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An approach to teaching science concepts to some children with autism spectrum disorders (ASD)

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Abstract
Children with autism spectrum disorders (ASD) often display a triad of impairments in social interaction, communication and imagination. If non-verbal, they are often mistakenly regarded as mentally challenged, lacking the ability to learn and understand what is taught to them. Children with ASD are observed or known to be highly visual, echolalic, repetitive and unimaginative learners. Although many of them are unable to take all the facts they know and link them together to form meaningful concepts or create new ideas, it does not mean they cannot learn and/or understand. Currently, the domain of imagination remains the least charted terrain of the human mind. This paper attempts to examine the current theoretical understanding of the process of imagining and how to harness it to create an approach to teach science concepts meaningfully to those children with ASD who have central coherence learning styles and limited receptive language skills.

Keywords: Autism, Imagination, Science, Syllogistic reasoning, Systemizing

1. Introduction

Our current understanding of autism comes from the writings of Dr Leo Kanner (1943) [33] and Dr Hans Asperger (1944) [1] – both are regarded as the pioneers in the field. Siegel (1996) used the term Autism Spectrum Disorders (ASDs) in her nosology to encompass autistic disorder (i.e., the classical autism as described by Dr Kanner) and non-autistic Pervasive Developmental Disorders (PDDs), which include Asperger's Syndrome, Fragile X-Syndrome, Rett's Syndrome, Childhood Disintegrative Disorder, and PDD-Not Otherwise Specified (PDD-NOS), and correspond exactly to what the DSM-IV-TR (American Psychiatric Association, 2000) refers to collectively as Pervasive Developmental Disorders.

Empathizing Skill

According to Chia (2008a) [11], the current definition of ASD emphasizes on problems in the process of empathizing skill, which involves two main abilities: the first ability is to attribute mental states of mind to other people as a natural way of understanding them; and the second ability is to respond or react with an automatic appropriate emotion to other people's mental states of mind. In other word, empathizing concerns what is known as the theory of mind or mind-reading. The two abilities form a major ingredient in successful social interaction (Chia, 2008a) [11], and a major failure in empathizing results in severe deficits in one or two or all three of the following three structural process malfunctions: (1) affect-sensation-conation, (2) affect-sensation-cognition process, and (3) conation-sensation-cognition (Chia, 2010a) [14]. The key component of the mind that would be badly affected in empathizing failure is the sensation or sensory processing which receives sensory inputs for moderation and integration to make sense of the surrounding in its response to the external stimuli (Chia, 2008b) [12].

According to the structuralist model of ASD (see Figure 1) proposed by Chia (2008b, 2010b) [12, 15], he argues that the disorder is manifested by a severe deficit in the empathizing process. The empathizing deficit causes deficits in the three key components of the mind – affect, conation and cognition – and all three are inter-linked by the process of sensation or sensory processing. The affect involves self-esteem, the conation concerns self-will and the cognition involves learning and thinking. All three factors are linked by sensation (sensory process), which involves two interoceptive senses (vestibule and proprioception) and exteroceptive senses (visual, auditory, haptic, olfactory and gustatory) as well as perception. How sensation processes and understands sensory inputs can affect the motor coordination and motoric outputs (i.e., motions and movements). The sensation between affect and conation consists of self-awareness and self-regulation respectively (Chia, 2010b) [15]. The sensation between cognition and conation consists of self-learning and self-regulation respectively. The sensation between affect and cognition consists of self-awareness and self-learning respectively.

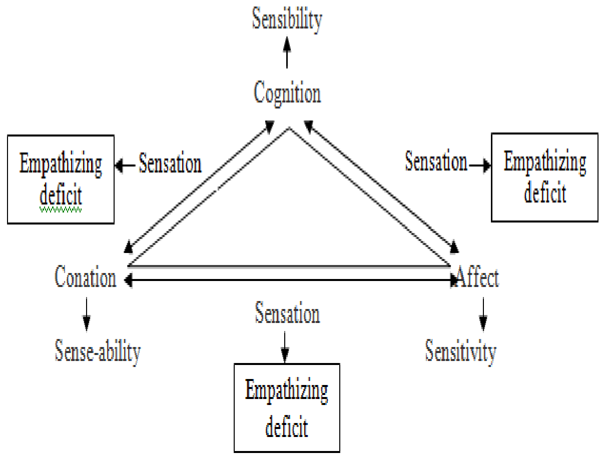


Fig 1: Structuralist Model of Empathizing Deficits in ASD (Chia, 2010b [15], p.6)

A severe deficit in affect-sensation-conation process often results in some form of temper tantrum (e.g., an autistic child would suffer a meltdown when he is placed in totally unfamiliar environment) with loud cries or screaming his head off. On the other hand, a severe deficit in affect-sensation-cognition process can cause self-stimulatory behavioral traits (also known as "stimming") such as vocal stimming or making neologic utterances. Lastly, a severe deficit in conation-sensation-cognition process can result in motor stimming such as rocking oneself while staring blankly into the air or lining objects in a straight line.

As mentioned earlier, empathizing concerns what is known as the theory of mind or mind-reading. Another term that has been used to mean the same thing is mentalizing (Frith & Frith, 1999) [25]. Empathizing deficits, therefore, refer to one's failure to make connection to another individual's experience and to respond appropriately to that person. Functional imaging studies (e.g., Cody, Pelphrey, & Piven, 2002; Di Martino & Castelianos, 2003) [21, 23] implicate prefrontal cortex and posterior superior temporal sulcus as components of this capability to empathize or mentalize.

Systemizing Ability

Recent studies (e.g., Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003 [5]; Lawson, Baron-Cohen, & Wheelwright, 2004) [41] suggest that though individuals with autism display empathizing deficits, they have intact or even superior systemizing ability. Baron-Cohen (2003) [4, 5] defines *systemizing* as "the drive to understand a system and to build one" (p.61). By the term *system*, Baron-Cohen (2003) [4, 5] explains that it refers to "anything that is governed by rules specifying input-operation-output relationships" (p.61). Such a definition of system goes beyond machines and academic subjects and concepts. It also includes libraries, hospitals, police, armed forces, economics and the list can be endless.

According to Baron-Cohen (2003) [4, 5], "systemizing involves first the analysis of the features in a system that can vary, followed by close, detailed observation of the effects that occur when each feature is varied ("systematically")" (p.61). Chia (2010b) [15] has interpreted Baron-Cohen's theory of systemizing in the following Figure 2, which he has gone on to apply in planning teaching and/or learning objectives in designing treatment plans for individuals with autism.

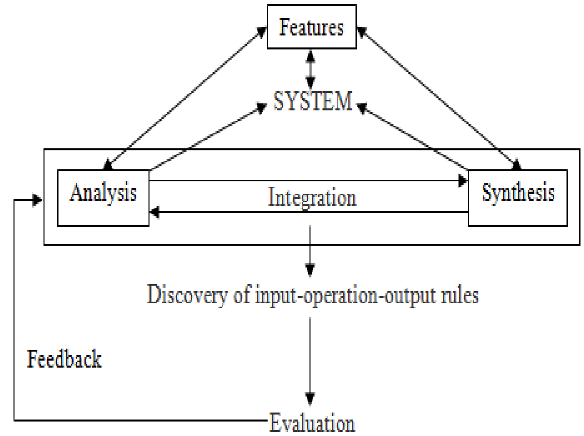


Fig 2: Interpretation of Baron-Cohen's (2003) Theory of Systemizing (Chia, 2010b [15], p.8)

Repeating such observations leads one to discover the input-operation-output rules that govern the behavioral traits of the system. "Systemizing, therefore, needs an exact eye for detail, since it makes a world of difference if one confuses an input or operation for another... The pay-off of good systemizing is not only being able to understand the system but also being able to predict what it will do next" (Baron-Cohen, 2003 [4, 5], p.62).

The key factor about the process of systemizing is that the system is finite, deterministic and lawful (Baron-Cohen, 2003) [4, 5]. That is to say that once the underlying rules and regularities of any system have been identified and learnt, prediction of how it operates becomes something absolute. Baron-Cohen (2003) [4, 5] has stressed that this principle holds true even for more complicated systems, where there are many more parameters, or where the rules and regulations are much more elaborate. However, "the rules are in principle specifiable" (Baron-Cohen, 2003 [4, 5], p.62).

In fact, as Baron-Cohen (2003) [4, 5] has gone on to argue as follows:

"[S]ystemizing is a process in the mind, and as such it can indeed be applied to almost any aspect of the environment. In practice, systemizing is most easily applied to agents (i.e., entities that are capable of self-propulsion, even virtual ones, such as cartoon characters), while systemizing is most easily applied to lawful aspects of environment. And there are many lawful aspects of the environment to discover, suing this process" (Baron-Cohen, 2003 [4, 5], p.62).

In short, skill of systemizing refers to that ability to analyze and to build systems so as to understand and predict the functional behavior of impersonal events or inanimate or abstract entities. Baron-Cohen (2003) [4, 5] and Myers, Baron-Cohen and Wheelwright (2004) [41] have listed the following six kinds of system that exist, which the human brain can analyze and/or systemize:

a) Abstract systems, e.g., computer programs including digital games, and mathematical concepts as in integration and 3x3 matrices (see Brill, 1940; Chia 2008c) [6, 13];
b) Mechanical systems, e.g., machines and tools (see Brink, 1979; Hoffman & Reeves, 1979) [7, 31];
c) Motoric systems, e.g., 3-D drawing, piano finger technique or a lawn tennis short (see Charness, Clifton, & MacDonald, 1988; Selfe, 1977) [9, 58];
d) Natural systems, e.g., biological processes like respiration, and geographical phenomena like earthquakes and wind directions (see Grandin, 2000; Grandin & Johnson, 2005) [27, 29];

e) Organizable systems, e.g., Dewey Classification System as used in library cataloguing, and a stamp or sticker collection (see Chia, 2007; Shah & Frith, 1993) [10, 59]; and
f) Social systems, e.g., business management or a football team (see Golan & Baron-Cohen, 2008; Lawson, 2001) [40].

The way an individual with ASD makes sense of any of these systems is not in terms of mental states, but in terms of underlying rules and regularities as understood by the mind basing on the input-operation-output principle. Such superior systemizing ability can be seen in those termed as autistic savants, who may have two or more savant abilities (Treffert, 1989) [65].

However, there is also another lesser-known sub-group of autistic crypto-savants, who, “because of their inability to communicate (non-verbal), have savant skills that are hidden, or secret, and unknown to those around them” (Rimland, 1990 [57], p.3). This group of autistic crypto-savants, too, manifests their systemizing ability. However, this aspect is often ignored in most definitions of ASD.

As a result, Chia (2008a) [11] has provided his re-definition of ASD and a later modification to this definition by Chia, Kee and Shafudin (2010) [18]: “a neuro-developmental syndrome of constitutional origin (genetic) *and whose cause could also be epigenetic*, and its onset is usually around first three years of birth, with empathizing or mentalizing deficits that result in a triad of impairments in communication, social interaction, and imagination (or presence of stereotyped behaviours), but may, on the other hand, display (especially by autistic savants) or hide (especially by crypto-savants) a strong systemizing drive that accounts for a distinct triad of strengths in good attention to detail, deep narrow interests, and islets of ability” (Chia, 2008a [11], p.10; words in italics are a recent addition to the re-definition, see Chia, Kee, & Shaifudin, 2010 [18], p.8).

2. Autism and imagination

The term *imagination* can range from “the ability to think of something not presently perceived, but spatio-temporally real” to “the ability to create works of art that express something deep about the meaning of life” (Stevenson, 2003, p.238) [63]. In short, imagination refers to that cognitive process of being able to form a particular sort of mental representation of a certain thing. This means having a mental image, which is to have a perception-like experience triggered by something other than the appropriate external stimulus. For instance, a person might have “a picture in the mind’s eye or... a tune running through one’s head” (Strawson, 1970, p.31) [64] without the presence of any other sensory (e.g., visual or auditory) object or episode. The Stanford Encyclopedia of Philosophy (2011) [62] has provided a clear description of imagination (or the process of imagining) as a special mental state different from others below.

“Imagining is typically distinguished from mental states such as perceiving, remembering and believing in that imagining *S* does not require (that the subject consider) *S* to be or have been the case, whereas the contrasting states do. It is distinguished from mental states such as desiring or anticipating in the imagining *S* does not require that the subject wish or expect *S* to be the case, whereas the contrasting states do. It is also sometimes distinguished from mental states such as conceiving and supposing, on the grounds that imagining *S* requires some sort of quasi-sensory or positive representation of *S*, whereas the contrasting states do not.” (Standard Encyclopedia of Philosophy, 2011, para.1) [62].

Imagination remains the least charted terrain of the human mind. When we talk about the imagination of children with ASD, very often they are described as having a faulty process of imagining, or limited or no imagination at all. It is still not very certain if indeed children with ASD have impaired imagining process or imagination although it is one of the triad of impairments in the classical definition of autism. The reason is that imagination or imagining as a cognitive (or meta-cognitive) process is still not fully studied or clearly understood.

There is still no consensus among those who work on the topic as the term *imagination* or *imagining* has been used too broadly to allow simple taxonomy or definition (The Stanford Encyclopedia of Philosophy, 2011) [62]. On the one hand, Walton (1990) [66] distinguishes between spontaneous and deliberate imaginings (i.e., imaginings that happen with or without conscious direction), between occurrent and non-occurrent imaginings (i.e., imaginings that do or do not occupy one’s explicit attention), and between social and solitary imaginings (i.e., imagining episodes that happen with or without the joint participation of others). The autistic imagining style is most likely spontaneous, non-occurrent and solitary but this needs to be confirmed by evidence-based studies. On the other hand, Currie and Ravenscroft (2002) [22] have distinguished among three types of imaginings: creative imagining (i.e., combining ideas in unexpected and unconventional ways), sensory imagining (i.e., perception-like experiences in the absence of appropriate stimuli), and recreative imagining (i.e., experiencing or thinking about the world from a perspective different from the one that is being experienced currently).

Nagel’s (1974) [47] distinction between sympathetic imagining (i.e., imagining oneself undergoing a certain experience) and perceptual imagining (i.e., imagining oneself perceiving a certain event or state of affairs) is most applicable to individuals with autism. Either of the imaginings can happen propositionally or objectually.

Firstly, to imagine *propositionally* (belief-like) is to imagine standing in some mental relation to a specific proposition. For instance, a child with autism might imagine a train whistles loudly as it rambles by and so he made the noise repeatedly, while the people around him did not know or understand why he was disruptive.

Secondly, to imagine *objectually* (either really visible and tangible or virtually visible and intangible) is to imagine standing in some mental relation to a representation of an imaginary (intangible) or real (tangible) entity or state of affairs (Martin, 2002; Noordhof, 2002; Yablo, 1993) [43, 48, 69]. For instance, playing in a cyber-game, an autistic youth takes up an avatar (e.g., a star trooper) that represents him in a hostile virtual environment (e.g., a planet in a distant galaxy), where he would be fighting against dangerous aliens. The simulated environment can be similar to the real world in order to create a life-like experience for the gamer. White and Le Cornu (2010) [68] argue that virtual world experiences are real “in which participants’ experience is actually secondary, mediated through vision, yet such is the power to draw in and engage that, together with the human ability to project and imagine, participants have the impression of learning through primary experience” (p.192). With additional inputs of other sensory information, such as sound through speakers or headphones, and touch through some advanced haptic systems generally known as force feedback, virtual experiences can become more real than ever. Hence, depending on how one looks at it, virtual reality can considered as genuinely objectual (visible and tangible) or virtually objectual (visible and intangible).

Finally, the author of this paper has proposed three types of rational imagination or imagining. Firstly, the factual imagination or imagining refers to that of or pertaining to facts. In other words, this form of rational imagination is based on or restricted to facts. Secondly, the counterfactual imagination or imagining concerns with expressing what has not happened but could, would, or might under differing conditions. Lastly, the nonfactual imagination or imagining refers to the awareness of what that is known to be fictitious or unreal. Most, if not all, children with ASD have no difficulties in factual imagining (e.g., the ascending order of numbers from 1 to 100 or more, red lights means stop and green light means go) as they have good visual memory. However, it is difficult for them to express in terms of counterfactual imagination especially if they are asked a question such as "What would you do if you came home from school one day and nobody was at home to open the door for you?" or "What would you do if your teacher scolded you for not having done your homework?" Most would insist that such an incident could not have taken place because "Mum will always be at home waiting for me to come back from school" or "Teacher cannot scold. Teacher helps me in my homework." In fact, to them, such thoughts about how an event might have turned out differently 'if only...', which can emphasize a causal relation, or thoughts about how an event might have turned out the same 'even if...', which can deny a causal relation, cannot possibly happen (Byrne, 2007) [8]. It is even harder for individuals with ASD to accept that which is fictitious or non-existent as in nonfactual thoughts such as a fairy godmother, a flying carpet and/or a singing vase.

3. Understanding the autistic logic

There are students with ASD (NOT all of them) who may find it challenging to take all facts they know and link them together to form meaningful concepts (Grandin, 2008) [28]. In other words, this group of students with ASD manifests limited ability to understand context or to see the big picture, which underlies the central disturbance in ASD. According to the weak central coherence theory, also known as central coherence theory, first advanced by Frith (1989) [24], there are some individuals with ASD whose specific perceptual-cognitive style cause them to process at local detail over global processing. The idea is that a normally developing individual has strong central coherence leading him or her to rapidly focus on the larger picture at the expense of small details. However, "[A] child on autistic spectrum is thought of as having weak central coherence, leading him or her to the opposite focus to dwell on each component part at the expense of the whole" (Myers, Baron-Cohen, & Wheelwright, 2004, p.65-66) [41].

It does not mean that student with ASD lack the imagination or are impaired in their imagining. It is just that such individuals have a different imagining or thinking style. Hence, concept formation is best taught through taking note of "all the little details and putting them into simple categories to form concepts and promote generalization" (Grandin, 2008, p.33) [28]. The ALS is an experimental approach to teaching science to children with ASD, especially those with weak central coherence.

According to Chia (2011a) [16], all the six systemizing abilities form parts of the Autistic Logic System (also known as Autistic Logic Analysis/Synthesis or ALA/S for short) in analyzing and synthesizing of stimuli that a child with autism is constantly encountering (see Figure 3).

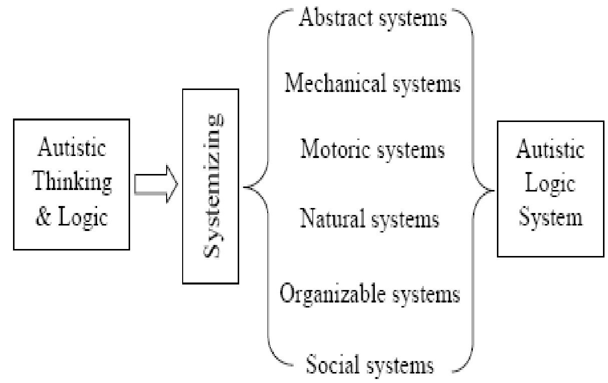


Fig 3: Model of the Autistic Logic System (Chia, 2011a)

"The term *logic* used in Autistic Logic System refers to inductive reasoning, which is drawing general conclusions from specific examples, and deductive reasoning, which is drawing logical conclusions from definitions and axioms" (Chia, 2011a, p.80-81) [16]. A similar dichotomy is analysis (whole → parts approach, i.e., studying an object as a whole by examining its component parts) and synthesis (parts → whole approach, i.e., considering how the component parts can be put together to form a whole).

The Autistic Logic System (ALS) – being a form of syllogistic reasoning or rational thinking – appeals to the way an individual with ASD thinks, i.e., autistic thinking (Chia, 2011a) [16]. Unlike the way in which normal individuals think, these systemizing abilities with their respective autistic thinking styles affect the way individuals with ASD perceive their immediate world around them, i.e., autistic logic, as in sensory imagining which can be propositional or objectual. This is because individuals on the autism spectrum possess idiosyncratic logic that does not make sense to others. According to Paxton and Estay (2007) [51], autistic logic is associational and is not always logical to non-autistic people. Hence, the peculiar behavior of individuals with ASD may annoy the people around them, simply because it is a case of unusual problem solving that may seem logical only to someone who has ASD.

Autistic logic is the base for autistic problem solving through one or more of the six systemizing routes that Myers, Baron-Cohen and Wheelwright (2004) [41] have identified (see Figure 3). As already mentioned earlier, the way an individual with ASD, especially an autistic savant, makes sense of any of these systems is not in terms of mental states, but in terms of the underlying rules and regularities. Then there are those who are mentally challenged and non-verbal (i.e., the inability to communicate) autistic, but they also possess savant skills that are hidden or secret and unknown to others. They have been termed as autistic crypto-savants (Rimland, 1990) [57], but this sub-group has often been ignored or forgotten in many descriptions of ASD in current literature.

Chia (2011a) [16] has identified several factors that define autistic logic. Firstly, individuals with ASD engage in visual thinking, i.e., they see pictures inside their head. Next, they have no problem in engaging in literal rational thinking but they are unable to create alternatives to reality, i.e., the lack of counterfactual reasoning or thinking. Thirdly, their sense of self or reference to self is also very lacking. Also, their theory of mind or empathizing is impaired. Moreover, they manifest difficulty with change and shifting attention from one activity or situation to the next. These individuals with ASD also display weak executive functioning ability, which includes poor central coherence, cognitive inflexibility, organizational deficits, source monitoring difficulty, impulsivity and disinhibition with poor ability to control emotions, and poor meaning attribution (or hyperlexic tendency). Finally, they may possess strong systemizing ability based on autistic thinking and logic, in-the-moment thinking, and black-and-white thinking. It is this last factor that affects autistic logic system most. It involves three important sub-processes of systemizing ability: autistic thinking and logic, in-the-moment thinking, and black-and-white thinking.

Autistic Thinking and Logic

Autistic thinking includes idiosyncratic logic and incoherence (Weiner & Greene, 2008) [67]. It refers to the inclination of an individual with ASD to focus on specific details instead of the bigger picture. Hence, it is difficult to understand why such an individual may behave oddly at times and often attribute inaccurate meanings to autistic behaviors (Jacobsen, 2003) [32]. One possible explanation is that an individual with autism lacks the ability to create counterfactual thoughts, which take place when a child engages in pretend play, for instance (Harris, 2000; Riggs & Peterson, 2000) [30, 56]. Another explanation is that an individual with autism could have rely heavily on perception-like experiences in the absence of appropriate stimuli to experience or think about the world from a perspective different from the one that experience presents. In this case, this individual is using sensory recreative imagining process to make sense of what he/she is experiencing at that point in time. This imagining process consists of two types of imagination: sensory imagination and recreative imagination (Currie & Ravenscroft, 2002) [22]. According to Grandin (2008) [28], an autistic mind is detail-oriented, specific and specialized, and there are three different autistic thinking styles (although this author believes there are still many others).

Among the three autistic thinking styles mentioned by Grandin (2008) [28], the visual or pictorial thinking style is most common. According to the picture theory (Kosslyn, 1980, 1994; Kosslyn, Thompson, & Ganis, 2006; Shepard, 1982) [37, 38, 60], the mental representations a person experiences in the case of visual imagining represent spatial relationships via representational properties that are themselves inherently spatial. Visual or pictorial thinking involves the sensory recreative imagining (see Currie & Ravenscroft, 2002 [22], for more detail). Such autistic thinkers may have superior motoric systemizing ability and they love drawing (Selfe, 1977) [58], creating concrete poems (Chia, Wong, & Ng, 2009) [19] and building Lego blocks (Le Goff, 2004) [42]. They are easily immersed in projects. Working with such thinkers, Grandin (2008) [28] has advised educators to "[Keep in mind that verbal responses can take longer to form, as each request has to be translated from words to pictures before it can be processed, and then the response needs to be translated from pictures into words before it is spoken" (p.16). Koene (2009) [35] has used empirical semantics to explain that there is some kind of compositionality that bridges between the language used and the surrounding world encountered, the information of complex forms systematically built up from the information contributed by its composing parts, object by object, then translating it into word by word, and construction by construction, to recreate a meaningful conscious experience of reality. "Our ability to reproduce bits and pieces of experience when the real thing is out of sight is our first way to conceive of things beyond the range of our senses. Our grasp of reality consists of our brain's ability to call it into existence to ourselves both in its presence and it its absence" (Koene, 2009, p.11) [35].

The musical and mathematical thinking is the next autistic thinking style, patterns dominate the process. Both music and mathematics are a world of patterns and they involve abstract, motoric and organizable systemizing abilities. Such individuals with ASD think this way display strong associative abilities. They show a keen interest in seeking relationships between numbers or musical notes. Some of them may demonstrate savant-like lightning calculation skills or fantastic ability to play a piece of music after hearing it only once. In other words, their musical talent emerges without any formal instruction (see Chia, 2008a [11], for more detail). According to the propositional or descriptive theory (alternative to picture theory) (Pylyshyn, 1973, 2002, 2003) [52, 53, 54], such thinking style involves visual mental images that are non-pictorial, pattern-like representations of visual scenes.

Verbal logical thinking is the third autistic thinking style. Individuals with such thinking style may love lists and numbers, especially those with abstract and organizable systemizing abilities. They memorize train or flight schedules, chronology of historical events and sports statistics for example. Some of them are whizzes at learning many different foreign languages but are most likely to be hyperlexic, i.e., speaking or reading without real comprehension. There are different types of hyperlexia that afflict children with autism (see Chia, Poh, & Ng, 2009, for more detail) [20] but it is beyond the scope of this paper. Such a thinking style probably involves spontaneous, non-occurrent, solitary imagining, which has been mentioned earlier. Grandin (2008) [28] advises that we "can use these interests and talents as motivation for learning less-interesting parts of academics" (p.17).

In-the-Moment Thinking

This refers to the way individuals with ASD perceive events or "experience life around them in the moment, without a sense of the past or the future" (Paxton & Estay, 2007, p.73) [51]. Termed it as illusive perception, these individuals do not transfer learning to different situations and encounter challenges in recalling what they have learnt especially when their cognitive state and ability fluctuate from time to time (Ory, 1995) [49]. This problem can be compounded by abnormalities in the sensory processing (Attwood, 1998) [3]. Moreover, when individuals with ASD are over-stimulated, they also suffer emotional dysregulation or meltdown (Laurent & Rubin, 2004; Raymaekers, van der Meere, & Roers, 2004) [39, 55].

Black-and-White Thinking

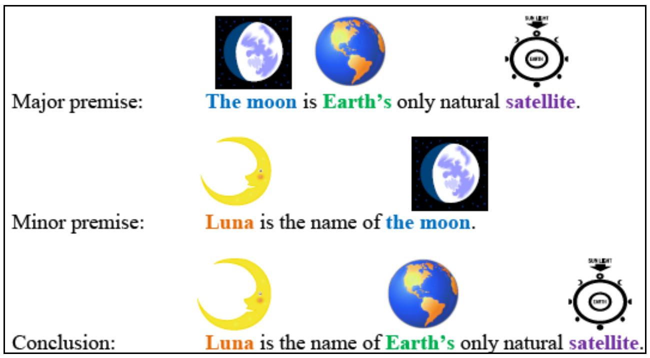
Individuals with ASD think in extreme ends, between black and white, right and wrong, true and false, good and bad. Averroes (b.1126-d.1198), an Andalusian Muslim polymath, defined this as a tool of logic 'for distinguishing between the true and the false'. Hence, it is not surprising to note that individuals with ASD love rules that are consistent and will obey and follow these rules. They also expect others to obey and follow the same rules. According to Attwood (1998) [3] and Ory (2002) [50], rules and regulations, rituals and routines help make abstract social practices concrete for these individuals with ASD.

4. Syllogistic reasoning as pedagogical approach

The ALS consists of two steps – analysis and synthesis. It is concurrently being studied and researched at the National Institute of Education as an experimental pedagogical approach, which is an intervention strategy under *psychogogy* [1] (the term being first coined by Maslow, 1943, 1965; also see Chia, 2011b, for more detail) [44, 45, 17], used in teaching science concepts and making meaningful sense to students with ASD, who are attending either mainstream or special schools in Singapore (see Chia, 2011a, for more detail) [16]. In a typical science lesson taught to these students, pictures are used to provide visual support in their conceptual formation as well as understanding what they are learning or being taught.

As mentioned earlier, ALS is a form of categorical syllogism [2] consisting of three parts: the major premise, the minor premise, and the conclusion or learning point. Each of the three parts is known as a categorical proposition, which, in turn, consists of two categorical terms – the subject and the predicate – and affirms or denies the latter of the former. Both the major and minor premises have one *term* (any word or group of words considered as a member of a construction or utterance) each in common with the conclusion: in a major premise, this is the *major term* (i.e., the predicate of the conclusion); in a minor premise, it is the *minor term* (the subject) of the conclusion.

In the illustration below, the author has shown how the ALS is used to introduce Luna, the Earth's moon, as the only natural satellite (see Chia, 2011a, for detail) [16].



Alternatively, the above categorical proposition can be expressed in more controlled structures as follow:

Major premise:	The moon is Earth's only natural satellite.
Minor premise:	Luna is the moon.
Conclusion:	Luna is Earth's only natural satellite.

where... The moon (M) is Earth's only natural satellite (E); Luna (L) is the moon (M); and Luna (L) is Earth's only natural satellite (E). The syllogism can be expressed in the following abstract form:

Major premise:	M is E
Minor premise:	L is M.
Conclusion:	L is E.

In addition, the author has cited two examples of actual application of ASL. In the first example, ASL was used by a special education teacher to teach a group of children with ASD to differentiate between parrots as birds that can fly and children as non-birds that cannot fly. In the second example, ASL was used by another special education teacher to teach magnetism to a Primary 5 class of six autistic students: like poles repel and unlike poles attract (see Chia, 2011, for detail). Figure 4 below shows how the categorical terms – subjects and predicates – in the three categorical propositions are related to each other.

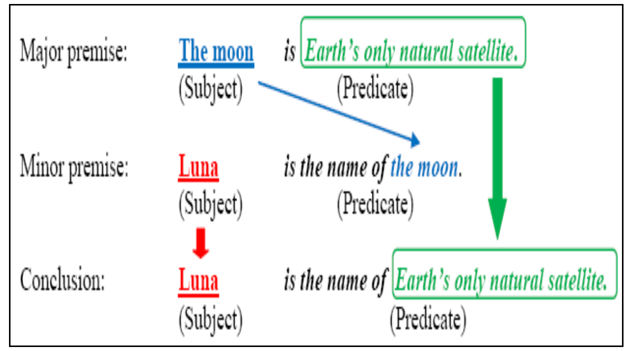


Fig 4: Interrelationships among Terms within the Three Categorical Propositions

Notice that there are three terms in the three categorical propositions given in Figure 4. The underlined words are subjects while the words in italic form the predicates. There are three types of predicates here. The first type of predicate ***Earth's only natural satellite*** that is boxed is the major predicate found in the major premise. The second type of predicate is the one in which the subject **The moon** in the major premise becomes a part, i.e., ***the moon*** of the predicate in the minor premise. The words in bold black italic, i.e., ***is the name of***, is an additional term – known as supplemental – found in the predicate of the minor premise and the conclusion. This third type of predicate provides more information to the learning point.

5. First Example of ALS Application

Here is the first example to show how a special education teacher has used ALS to teach a group of children with high-functioning ASD in a special school catering to children with varied disabilities. In this example, the teacher attempted to illustrate how the entire process of ALS through analysis, synthesis and combinations of major premises, minor premises and conclusions was successfully done to help her children establish meaningful associations between the various concepts taught/learnt.

Pre-ALS Step:

The following background information for the child was established at the beginning of ALS:

- Birds have wings. (Picture cards were used to show the child all kinds of birds, e.g., parrot, chicken, swan, ostrich.)
- Some birds have no wings. (A picture card of a kiwi was shown.)
- Birds can fly. (Picture cards with different kinds of birds flying in the air were shown.)
- Some birds cannot fly. (Two picture cards – ostrich and emu – were shown to the child.)

ALS Step 1: Analysis

First concept to be learnt/taught.

1st Major premise:	Birds can fly.
1st Minor premise:	Parrots are birds.
1st Conclusion:	Parrots can fly.

Second concept to be learnt/taught:

2nd Major premise:	Parrots can fly.
2nd Minor premise:	Children are not parrots.
2nd Conclusion:	Children cannot fly.

ALS Step 2: Synthesis

In the first part of this second step, the 1st and 2nd major premises are combined to form a joint major premise. Symbols (instead of picture cards) are used to introduce functional words, which are difficult to be presented by pictures and not easily understood by children with ASD, e.g., √ → **can**, = → **are**, → ***that***.

1st Major premise:	Birds can fly.
2nd Major premise:	Parrots can fly.
Joint major premise:	Birds √ fly → Birds **can** fly. Parrots √ fly → Parrots **can** fly. Parrots = birds → Parrots **are** birds. Parrots = birds**...** √ fly → Parrots **are** birds ***that*** **can** fly.

In the second part of this second step, the 1st and 2nd minor premises are combined to form a joint minor premise. Symbols are again used to introduce functional words, which are difficult to be represented by pictures and not easily understood by children with ASD, e.g., √ → **can**, **X** → **cannot**, ***β*** → ***but***.

1st Minor premise:	Parrots are birds.
2nd Minor premise:	Children are not parrots.
Joint minor premise:	Parrots √ fly → Parrots **can** fly. Children **X** fly → Children **cannot** fly. Children **X** fly ***β*** parrots √ fly → Children **cannot** fly ***but*** parrots **can** fly.

In the third part of this second step, the 1st and 2nd conclusions are combined to form a joint conclusion. Symbols are also used to introduce functional words, which are difficult to be represented by pictures and not easily understood by children with ASD, e.g., √ → **can**, **X** → **cannot**, ***β*** → ***but***.

1st Conclusion:	Parrots can fly.
2nd Conclusion:	Children cannot fly.
Joint conclusion:	Parrots √ fly → Parrots **can** fly. Children **X** fly → Children **cannot** fly. Children **X** fly ***β*** parrots √ fly → Children **cannot** fly ***but*** parrots **can** fly.

Post-ALS Step:

Below are the three concepts that were taught to/learnt by the child with ASD through meaningful associations between 1st and 2nd major premises to form a joint major premise, 1st and 2nd minor premises to form a joint minor premise, and 1st and 2nd conclusions to form a joint conclusion.

- Parrots are birds that can fly.
- Children are not parrots that are birds.
- Children cannot fly but parrots can fly.

6. Second Example of ALS Application

In this second example, ALS was used by another special education teacher to plan and later to teach a science lesson on magnetism to a group of six Primary 5 students with ASD who were attending a special school for ASD (see Chia, 2011a, for more detail).

Pre-ALS Step:

The background information was provided at the beginning of the lesson to frontload the students with the necessary knowledge in order to prepare them for the new topic on magnetism as in this illustration. A real bar magnet was used and shown to the students. Alternatively, every student could be given a piece of bar magnet so that he/she could actually touch, feel and/or explore with it.

- This is a magnet.

- N is North Pole.
- S is South Pole.

ALS Step 1: Analysis

First concept to be learnt/taught:

Once the background information was provided, the first concept (as given in the conclusion/learning point) was taught to the students by first introducing the major premise and then the minor premise. Real bar magnets were used and the two poles were pointed out for the students to see that N is North Pole and S is South Pole.

1st Major premise: Any magnet has two poles N and S.

1st Minor premise: North and South can be found on any magnet.

1st Conclusion: North and South are the two poles N and S.

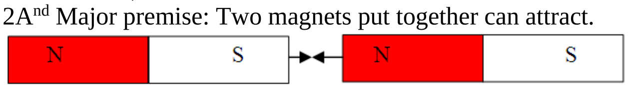
Second concept to be learnt/taught:

This second concept was divided into two sub-concepts 2A and 2B. Each of the sub-concepts is briefly described below.

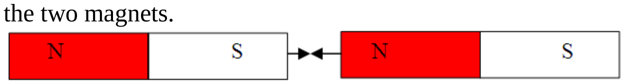
Second concept 2A to be learnt/taught:

The second concept 2A (as given in the conclusion/learning point) was taught next: different poles put together can attract (represented by two short arrows pointing and touching each other at the tip. Real bar magnets were used throughout the lesson since students with ASD learn and understand better with real things they can see, touch, feel and/or examine (Kee & Loh, 2009) [34].

2And Major premise: Two magnets put together can attract.



2And Minor premise: Different S and N poles can be seen on the two magnets.

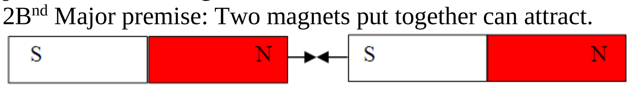


2And Conclusion: Different S and N poles put together can attract.

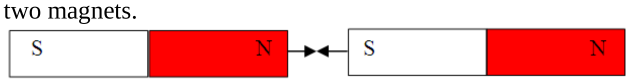
Second concept 2B to be learnt/taught:

The second concept 2B was taught as a repetition of the previous concept 2A, except that the positions of the two unlike poles of the two magnets are now reversed.

2Bnd Major premise: Two magnets put together can attract.



2Bnd Minor premise: Different N and S poles can be seen on the two magnets.



2B^nd Conclusion: Different N and S poles put together can attract.

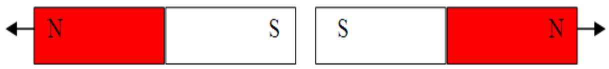
Third concept to be learnt/taught:

This third concept was divided into two sub-concepts 3A and 3B. Each of the sub-concepts is briefly described below.

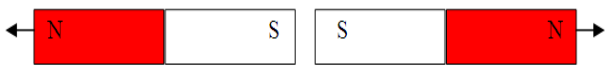
Third concept 3A to be learnt/taught:

The third concept 3A (as given in the conclusion/learning point) was taught next: same S poles put together can repel (represented by two short arrows pointing away on the opposite ends of the two bar magnets). Again real bar magnets were used since, according to Kee and Loh (2009) [34], students with ASD can learn and understand better with real things they can see, touch, feel and/or examine.

3A^rd Major premise: Two magnets put together can repel.



3A^rd Minor premise: Same S poles can be seen on the two magnets.

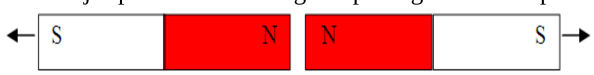


3A^rd Conclusion: Same S poles put together can repel.

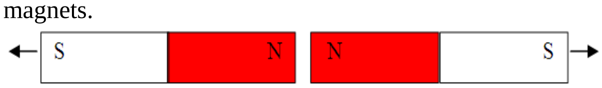
Third concept 3B to be learnt/taught:

Similarly, like the second concept 2B, the third concept 3B was a repetition of the previous concept 3A, except that this time the same N poles are facing each other.

3B^rd Major premise: Two magnets put together can repel.



3B^rd Minor premise: Same N poles can be seen on the two magnets.

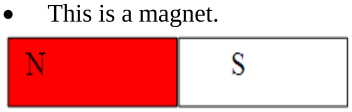


3B^rd Conclusion: Same N poles put together can repel.

ALS Step 2: Synthesis

Unlike in the previous first example, in this second example, the ALS Step 2 of synthesis involved in gathering the background information and conclusions or learning points for the purpose of summarizing the key concepts that were learnt or taught in this lesson.

- This is a magnet.



- N is North Pole.
- S is South Pole.

- North and South are the two poles N and S.
- Different S and N poles put together can attract.
- Different N and S poles put together can attract.
- Same S poles put together can repel.
- Same N poles put together can repel.

7. Conclusion

Based on the feedbacks from the special education teachers, who have used ALS to teach various science concepts, their biggest challenge is that a large amount of time has been spent in designing a detailed lesson plan and then rehearsing the lesson procedure mentally before the actual teaching. The entire process of ALS may take up more time and effort in preparing a good lesson (e.g., thinking through the sequence of pedagogical steps, and getting the necessary materials for experiments), especially for difficult topics such as photosynthesis, pollination and climate change. However, its benefits are immeasurable such as the intrinsic satisfaction an educator can derive from it when his/her students with ASD begin to make sense of what they are learning or being taught.

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