted Thinking Type, The Extraverted Feeling Type, The Introverted Feeling Type (Fordham, 1978). Therefore, Carl Jung's model for personality types have many common points especially with Aristotle Square of Opposition.

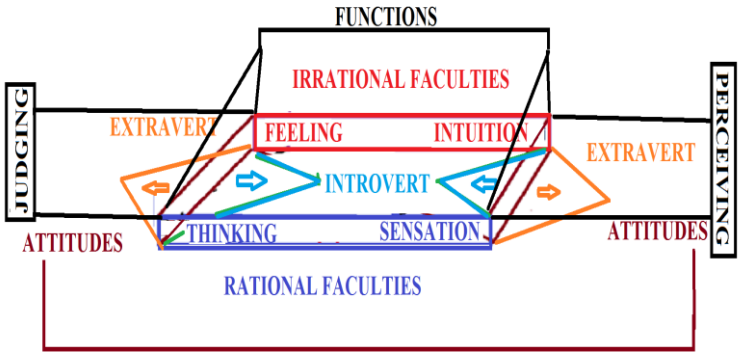

Figure 14. Carl Jung's model for personality types.

The Myers-Briggs Type Indicator (MBTI), developed by Isabel Briggs Myers and Katharine Cook Briggs based on the psychological theories of Carl Gustav Jung can be given another example for logic diagrams. They deduced that there were four dichotomies which made people differ from one another and referred to them as 'type preferences'. Thefore MBTI utilizes an individual's dominant preferences on four opposing dimensions: extroversion-introversion (E-I), sensation-intuition (S-N), thinking-feeling (T-F), and judgment-perception (J-P) to determine his/her personality types. Combinations based on these four categories of type preferences result in 16 different personality types as given below and shown in Figure 15 as a logical diagram (Fretwell, Lewis, Hannay, 2013)

1. ISTJ – Introverted Sensing with Thinking , 2. ISFJ – Introverted Sensing with Feeling

3. INFJ – Introverted Intuition with Feeling , 4. INTJ – Introverted Intuition with Thinking

5. ISTP – Introverted Thinking with Sensing , 6. ISFP – Introverted Feeling with Sensing

7. INFP – Introverted Feeling with Intuition , 8. INTP – Introverted Thinking with Intuition

9. ESTP – Extraverted Sensing with Thinking, 10. ESFP – Extraverted Sensing with Feeling

11. ENFP – Extraverted Intuition with Feeling, 12. ENTP – Extraverted Intuition with Thinking

13. ESTJ – Extraverted Thinking with Sensing, 14. ESFJ – Extraverted Feeling with Sensing

15. ENFJ – Extraverted Feeling with Intuition, 16. ENTJ – Extraverted Thinking with Intuition

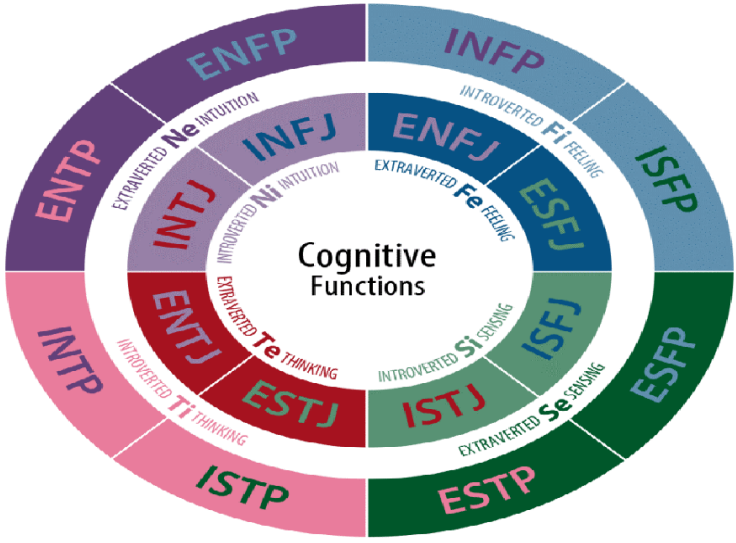

Figure 15. The logical diagram of Myers-Briggs Type Indicator (MBTI) (https://bhsbeat.org/1055/beyond-the-den/all-about-the-myer-briggs-type-indicator).

There are many examples in the field of education that are related with logic diagrams such as Piaget's cognitive development theory, Kolb's learnng styles, Gregorc Learning Style model. However as it can be seen below they have similar epistemological structure just as in the case of Square of Opposition.

Piaget's cognitive development theory identifies those basic developmental processes that shape the basic learning process of adults. According to this model, development from infancy to adulthood moves from a concrete phenomenal view of the world to an abstract constructionist view, from an active egocentric view to a reflective internalized mode of knowing. In the first stage (0–2 years), the child is predominantly concrete and active in his learning style. In the second stage of cognitive growth (2–6 years), the child keeps his concrete orientation however begins to develop a reflective orientation. In the third stage of cognitive growth (7–11 years), the intensive development of abstract symbolic powers begins. In the Piaget's final stage of cognitive development (12–15 years) the adolescent moves from symbolic processes based on concrete operations to the symbolic processes of representational logic, the stage of formal operations (Kolb, 2015). As it can be seen, the model of Piaget has the similar topology in accordance with the structure of logical diagrams.

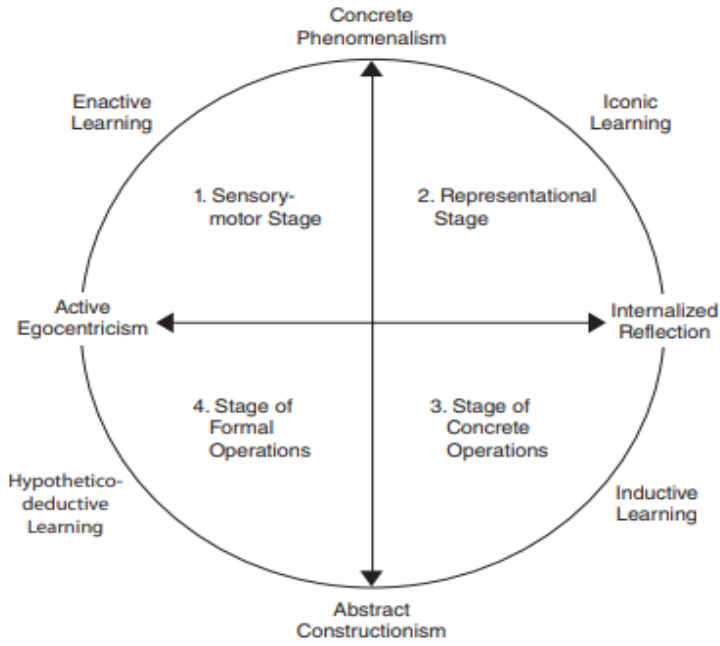

Figure 16. Piaget's Model of Learning and Cognitive Development (Kolb, 2015)

Kolb's learning styles can be regarded as the most prominet example of logic diagrams based on Experiential Learning Theory (ELT). According to this model, The Experiential Learning Cycle has four dimensions as Concrete Experience (CE) and Abstract Conceptualization (AC)—and two dialectically related modes of transforming experience—Reflective Observation (RO) and Active Experimentation (AE). This dimension is also related with the process of brain functioning as shown in Figure 17. "The figure illustrates that concrete experiences come through the sensory cortex, reflective observation involves the integrative cortex at the back, creating new abstract concepts occurs in the frontal integrative cortex, and active testing involves the motor brain. In other words, the learning cycle arises from the structure of the brain ." (Zull 2002: 18-19; 2011, cited by, Kolb, Kolb, 2013).

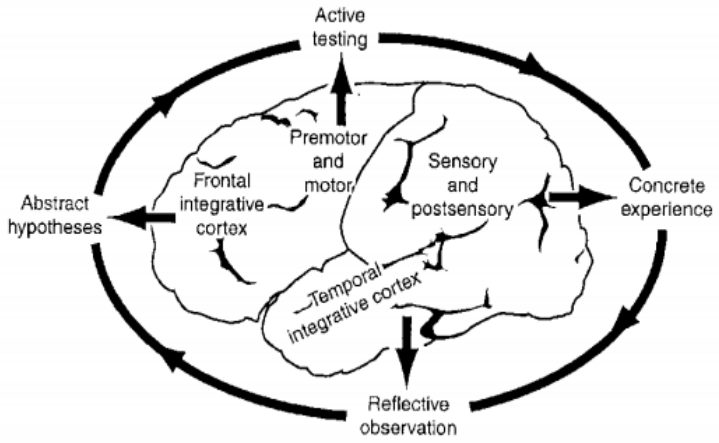

Figure 17. The experiential learning cycle and regions of the cerebral cortex (Kolb, Kolb, 2013).

Kolb's create his model based on two axes that one is the east-west axis referred as the processing axes (how we approach a task), and the north-south axis called as the perception axes (how we think or feel about it). Hence based on two axes, the crosssections of four dimensions as Concrete Experience (CE) and Abstract Conceptualization (AC)—and two dialectically related modes of transforming experience—Reflective Observation (RO) and Active Experimentation (AE) result in four different learning styles as Accommodating (CE/AE), Diverging (CE/RO), Converging (AC/AE), Assimilating (AC/RO) (Kolb, Kolb, 2013).

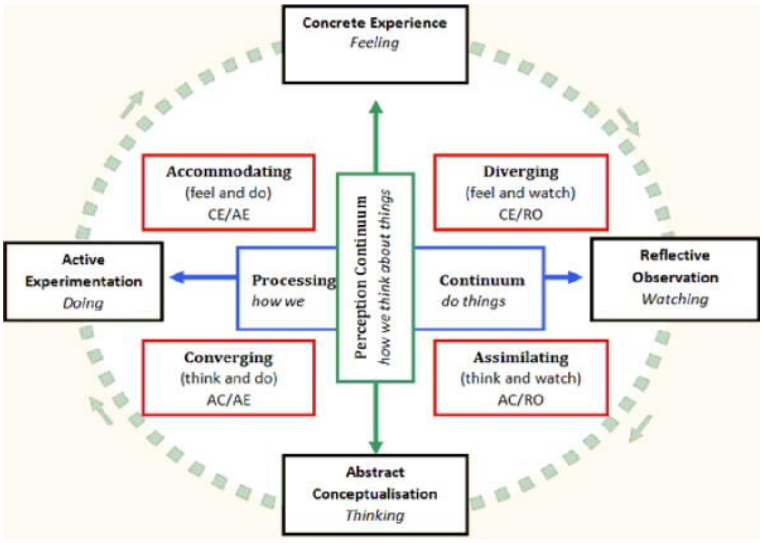

Figure 18. Kolb's learning style

In this respect people having diverging style are preferring to feel and to watch. They prefer to watch rather than do, tending to gather information and use imagination to solve problems. People having assimilating style are preferring to watch and think. The assimilating learning preference is for a concise, logical approach. eople with a converging learning style can solve problems and will use their learning to find solutions to practical issues, hence they are more prone to think and do. Individuals having accommodating learning style are more inclined to feel and do. These people use other people's analysis, and prefer to take a practical, experiential approach (Kolb, Kolb, 2013)

Kolb's learning styles later were refined further into a nine style typology just as a model having dimensions as The Initiating style, The Experiencing, The Imagining style, The Reflecting style, The Analyzing style, The Thinking style, The Deciding style, The Acting style, The Balancing style. These nine KLSI 4.0 learning styles further define the experiential learning cycle by emphasizing four dialectic tensions in the learning process. For instance, the Initiating style has a strong preference

for active learning in context (Accommodation) while the Analyzing style has a strong preference for reflective conceptual learning (Assimilation) (Kolb, Kolb, 2013).

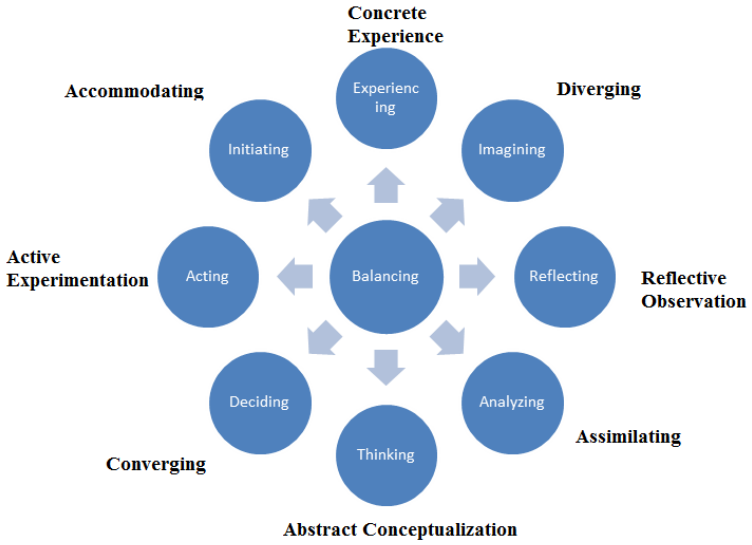

Figure 19. KLSI 4.0 learning styles (Kolb, Kolb, 2013)

There is another similar learning style having logical diagram called as Gregorc Learning Style. According to this model, there are two types of mediation abilities as perception and ordering. Perception refers how individual receives information. According to Gregorc, this can be achieved in two ways as abstract or concrete. Abstract perception is related with concepts or feelings whereas concrete perception is related with sensory or physical input. Ordering dimension refers how individual arranges and uses the information. There are two opposite dimensions for this as well. One is sequantial that is organizing the data in a linear fashion and other one is random that is processing the information in a netlike fashion. Therefore, Gregorc's model can be given as an example of logic diagram in this sense because it uses dichotomy in a given space having coordinates (Harasym, Leong, Lucier and Lorscheider, 1995).

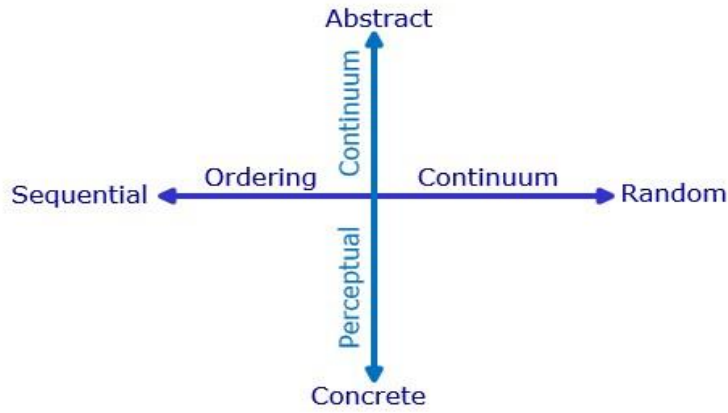

Figure 20. Gregorc Learning Style model

The similar logical diagram can be found in the Herrmann Whole Brain Dominance Theory. According to this model, Whole Brain is divided into four equal quadrants, designated as A, B, C, and D. These consist of the left and right cerebral hemispheres and the left and right halves of the limbic system. The two left side structures combine to represent what is popularly called left brain thinking. The two right side structures combine to represent right brain thinking. The two cerebral structures combine to represent cerebral thinking and the two limbic structures combine to represent limbic thinking (http://think.herrmannsolutions.com). According to this model, the upper left mode, or A-quadrant, associated with logical, analytical, fact- based and quantitative thinking. The lower left mode is associated with organised, sequential, planned and detailed thinking. The lower right mode is associated with interpersonal, feelingbased, kinaesthetic, emotional thinking, and the upper right mode is associated with holistic, intuitive, integrating and synthesising thinking (De Boer, Toit, Scheepers, Bothma, 2013).

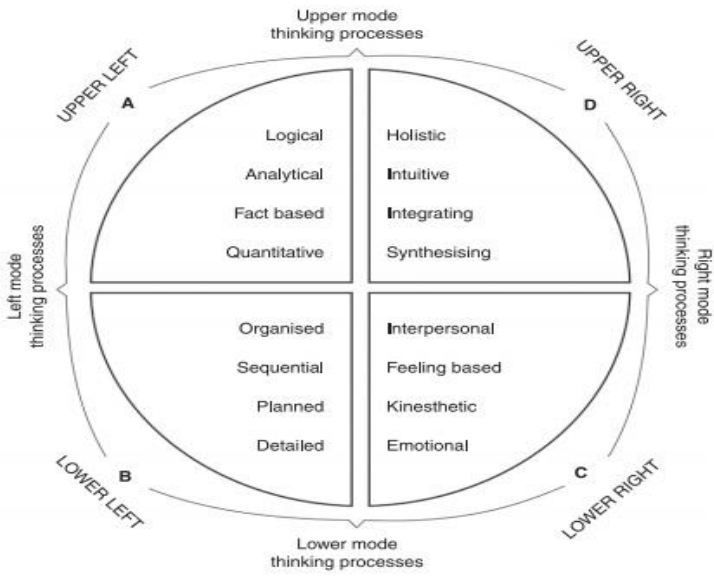

Figure 21. Herrmann Whole Brain Dominance Theory (De Boer, Toit, Scheepers, Bothma, 2013).

Eagleton and Muller (2011) developed a model for whole brain learning of physiology based on Curry's onion model in which Curry located the effect of personality traits as the inner layer of learning, information-processing styles as the middle layer of learning, and environmental and instructional preferences as the outer layer of learning. A diagram (Fig. 24) was designed to illustrate the integration of personality traits, information-processing styles, and environmental and instructional preferences (Eagleton and Muller, 2011).The ideas in this model has also similar structe in accordance with the rules what a logical scheme has just as Square of Opposition but the only difference is that this model has inner and outer dimensions like Jung's model. According to this model, the central layer is used to describe the personality traits that influence learning. The middle layer is used to distinguish between the perceptual and information-processing styles that influence learning. Moreover, the outer layer of the proposed model refers to instructional and environmental preferences (Eagleton and Muller,

2011).

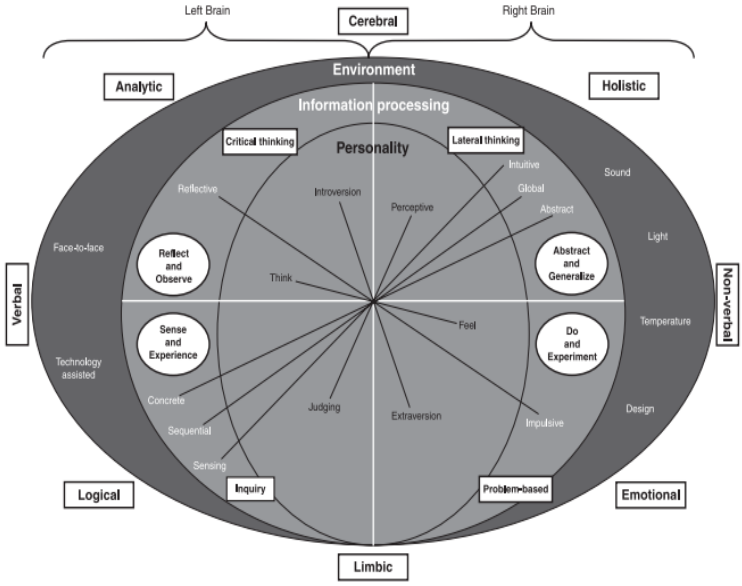

Figure 22. Eagleton and Muller (2011)'s model

Table 2. Summarization of the functions of some logic machines in education as well as psychology

Name of the logic machine	**Characteristics**	**Function**
Carl Jung's model for personality types	Componenents	Intuition, sensation, thinking and feeling as the four basic archetypes
	Rule	Opposition of the elements in terms of their characteristics
	Main Aim	Explaining the personality types
The Myers-Briggs Type Indicator (MBTI)	Componenents	Intuition, sensation, thinking and feeling as the four basic archetypes
	Rule	Opposition of the elements in terms of their characteristics
	Main Aim	Enciphering
Piaget's Model	Componenents	Cognitive development of human growth

of Learning and Cognitive Development	Rule	Matching
	Main Aim	Understanding the cognitive development of humans
Kolb's learning styles, Gregorc Learning Style model Herrmann Whole Brain Dominance Theory, Eagleton and Muller (2011)'s model	Componenents	Concrete Experience (CE) and Abstract Conceptualization (AC) Reflective Observation (RO) and Active Experimentation (AE)
	Rule	Opposition of the elements in terms of their characteristics and matching as well as correlating
	Main Aim	Understanding the reasoning styles of the individuals

As it can be seen in Table 2 that logic machines have be used for many purposes ranging from personality types to learning styles. They could be regarded as the simple computers for scientists for centuries for social sciences as well.

Conclusion

When the literature regarding logic diagrams in various disciplines is investigated, it can be inferred that they have common structure so that they have many similarities even sometimes it is very difficult to distinct the models in the same field from each other conceptually. The characteristics of those logical diagrams can be given as below:

1- *Logical diagrams have boundaries:* When logical diagrams are investigated, it can be seen that they are conceptually restricted within a space, For example, Aristotle Conceptualization of four elements is bounded by platonic solids standing for four elements. Similarly Kepler's model is also restricted by by platonic solids. As for the learning styles, they are bounded by concepts such as traits like intuition, sensation, thinking and feeling.

2- *Logical diagrams have directions:* When logical diagrams are investigated, it can be inferred that they have directions

based on dichotomy and similarity. The best example for this, Aristotle's Square of Opposition in which there are prepositions that are naturally opposed to each other. Similarly, as for the logical diagrams in education and psychology, they are created based on the dichotomy of metaphorical right and left brain traits.

3- *Logical diagrams are dialectical:* They benefited from interdepedence of variables proposed in a given logical system through using the the law of contradiction of formal logic.

4- *Logical diagrams are descriptive:* When logical diagrams are investigated, it can be inferred that they are explanatory in nature. For instance, the models of learning styles are trying to describe the traits of the preferences of individuals having particular learning style.

5- *Logical diagrams are qualitative:* The most speculative aspect of logical diagrams is that they are mostly qualitative rather than quantitative. Descartes is the one that turns the foundations of logical diagrams into what is called today as cartesian coordinates. Because of this reason, one might argue that their conceptual nature is speculative. For instance, many neuropsychiatrists are against the learning styles models just because they don't have data for the instantenous processing of brain such as brain scans or brain waves. However, these might be related with more deep and abstract constructs of the mind rather than the instantenous ones. Just as there is no way to see the concept of economy in the bazaar, there is no way to see the concept of learning styles in the brain images because it is more deep and abstract concept.

6- *There are variables in logical diagrams negatively or positively correlated with each other:* Logical diagrams have main variables that are negatively or positively correlated with each other. However, these correlations are mostly conceptual correlations rather than emprical ones. Therefore, expecially for logical diagrams used in education and psychology, it is important to keep in mind that the variables are mostly conceptual rather

than behavioral because humans are complex organisms who show contradicting behaviours because of the hidden variables that might not been taken into account.

One point that should be taken into consideration is that conceptual opposition or correlation doesn't guarantee the real manifestation of those models. For instance, individual can show varios opposite characteristics depending on the content and context. Therefore, altough they are useful for understanding and explaining the rule behind the phenomena for simplicity, they might be in cases they are not realistic where some hidden factors go beyond the ordinary and formal logic.

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