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ELABORATO FINALE

A TALE OF TWO MINDS: RETHINKING MATH AND LITERATURE EDUCATION

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Contents

INTRODUCTION

Trivium vs quadrivium, humanities vs STEM, mentalistic vs mechanistic: the divide between mathematical and literary disciplines, and between those who study “people” versus “things,” is as old as Western education. C.P. Snow's "two cultures" continue to shape how we perceive knowledge and learners. The "math person" is often imagined as a socially awkward male, fascinated by the mechanics and numbers, while the "language person" is seen as a socially sensitive female who finds math disheartening (Cvencek et al., 2011; Van Hek & Kraaykamp, 2023).

Researchers such as Baron-Cohen (2002) and Badcock and Crespi (2008) have explored these distinctions, identifying cognitive profiles similar to these stereotypes. Systemizers thrive in structured, rule-based systems like mathematics, while empathizers have an easier time understanding social systems. Similarly, mechanistic thinkers focus on patterns and systems, while mentalistic thinkers are drawn to social cognition and creativity. These profiles and their hypothetical evolutionary origins, explain why some students excel in certain subjects and competencies while others, equally intelligent and with a similar background, encounter difficulties.

Many students experience anxiety and inadequacy in learning mathematics (Lutternberger et al., 2018), and they have the perception that math is uninteresting and disconnected from their life (Martínez-Sierra & García González, 2014). For students with conditions like dyscalculia, this challenge is even more pronounced, as they face specific difficulties in processing numbers and performing mathematical operations (Butterworth, 2005).

Western societies suffer from low enrollment in STEM degree programs, especially from women and minorities, and a shortage of workforce in mathematics, computer science, and engineering fields (Smith & White, 2024).

On the other hand, the social communication abilities required to understand and enjoy literature are often taught with the assumption that social skills are something you either "get or don’t." This presents significant challenges for students with autism spectrum disorders (ASD) who require explicit, structured guidance in social learning (Happé, 1995). Similarly, students with dyslexia face challenges in traditional reading-based learning environments, as they struggle to process written language (Lyon et al., 2003). At the same time, the nonclinical population is also reducing its reading time (Whitten et al., 2019). Despite these challenges, educational systems rarely adapt their methods to accommodate these students' needs, expecting them to fit into rigid molds.

This thesis advocates for a user-friendly approach to education that adapts content to different cognitive styles. Tools like the EIS Palette in mathematics allow students to shift between enactive, iconic, and symbolic stages of understanding, providing a more inclusive way to teach complex concepts (Bruner, 1966). In literature and social learning, tools like visual novels—interactive narratives that allow students to make decisions and explore social dynamics—offer modern ways to teach empathy and social cognition. These approaches can be particularly effective for students who find traditional, text-heavy learning challenging, such as those with dyslexia or autism.

Chapter 1 will introduce the cognitive profiles of systemizers and empathizers, along with mechanistic and mentalistic thinkers, explaining the evolutionary hypothesis of the strengths and weaknesses of the different thinking profiles and how they affect students’ learning in both mathematical and literary contexts. Chapter 2 will focus on mathematical cognition, examining how students struggle with rule-based systems and how conditions like dyscalculia and math anxiety exacerbate these challenges. Chapter 3 will delve into language, theory of mind, and social cognition, exploring how reading ability and social communication develop and what problems can emerge through their development. Finally, Chapter 4 will propose interventions to make education more inclusive, such as using the EIS Palette in math and interactive media like visual novels in social learning. By comparing different approaches to educational interventions, this chapter will identify ways to integrate flexible, accessible approaches that support all types of thinkers.

CHAPTER 1 - Thinking people and thinking numbers: a culture for each mind

1.1 Mathematics and literature: definitions, importance, and crisis

Poets and mathematicians often look like representatives of two different intellectual worlds: on one side, the humanities, centred on literature, and on the other, the sciences, with mathematics at their core. C.P. Snow described how these two cultures are perceived as having little if anything in common, shaped by different modes of thought (1959). This split supports the idea that math and literature are exclusive areas, open only to those with “inborn” talent, which reinforces a kind of elitist mindset. Often, students who find math difficult are labeled as unfit for STEM, and those who have issues with communication are seen as lacking the right skills for the humanities. Instead of making these subjects more inclusive, education focuses on “fixing” the individuals, even though both disciplines are human-made systems, meant to be understood by a broader audience (Lam, 2024).

Teachers’ judgments and grades often lead students to quickly decide they are either good at STEM or the humanities and unable in the other field, reinforcing Snow's “two cultures” divide. But what are these “two cultures”?

1.1.1 Mathematics: critical yet daunting

Mathematics is the study of numbers, structures, quantities, and patterns, offering tools to model and understand the physical world (Dugger, 2010). Countries that prioritize mathematics education tend to lead in fields such as engineering, data science, and artificial intelligence, all of which are important to address global challenges like climate change, healthcare, and infrastructure development (Brown et al., 2011). Mathematics provides the other STEM disciplines—Science, Technology, and Engineering—with essential tools to analyze systems, solve problems, and innovate across scientific fields. Whether in physics, biology, engineering, or computer science, mathematics is the language that enables scientists and engineers to interpret the world and develop new technologies (Dugger, 2010). Mathematics equips individuals with the ability to think logically, solve problems systematically, and make informed decisions, helping them manage personal finances, understand data, and interpret statistical information to evaluate scientific claims (Leyva et al., 2022).

Since the mid-20th century, especially with the post-World War II surge, governments have seen mathematics as a driver of scientific progress and have invested heavily in STEM education to provide a workforce that could lead to technological progress (Salzman & Douglas, 2023). Yet, despite these efforts, many students find math difficult due to its abstract nature, leading to high dropout rates in STEM. As many as 60 percent of students who enroll in math-intensive disciplines, like engineering, change majors before graduation (Chen, 2013).

Math is often seen as difficult and exclusive. Many students believe math talent is “innate,” discouraging them when faced with obstacles. This contributes to a shortage of STEM graduates (Chen et al., 2024) and to educational institutions across the world to seek solutions to increase the attractivity of STEM majors.

1.1.2 Literature: the inanimate social-skills teacher

Literature is the foundation of the humanities, expressing human experience, culture, and emotions through novels, poetry, and essays. It also explores issues such as identity, ethics, history, and relationships. Literature is often described as that which "opens the mind" of the reader. It plunges them into the lives, thoughts, and emotions of people they will never meet.

Kidd and Castano (2013) conducted a series of five experiments with the express purpose of investigating the relationship between reading and empathy. Participants were randomly assigned to read literary fiction, popular fiction, non-fiction, or nothing at all, and then completed tasks designed to assess Theory of Mind (ToM), the ability to attribute mental states, including thoughts, emotions, and intentions, to others. To measure this, the Reading the Mind in the Eyes Test

(RMET) and the Yoni Test were used. The RMET asks participants to look at pictures of the eye region and identify the emotions. It is a task that shows how well you can infer a person's state of mind from subtle visual cues. The Yoni test requires participants to infer a character's cognitive, belief, and affective emotional states from minimal information. Those who read literature scored higher on the ToM tasks, suggesting a temporary increase in empathy. Engaging with complex narratives and characters in literary fiction seems to trigger cognitive processes associated with empathy. Literature even refines communicative skills, providing the means to conceptualize, interpret, and express a point or argument effectively - a skill that is highly valued in various professions, including law, education, and health care.

At a social level, literature is a way of transmitting cultural heritage and providing inspiration for ethical reflection. Through storytelling, literature reveals shared values, histories, and traditions, bringing a valuable understanding of humanity and promoting social cohesion. Literature stimulates critical thinking about contemporary moral and ethical issues and helps to create informed and active citizens who can address complex problems in society.

This may be linked to the emphasis modern educational systems place on technical and vocational training, which has fostered a perception that literature and humanities are less practical and financially secure career paths. This shift reflects an increased focus on economically productive fields at the expense of those promoting critical thought and social awareness (Nussbaum, 2010). Consequently, literature as a course has become less popular in colleges, with humanities departments facing funding reductions.

Further, the rise of digital media has reshaped entertainment and leisure preferences. Short, easily digestible digital content has largely replaced paper novels, yet much of it lacks the depth and reflective quality associated with literature. This shift has raised concerns about the potential long-term effects on critical thinking and engagement with complex, layered narratives (Hicks, 2023).

1.1.3 From two cultures to two minds

While C.P. Snow’s concept of the 'two cultures' focused on the social and intellectual divide between science and the humanities, modern psychology and cognitive neuroscience have expanded this conversation by examining both genetic and neural factors that influence individuals' inclinations toward one field or the other.

Genetic factors provide the blueprint for brain development, shaping the structure and function of various brain regions. For instance, genetic influences have been linked to differences in brain areas like the medial prefrontal cortex and right hippocampus, which are tied to analytical thinking and social cognition (Takeuchi et al., 2014).

Neural processing refers to how information is generated while these regions are involved during the performance of various tasks. For example, the medial prefrontal cortex uses more logical reasoning, which is more characteristic of science-oriented individuals, whereas the temporoparietal junction and limbic system are more integral to the social cognition and emotional interpretation typically made by humanities-focused individuals (Takeuchi et al., 2015).

Knowing how genetics and brain activity predispose individuals to certain ways of thinking explains why individuals have preferences for some subjects over others. This knowledge enlightens schools in tweaking their methods to fit different ways of thinking, thereby making science and humanities accessible to all learners.

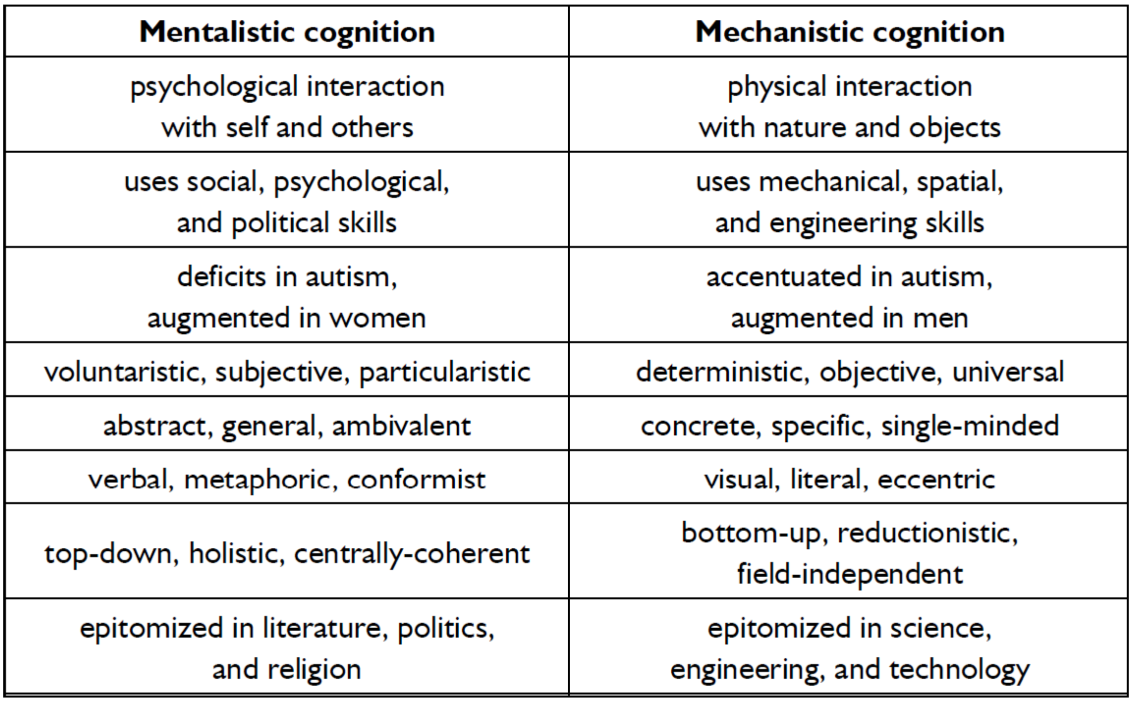
1.2 Genes, STEMs, and humanities

1.2.1 Imprinted genes and fetal testosterone

According to the diametric mind theory, the path to becoming a “math” or a “language” person begins before birth, shaped by the influence of imprinted genes on brain development (Badcock & Crespi, 2008; Badcock, 2019). Imprinted genes are unique because only the copy inherited from either the mother or father is expressed, while the other remains silent. For most genes, it does not matter whether the expressed copy is maternal or paternal—if one copy has a mutation, the functional copy can compensate, reducing the risk of harmful recessive mutations. This redundancy improves overall population fitness. However, imprinted genes lack this advantage, leading to many theories about why they evolved this way (Hubert et al., 2022; Hunter et al., 2007).

Proponents of the diametric mind theory suggest that imprinting results from an evolutionary "tug of war" between maternal and paternal genes. Maternal genes shared equally among offspring, are believed to promote a balanced use of resources, ensuring the mother's future reproductive success. In contrast, paternal genes, which may compete with those from unrelated males, aim to secure as many resources as possible for their carrier, even at the mother's expense (Ishida & Moore, 2013).

This genetic conflict, according to the theory, positions our minds along a continuum between mechanistic and mentalistic thinking. At one end of the spectrum lies autism, marked by challenges in social interaction and communication, and repetitive behaviors. This condition is seen as an "extreme paternal" brain, dominated by mechanistic thinking, focused on systems, patterns, and logical analysis, which are traits often useful in STEM fields. At the other end is schizophrenia, characterized by disruptions in thought, perception, and emotions, often manifesting in hallucinations and delusions (Valle, 2020). Schizophrenia is seen as an "extreme maternal" brain, focusing heavily on mentalistic thinking—emphasizing emotions, intentions, and social cues (Badcock & Crespi, 2008). Table 1 summarizes the characteristics of mentalistic and mechanistic cognition.



Mentalistic cognition	Mechanistic cognition
psychological interaction with self and others	physical interaction with nature and objects
uses social, psychological, and political skills	uses mechanical, spatial, and engineering skills
deficits in autism, augmented in women	accentuated in autism, augmented in men
voluntaristic, subjective, particularistic	deterministic, objective, universal
abstract, general, ambivalent	concrete, specific, single-minded
verbal, metaphoric, conformist	visual, literal, eccentric
top-down, holistic, centrally-coherent	bottom-up, reductionistic, field-independent
epitomized in literature, politics, and religion	epitomized in science, engineering, and technology

Table 1. Contrasting characteristics of mentalistic cognition (associated with maternal imprinted) and mechanistic cognition (caused by paternal imprinting). Reproduced and adapted from Badcock (2019).

The imprinted brain hypothesis extends beyond disorders, proposing that the balance of maternal and paternal gene expression influences brain development along this continuum. Every individual falls somewhere along the mentalistic-mechanistic spectrum, leaning more toward one side without necessarily having a disorder (Badcock & Crespi, 2008; Badcock, 2019).

This model is not the only framework exploring cognitive differences between "people-thinkers" and "things-thinkers." Simon Baron-Cohen’s (2002) Empathizing-Systemizing theory offers a different perspective, categorizing individuals along two cognitive dimensions: empathizing and systemizing. Baron-Cohen’s theory is based on the biological impact of fetal testosterone levels, which influence cognitive development. Higher levels of testosterone during fetal development lead to what he calls the "extreme male brain," associated with strong systemizing skills and a preference for rule-based, mechanistic thinking. People with autism often exhibit this extreme systemizing profile, excelling in tasks involving non-social systems and structured problem-solving, such as those found in STEM fields. Lower testosterone levels, on the other hand, are linked to stronger empathizing abilities, enabling better social cognition and emotional sensitivity. Most individuals fall between these two extremes, leaning slightly toward systemizing empathizing, or balancing both traits.

Though the diametric mind theory and the empathizing-systemizing theory focus on extremes, they provide evidence that genetic imprinting and prenatal hormone exposure shape everyone's mind, placing individuals somewhere along the spectrum between people-focused and thing-focused thinking. By evaluating the strengths and weaknesses of "things-thinkers" and "people-thinkers," we can start to reimagine how knowledge from disciplines like mathematics and literature, as C.P. Snow described, can be taught in ways that appeal to a broader range of learners.

1.2.2 Things-thinkers: mechanistic cognition, systemizing, and autism spectrum disorder

The two main symptom categories for autism spectrum disorder in the latest version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) are social communication deficits and restrictive, repetitive behaviors. Social communication deficits primarily affect non-verbal communication and socio-emotional reciprocity, while restrictive patterns of behavior can include repetitive movements, strict routines, fixated interests, and unusual sensitivity to sensory stimuli (American Psychiatric Association, 2013).

Restrictive behaviors often manifest as repetitive actions and intense, focused interests. Common areas of interest include the mechanics of objects, music, numbers, and nature. While the content of autistic individuals' interests is not necessarily unusual, what sets them apart is the amount of time they dedicate to these activities, as well as the methodical and systematic approach they adopt (Grove et al., 2018). These behaviors are further explained by two additional non-social symptoms of autism: repetitive behavior and sensory hypersensitivity (Baron-Cohen et al., 2009). Sensory hypersensitivity, particularly in response to auditory, visual, and tactile stimuli, can heighten attention to detail, allowing individuals to notice subtle differences and patterns that may go unnoticed by others. For example, some autistic children might watch a washing machine spin or listen to its rhythmic sounds, checking for any subtle changes. This heightened attention to sensory details can lead to a strong understanding of physical properties, and sometimes even evolves into an interest in physics (Baron-Cohen, 2002).

Characteristics of mechanistic thinking, like rule-based logic, attention to detail, strong visual-spatial skills, and the ability to spot patterns, are closely related to Baron-Cohen’s concept of "systemizing." Badcock (2009) suggests that “mechanistic cognition” might be a better term than “systemizing” because it describes the detailed, bottom-up way that people with autism often process information. Both Baron-Cohen and Badcock argue that these mechanistic traits, like logical reasoning and pattern recognition, have offered evolutionary advantages throughout history.

Baron-Cohen and Badcock both suggest that systemizing and mechanistic traits, which are very strong in people with autism, may have been especially useful in areas like science, engineering, and technology. Recognizing patterns, following rules, and testing ideas repeatedly are all important in scientific work. Autistic people’s cognitive style, often described as "if p, then q" reasoning (like "If the washing machine is unbalanced, it shakes"), supports scientific thinking, which is based on systematic rules. Conditional reasoning is key for forming hypotheses and creating predictions in research (Baron-Cohen et al., 2009).

Mechanistic thinkers, or systemizers, excel at finding patterns, examining variables, and predicting how systems behave in different situations. These skills are essential for success in mathematics, a field built on logical rules, patterns, and abstract ideas that need detailed and careful analysis. Studies show a connection between systemizing ability and mathematical talent. Baron-Cohen et al. (2001) found that scientists, especially mathematicians, score higher on the Autism-Spectrum Quotient than humanities students. Another study (Baron-Cohen et al., 2007) even found autism to be more common among mathematicians (1.85%) than in the general population (0.24%). Research by

Conson et al. (2013) also showed that people with more autistic traits performed better in visual-spatial tasks, like finding hidden shapes and mental rotation. Autistic adults without intellectual disability also did better than people with schizophrenia in areas like visual attention, working memory, and vocabulary (Kuo & Eack, 2020).

Higher systemizing scores are also linked to better math performance in the general population (Bressan, 2018) a study, participants rated their math skills, took a timed math test, and filled out the Systemizing Quotient (SQ-Short), which checks for systemizing preferences. The results showed that stronger systemizing traits were positively related to math skills, even when other factors like non-mathematical intelligence, job type, and sex were taken into account. These findings suggest that systemizing helps people succeed in math, and some autistic people's strong math skills may be due to this systemizing style (Bressan, 2018).

Autism is known to have high heritability (Hoekstra et al., 2007; Frazier et al., 2014). Relatives of people with autism often show what's called a broader autism phenotype (BAP), meaning they may have some autistic-like traits such as less interest in social interaction and a liking for routine (Sucksmith et al., 2012; Dovgan & Villanti, 2021). These family members also tend to have stronger systemizing traits and are more likely to work in STEM professions than relatives of neurotypical people (Baron-Cohen et al., 1997; Hoekstra et al., 2007).

Badcock (2019) argues that the reason we still see autism traits in the population is because these traits offer evolutionary advantages. Mechanistic thinking, which involves logical, rule-based thinking and problem-solving, would have been very useful for early humans in things like making tools, building shelters, or finding food. The ability to see patterns, solve problems, and use logical reasoning probably gave a survival advantage in non-social tasks, and as a result, genes connected to mechanistic cognition have been passed down, adding to the cognitive diversity we see in humanity today.

Although mechanistic cognition has clear benefits in non-social areas, it can also come with challenges in social cognition. A main feature of autism is difficulty with social communication, which can lead to misunderstandings, conflicts, and sometimes social isolation (Llaneza et al., 2010). Despite their cognitive strengths, autistic people often face issues in school, university, and work settings that require strong social skills (Baldwin et al., 2014; Chan et al., 2018; Cheriyan et al., 2021; Gurbuz et al., 2019).

Understanding the opposite side of the cognitive spectrum, which involves mentalistic thinking and empathizing, shows us the importance of social skills and creativity in fields focused on human interaction, communication, and the arts.

1.2.3 Psychosis, mentalistic cognition, and the evolution of language

In the diametric model of the mind, mentalism refers to a cognitive style that focuses on interpreting the thoughts, emotions, and intentions of others. This concept aligns with Baron-Cohen's Empathizing-Systemizing (E-S) theory, which identifies empathizing as the cognitive trait most closely associated with mentalism. However, Baron-Cohen (2009) primarily contrasts empathizing with systemizing. He defines empathizing as the drive to recognize emotions and thoughts in others and respond appropriately. The theory suggests that individuals who score high in empathizing excel in social communication and interaction—skills often lacking in strong systemizers. Baron-Cohen argues that extreme systemizing is linked to the "male brain," which he attributes to higher prenatal testosterone exposure. On the opposite end of the spectrum, those with an "extreme female brain," resulting from lower testosterone levels, display heightened empathy, sometimes to the point of emotional overwhelm (Baron-Cohen, 2009).

Badcock (2009) critiques Baron-Cohen's concept of empathizing as too narrow, arguing it focuses too heavily on emotional responses. He favors the term "mentalism," which encompasses not just empathizing but also the cognitive ability to predict and understand others' thoughts, intentions, and emotions. Unlike Baron-Cohen's emphasis on emotional attunement, mentalism is broader, incorporating cognitive empathy—understanding others' perspectives without necessarily feeling an emotional connection. For example, individuals with psychopathic tendencies may lack emotional empathy but can still engage in mentalizing to manipulate others, while some individuals with autism may empathize deeply with animals or inanimate objects (Badcock, 2009). Additionally, while Baron-Cohen’s theory does not address psychosis, Badcock and Crespi describe psychotic and schizoaffective disorders as conditions of hyper-mentalism.

Schizophrenia spectrum disorders cover a wide range of symptoms, all of which involve psychosis as a common feature. Psychosis distorts reality, leading to delusions, hallucinations (sensory experiences without external stimuli), and disorganized thinking and behavior—known as "positive" symptoms. Other symptoms, called "negative," include flattened emotional expression, asocial behavior, and anhedonia (lack of pleasure), along with cognitive impairments and abnormal motor behaviors (Arciniegas, 2015). Schizophrenia is the most severe form, while milder conditions include schizoid personality disorder. This spectrum also includes schizoaffective disorder, schizotypal disorder, brief psychotic disorder, and catatonic disorder (Arciniegas, 2015). Mood disorders like bipolar I and II and major depressive disorder can also present with psychotic features, such as hallucinations, and are categorized by Crespi (2016) as psychotic-affective conditions, with different genetic and cognitive mechanisms from those found in autism spectrum disorders (ASD).

Schizophrenia, as defined by the DSM-5 (American Psychiatric Association, 2013), involves symptoms like delusions, hallucinations, disorganized thinking, and impaired emotional expression. Badcock and Crespi (2008) suggest that individuals with psychotic traits, due to unbalanced maternal imprinting, often show advanced social cognition, empathy, and emotional sensitivity—traits linked to creativity. While autistic individuals may find it difficult to interpret others’ intentions, those with schizophrenia tend to over-interpret social cues, even when none are present, as reflected in the persecutory themes of their delusions and hallucinations (Waters et al., 2012). Where autistic minds focus on visual and spatial details, schizophrenic minds generate verbal and social content even with minimal interaction. The "positive" symptoms of schizophrenia, such as delusions of persecution and magical thinking, are examples of "hyper-mentalism," where intentions are attributed to inanimate objects or unrelated events (Badcock & Crespi, 2008; Badcock, 2019).

The link between psychosis and language has long fascinated researchers. Language disorders are common in schizophrenia, often marked by abnormalities in speech production and comprehension (DeLisi, 2001). Crow (1997; 2000) suggests that schizophrenia may be "the price Homo sapiens pays for language." The genetic changes that enabled humans to develop complex linguistic abilities, like abstract thinking and symbolic representation, may have also increased vulnerability to schizophrenia. Crow argues that managing intricate language processes, including syntax and metaphor, places significant cognitive strain on the brain, which can sometimes result in cognitive breakdowns. Schizophrenia, characterized by disorganized thinking, delusions, and hallucinations, may represent the brain's failure to manage these complex processes efficiently.

Crow further proposes that atypical lateralization of language processing, where the usual dominance of the left hemisphere is less pronounced, may contribute to the disordered speech and thought patterns seen in schizophrenia (Crow, 1997; 2000). In this view, schizophrenia is an unintended consequence of the cognitive advancements that made human language possible.

Research shows that many of the neural circuits involved in language, particularly those in the basal ganglia and thalamus, are also implicated in schizophrenia (Ketteler & Ketteler, 2010). These subcortical circuits, responsible for higher-order language functions like resolving ambiguity, are disrupted in schizophrenia, leading to disorganized speech and thought patterns. The disorder may stem from a failure of lateralization, where weakened left-hemisphere dominance disrupts normal speech processing (Ketteler & Ketteler 2010). Mutations in the FOXP2 gene, critical for speech and language development, have been linked to language disorders, and variations of this gene are associated with auditory hallucinations in individuals with schizophrenia (Sanjuan et al., 2006).

Crow’s theory of linguistic impairment in schizophrenia aligns with Badcock and Crespi’s observation that psychosis can enhance social communication skills. Schizophrenia, the most extreme form of psychosis, often features disorganized speech. However, in individuals with milder schizotypal traits, characteristics like associative thinking and making unusual connections can foster creative and innovative language use, revealing a broader ability to generate original content.

Schizophrenia’s impact on language offers insight into how psychotic traits may have influenced the evolution of language in humans. The heightened focus on language processing and the over-interpretation of social cues seen in schizophrenia could represent an extreme form of the cognitive skills that helped early humans develop complex language systems. The "hyper-mentalism" of schizophrenia, where individuals assign meaning to inanimate objects or interpret ambiguous stimuli as socially significant, may have been an advantage in early societies, where inferring social intentions was vital for survival.

Genetic factors linked to psychosis may also contribute to cultural and artistic innovation. Families with a history of psychosis often include individuals who excel in creative fields, suggesting that the same cognitive mechanisms associated with schizophrenia enhance divergent thinking and the ability to create novel works (Tan & Grigorenko, 2013).

Mentalism and psychotic traits also influence literary creativity through their connection to enhanced Theory of Mind (ToM). The ability to understand and predict others' behavior helped early humans coordinate, share resources, and build social structures. Societies that developed strong social bonds thrived by working together to overcome challenges. Mild forms of hyper-mentalism, seen in schizotypal traits, may have contributed to the evolution of complex social interactions, artistic expression, and imaginative thinking, giving these societies an advantage in fostering collaboration and cultural innovation.

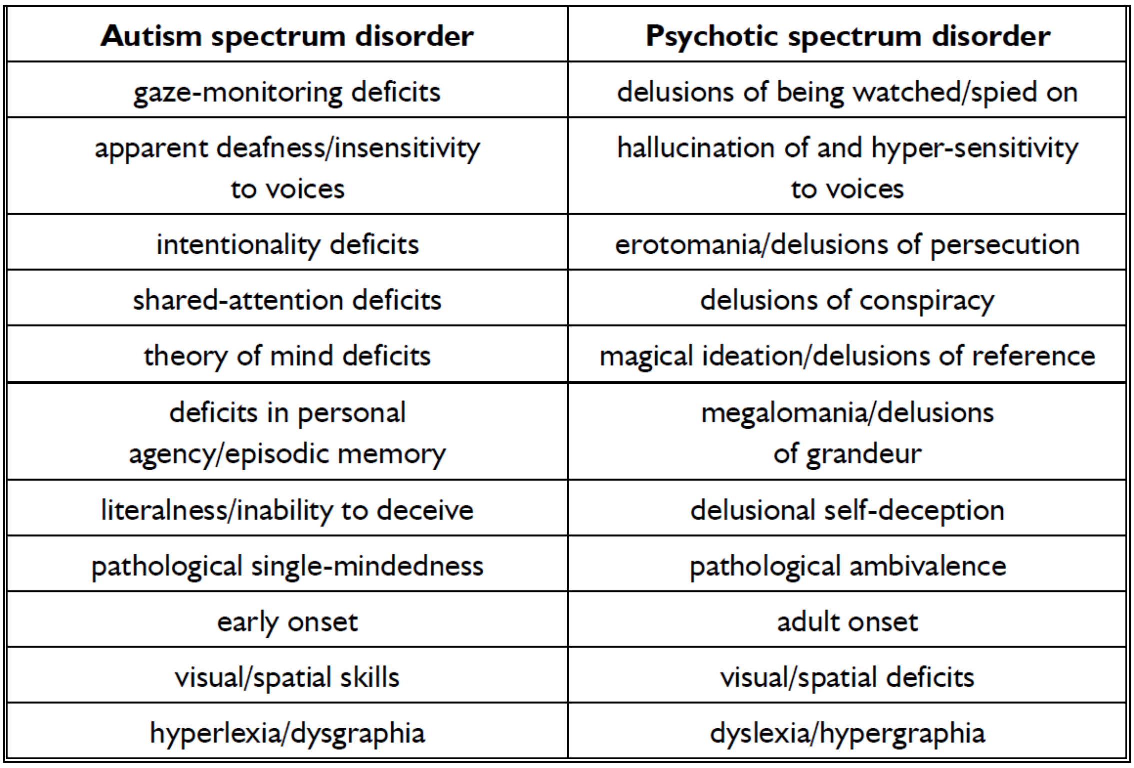
Creative writing relies on constructing complex characters and narratives. When readers interpret characters’ thoughts, motives, and emotions, they engage ToM, helping them relate to different experiences. This mental simulation allows readers to imagine alternative perspectives, enhancing empathy and social understanding (Kozak & Recchia, 2018). Literary works challenge both writers and readers to engage with complex emotions, strengthening ToM and increasing social awareness.

Despite its potential to enhance creativity, psychosis often leads to social and occupational difficulties. While some individuals with psychotic traits display high levels of creativity, psychosis can limit the practical expression of their ideas and their ability to collaborate (Grant et al., 2018; Holt, 2015). Many creative individuals with psychosis produce their best work during remission or recovery when their symptoms are better managed. This suggests that while psychosis may fuel creativity, managing symptoms is crucial for sustained productivity (Acar et al., 2017).

Creativity in writing is more strongly associated with bipolar disorder, a psycho-affective condition with less intense schizotypal traits than schizophrenia. Bipolar disorder, characterized by alternating periods of mania and depression, significantly impacts creative output. During manic episodes, individuals often experience heightened creativity, increased energy, and a flood of ideas, leading to prolific creative production. Many notable writers and poets (Virginia Woolf and Sylvia Plath are just two examples) have been diagnosed with bipolar disorder, with their most intense creative periods often corresponding to manic phases (Jamison, 1993).

The relationship between psychotic traits and literary creativity follows an inverted U-curve (Eysenck, 1995). Traits like mentalism, divergent thinking, and creating original associations boost creativity, but only in moderation. Similarly, attention to detail, intense focus, and rule-following promote success in STEM fields for those with autistic traits, but in excess, these traits can hinder career advancement.

A summary of characteristics associated with psychosis and autism according to Badcock (2019), is reported in Table 2.



Autism spectrum disorder	Psychotic spectrum disorder
gaze-monitoring deficits	delusions of being watched/spied on
apparent deafness/insensitivity to voices	hallucination of and hyper-sensitivity to voices
intentionality deficits	erotomania/delusions of persecution
shared-attention deficits	delusions of conspiracy
theory of mind deficits	magical ideation/delusions of reference
deficits in personal agency/episodic memory	megalomania/delusions of grandeur
literalness/inability to deceive	delusional self-deception
pathological single-mindedness	pathological ambivalence
early onset	adult onset
visual/spatial skills	visual/spatial deficits
hyperlexia/dysgraphia	dyslexia/hypergraphia

Table 2*. The diametrical symptoms of autism and schizophrenia in the diametric mind framework. Reproduced from Badcock (2019).*

1.2.4 Understanding minds to change cultures

Even though biological theories on cognition alone do not fully explain why people may feel drawn to one of Snow's two cultures, as their influences—like social class, nationality, schooling, and family encouragement—also play a role, these theories help us understand how our brains have evolved to manage the multifaceted and often contrasting activities required in both mathematics and social life. This perspective also sheds new light on phenomena such as the gender equality paradox.

The gender equality paradox describes a situation where, surprisingly, countries with high levels of gender equality have fewer women in STEM fields, while those with lower gender equality see more women in these areas. Stoet and Geary (2018) noted that girls in more gender-equal countries often score higher than boys in science and math, yet paradoxically, fewer women pursue STEM careers in such societies. To analyze this, they used the Global Gender Gap Index (GGGI), an annual report by the World Economic Forum that evaluates countries based on economic participation, educational attainment, health, and political empowerment, providing a complete view of the gender gap in each society. By comparing countries across varying degrees of gender equality, Stoet and Geary examined men's and women's educational and professional choices. The paradox suggests that, in more gender-equal societies, women may feel freer to choose careers based on personal cognitive preferences without facing economic or societal pressure to enter traditionally male-dominated, higher-paying fields like STEM.

On the other hand, in less egalitarian societies, women might feel more urged to enter STEM fields, as such careers provide opportunities for better economic well-being. This trend is partly explained by biological and cognitive theories, especially the Empathizing-Systemizing (E-S) Theory and the imprinted brain hypothesis. Typically, male fetuses are exposed to higher levels of testosterone, which could explain both their systemizing tendencies and the higher prevalence of autism among males (Baron-Cohen, 2009). Those with lower prenatal testosterone exposure, often females, generally lean toward empathizing (Baron-Cohen, 2009). However, it's important to note that cognitive differences are never absolute. Traits like empathizing and systemizing are shaped by genomic imprinting and fetal testosterone but are also influenced by the “male” or “female” characteristics of the brain—in Badcock's framework, by parental imprinting—rather than biological sex alone (Bressan & Kramer, 2021).

People who have a strong, systematic way of thinking often find success in STEM fields, regardless of gender, while those who think in a more empathizing way may be naturally drawn to areas like social sciences or literature. Theories about biological differences aren't meant to justify elitist or restrictive practices in education. Rather, they encourage us to rethink our methods of teaching and learning. By recognizing that thinking styles—shaped by prenatal hormones, genetic factors, and environment—can vary widely, we can start creating educational approaches that truly support the needs of different learners, rather than pushing all students into a single rigid framework.

For instance, conventional math pedagogy accommodates systematic, mechanistic thinkers but is unaccommodating to many. The approach of reforms can make math more accessible using intuitive, visual, or real-life examples that appeal more to different modes of thinking. Similarly, literature learners may require alternative approaches for developing language and social skills. The usual approach of analyzing dense texts in literary studies can be counterproductive in many cases. Providing multimedia tools, hands-on experiences, and more social, interactive forms of learning could offer new ways for students to build empathy and social awareness.
In this way, we can close the gap between Snow's two cultures by creating intellectual spaces that welcome a diversity of thinking styles, rather than forcing everyone into rigid educational structures.

CHAPTER 2 - The development of mathematical cognition, abilities, and anxiety

Math anxiety is a significant emotional challenge related to mathematics, impacting students worldwide. Unlike other subjects, mathematics has a specific type of anxiety associated with it—there is no "history anxiety" or "art anxiety" quite like it. This anxiety manifests as stress, nervousness, or even panic during math tasks, often leading to cycles of poor performance and avoidance behaviors. At high levels, this anxiety can even impair cognitive functions, resulting in avoidance and negative outcomes, as well as a lingering fear of the subject. As many as 68% of students enrolled in math classes experience severe math anxiety, which not only hinders their academic progress but also impacts their overall self-esteem and confidence in learning (Dowker et al., 2016). Students with high math anxiety are more likely to experience lower achievement and avoid pursuing careers in STEM fields, exacerbating skill gaps in these areas (Ashcraft, 2002).

To understand why mathematics triggers such intense fear, it’s essential to explore how mathematical cognition develops and the challenges students encounter along the way.

2.1 Development of mathematical skills: from early childhood to adulthood

Children begin developing mathematical abilities early, even before formal schooling. Infants as young as six months can distinguish between larger and smaller quantities, laying the foundation for what becomes their approximate number sense (ANS; Feigenson et al., 2004). ANS allows children to intuitively compare groups without counting, suggesting it is biologically rooted, potentially offering a survival advantage. Research indicates that performance on ANS tasks at an early age can predict later success in mathematics, with individual differences at age 14 explaining about 20% of the variance in standardized test scores (Halberda et al., 2008).

As children grow, they learn about numbers in simple ways, such as counting toys or saying number names, which shapes their understanding of quantities. During early childhood, they often use physical aids like fingers or blocks to help with counting, which supports foundational math learning. By kindergarten, most children can count to ten and understand that the last number they count represents the total quantity (Levine et al., 2010). Physical objects help children connect numbers to the world around them.

A major shift occurs as children start to perform calculations mentally rather than relying on tangible aids. Typically, between the ages of five and eight, children begin to depend more on mental representations than physical objects. This transition requires the development of working memory and semantic memory to facilitate logical thinking about numbers. Working memory allows children to temporarily store numerical information during problem-solving, while semantic memory securely stores basic math facts, such as addition rules (Geary, 2013).

The efficiency of these memory systems impacts children's math abilities. Differences in working memory account for almost 30% of the variance in arithmetic proficiency among children (DeStefano & LeFevre, 2004). For instance, solving "5 + 2 + 3" requires children to hold numbers in mind while recalling addition rules and interpreting the "+" symbol's meaning (Geary et al., 2007).

Attention is another critical factor in math learning. As problems become more complex, children must focus on essential information while ignoring irrelevant details. This is especially important in word problems, where extraneous information can complicate the thought process. Inhibitory control enables students to set aside distractions and focus on the necessary numbers and steps for problem-solving. Studies show that children with better attention skills perform well in math; strong attention in preschool predicts later math achievement (Blair & Razza, 2007).

Executive functions, including planning, organization, and problem-solving, are also essential for math proficiency. Children with strong executive function can manage complex problems that require careful planning and monitoring of steps. For instance, solving a challenging problem requires cognitive flexibility, or the ability to change strategies if the initial approach does not work. This flexibility is crucial for math success, as children who can adapt their problem-solving methods perform better on complex tasks (Diamond, 2013).

2.2 Talents and deficits: learning disorders and giftedness

As previously discussed, individuals with a systemizing cognitive style, including many on the autism spectrum, generally perform better than those with schizophrenia in areas such as visuospatial skills and memory (Baron-Cohen, 2002; Bressan, 2018; Kuo & Eack, 2020). Mathematical abilities vary significantly, from those excelling in abstract reasoning to others facing obstacles with foundational numerical concepts. To understand this spectrum, it is useful to examine difficulties such as dyscalculia as well as the exceptional abilities observed in savants and mathematically gifted individuals.

Dyscalculia is a learning disorder that makes understanding numbers and performing mathematical operations challenging. It affects approximately 3–7% of the population and is associated with deficits in the Approximate Number Sense (ANS), working memory, and spatial reasoning (Geary, 2013; Butterworth, 2012). Children with dyscalculia often find it difficult to comprehend numbers and may have trouble linking symbols to their corresponding quantities (Wilkey et al., 2020). For instance, they may see the number “5” without fully grasping the quantity it represents.

These difficulties extend beyond symbolic recognition; children with dyscalculia also find it hard to interpret non-symbolic numerical representations, such as dot patterns. Dyscalculia involves persistent issues with understanding numbers and often co-occurs with limitations in working memory and executive function, making tasks like multi-step problems or mental calculations especially demanding (Decarli et al., 2022).

Dyscalculia is not the only disorder that complicates math learning. Dyslexia, affecting approximately 5-10% of the population, is primarily known for its impact on reading (Snowling, 2013). It stems from deficits in phonological awareness and often affects semantic memory (Ferrer et al., 2009). Although dyslexia is typically seen as a language-based disorder, it significantly impacts mathematics due to difficulties with symbol recognition and manipulation, particularly in arithmetic and algebra (Snowling, 2013). Badcock (2009) links dyslexia to maternal imprinting, suggesting that it is more prevalent among individuals with psychotic traits.

2.2.1 Hypercalculia, savantism, and giftedness: why counting isn’t everything

"Savants" are individuals with generally low IQ scores who demonstrate exceptional abilities in specific areas (Park, 2023). Although only a small percentage of autistic individuals are savants, about three-quarters of people diagnosed with autism display some savant-like traits (Uddin, 2022). Many savants possess extraordinary numerical abilities, such as rapid calendar calculations, and display remarkable visuospatial skills, including the ability to draw detailed images from memory or reproduce realistic scenes after brief observation. Mathematical savants often exhibit hypercalculia, which allows them to perform complex calculations quickly and accurately (Ogun et al., 2022). They can effortlessly add large numbers or tackle advanced operations like factorization or matrix multiplication. Savants are typically strong in visuospatial tasks and have an impressive memory for visual details, numbers, and specific facts (Park, 2023).

The cognitive style of savants reflects traits that Badcock describes as characteristic of a mechanistic mind: a tendency to focus on details rather than broader contexts (weak central coherence), heightened sensory perception, strict rule-following for pattern recognition, repetitive behaviors, and challenges with Theory of Mind (Badcock, 2019; Park, 2023). However, savant skills are usually task-specific. While savants may excel at rapid calculations, they often find more abstract mathematical concepts challenging (Wallace, 2008)

This distinction illustrates the limits of rigid, mechanical thinking in mathematics. Although savants may be exceptional in calculation, they often lack the conceptual understanding needed to apply their skills in broader or novel ways. Conversely, mathematically gifted individuals integrate systematic thinking with creativity, enabling them to solve complex problems by adapting mathematical concepts flexibly across various contexts (Ogun et al., 2022). Gifted individuals tend to excel in problem-solving, pattern recognition, and generalizing mathematical ideas across domains; they also demonstrate strong spatial reasoning and abstract thinking skills (Geary, 2013). Many show an early aptitude for math, understanding numerical relationships intuitively, and thinking abstractly from a young age (Hannula & Lehtinen, 2005).

Research on the cognitive factors underlying mathematical giftedness indicates that gifted individuals have stronger connections between brain regions associated with spatial reasoning, numerical processing, and executive function. Significant areas include the intraparietal sulcus (IPS), which processes number magnitudes; the posterior parietal cortex (PPC), involved in spatial reasoning; the prefrontal cortex (PFC), which supports working memory and flexible thinking; and the hippocampus, essential for long-term memory retrieval (Szücs & Myers, 2017). Investigating mathematical giftedness not only offers insights into exceptional cognitive abilities but also provides a deeper understanding of how mathematical cognition functions more broadly.

2.3. The PISA and mathematics: global insights and mathematical curricula

The Programme for International Student Assessment (PISA) is a global evaluation conducted by the Organisation for Economic Co-operation and Development (OECD) that measures the performance of 15-year-old students in reading, mathematics, and science across participating countries. It is conducted every three years and serves as a benchmark for understanding how well different education systems prepare students for their future.

In terms of mathematics, PISA measures students' ability to formulate, employ, and interpret mathematical concepts in various situations. The focus is on mathematical reasoning and problem-solving. The test requires an integration of working memory, symbolic manipulation, and spatial reasoning.

When examining global results, constant trends emerge. Countries like Singapore, Finland, Japan, and South Korea consistently outperform others in mathematical achievement.

In the 2018 PISA results, Singapore ranked first in mathematics with a score of 569, well above the OECD average of 489 (OECD, 2019). This success is attributed to a curriculum that emphasizes conceptual understanding, problem-solving, and flexibility in applying knowledge. Singapore's mathematics curriculum is structured around the "Concrete-Pictorial-Abstract" (CPA) approach. This method encourages students to understand mathematical concepts first through tangible objects (concrete), then through visual representations (pictorial), and finally through abstract symbols (abstract). This progression mirrors the natural development of mathematical cognition, allowing students to gradually build a deep understanding of complex ideas. In addition to CPA, Singapore focuses on problem-solving and reasoning, with an emphasis on applying mathematical concepts to real-life situations. This pedagogical approach has been highly effective in helping students develop a flexible understanding of mathematics (Schoen et al., 2003).

Finland also performed well in the PISA mathematics assessment, with a score of 507 in 2018 (OECD, 2019). Finnish classrooms focus on fewer topics but explore each with more depth, allowing students the time to master the material. A hallmark of Finnish education is student-centred learning, which includes hands-on activities, group work, and open-ended problem-solving. Finland places great emphasis on individual support, ensuring that students who struggle with mathematics receive the help they need. A particular focus on developing spatial abilities is evident in the teaching of geometry through puzzles and shapes, which help students understand relationships between objects and their spatial properties (Andrews & al., 2014). For instance, spatial skills, such as mental rotation and visualization, are recognized as essential components of mathematical reasoning, particularly in geometry and algebra (Gilligan-Lee et al., 2022).

Japan achieved a PISA math score of 527 in 2018, placing it among the top countries (OECD, 2019). The Japanese education system introduces problem-solving early on, with teachers guiding students to explore mathematical concepts rather than merely memorizing formulas. Japan frequently uses a method known as “structured problem-solving,” where students first attempt problems independently and then discuss their solutions with peers. This approach encourages creativity and strengthens understanding of fundamental math concepts (Fernsham, 2007).

Italy, however, has lagged in PISA scores, earning only 487 in math in 2018, which is below the OECD average (OECD, 2019). Italian students often encounter difficulties with abstract concepts, as their education frequently emphasizes practice and memorization over critical thinking or exploratory learning (Ajello et al., 2018). Italian students typically find it challenging when asked to apply their knowledge to unfamiliar problems, revealing a contrast between rote learning and a more profound understanding (Ajello et al., 2018).

2.4 The four horsemen of math anxiety: symbolic formalism, decontextualization, cognitive workload, low-self efficacy

The differences we see globally in PISA results highlight not only educational quality gaps but also how teaching methods connect with natural mathematical learning processes. Countries that do well generally have lessons that let students slowly move from tangible things to abstract thought while encouraging problem-solving both alone and together with others—focusing on understanding concepts rather than just remembering facts.

In poorly performing countries, students find themselves dealing with four main difficulties recurrent in mathematical learning: the high amount of symbols, the decontextualization of the contents from real-world issues, the high cognitive workload on different processes, and the low self-efficacy caused by repeated negative experiences.

2.4.1 The strain of symbolic representation

In early schooling, kids usually learn math with things they can touch and pictures that help make sense of ideas. But as they get older, they must switch to using symbols which can be a sudden change, especially when early lessons were structured around hands-on learning (Mainali, 2021). This shift puts a heavy mental load since math symbols—like fractions or letters used for variables—are abstract and often do not connect well with everyday experiences (Diez-Palomar et al., 2007).

For example, cutting a pizza in two feels easy to understand, but the fraction 1/2 is not equally intuitive (Powell & Fuchs, 2015). This problem grows in algebra where letters like "x" and "y" represent unclear amounts. Having to remember the meaning of symbols—with complicated formulas, equations, and multiple symbolic expressions—slows down solving problems and leads to more mistakes (Geary et al., 2013; Shen et al., 2020).

2.4.2 Decontextualization

Mathematical concepts are often taught in a decontextualized way, without any historical background or explanation of why a particular formula, concept, or theorem was developed. The problems students deal with in class rarely mirror real-world math applications. A lot of students do not see how what they learn in math class matters outside of school, and this gap can drop their interest. In basic math classes, kids use material objects they can touch to understand quantities. As their education progresses, the content of math lectures feels like a whole different world, far from what they experience daily. For students, not having real-life examples makes things even trickier because they cannot see why what they are studying is important—especially in the case of themes like algebra or calculus.

While some enthusiasts may appreciate the beauty or elegance of mathematical processes without needing knowledge about their applications, also this aspect is rarely mentioned in textbooks or explained by teachers. For younger students, who are still developing their ability to think abstractly, understanding how math is useful in everyday life could be the first step toward encouraging a genuine curiosity about the subject.

2.4.3 The high cognitive workload of mathematics

For many students, one of the biggest challenges in mathematics is the high cognitive load it demands. Math requires the integration of various cognitive skills—working memory, executive function, spatial reasoning, and semantic knowledge—just to solve basic problems. When any of these skills is underdeveloped or strained, students can quickly feel overwhelmed and fall behind. Beyond dyscalculia, several other factors can hinder math performance, including disorders like attention-deficit disorder (ADHD) and dyspraxia, which impairs visual-spatial abilities, as well as negative teaching experiences that create gaps in knowledge and skills. A wide range of students seems destined to encounter barriers in their mathematical journey (Kanevski et al., 2023; Waber et al., 2021).

2.4.4 Low self-efficacy

Low self-efficacy in mathematics can be traced to four key factors, as outlined by Bandura’s (1997) social cognitive theory, which helps explain how individuals develop beliefs about their abilities. One of the most influential factors is mastery experiences—successes and failures that students experience directly. In math, students who make an effort to understand abstract concepts or get low grades often see these issues as signs of their lack of talent, which lowers their belief in themselves. Failing time after time makes them think that trying harder will not help, trapping them in a bad loop of avoiding math and feeling anxious (Schunk, 1989).

Conversely, students who do well in math tasks see the gains as proof they can conquer tough ideas with effort and determination. Another key point is learning by watching others. Students frequently look at how their peers perform. When they notice classmates succeed easily in math, it can cause them to doubt their skills. This happens more in settings where only a few shine, making students think success in math is for the naturally gifted only. The idea that some have an inborn talent for math can hurt perceptions and make students believe that skill is not something that can be achieved through hard work (Pajares, 1996). Consequently, many students give up on math entirely, thinking they will never reach the same level of ability no matter how much they try.

Social persuasion—the feedback students hear from teachers, parents, or friends—greatly affects self-efficacy. Good praise can raise a student's belief in their math skills, and bad remarks can lower it. For instance, frequently hearing that math is tough or being labeled as not “a math person” can harm self-efficacy (Schunk & Pajares, 2002). Well-intentioned comments regarding how challenging math is often have a boomerang effect because they reinforce the idea that only a few people are capable of understanding it. The more these negative messages mount, the heavier the insecurity and avoidance of the subject raise.

Physiological and emotional states affect further self-efficacy. Many students feel anxious, stressed, or frustrated when doing math work. Physiological reactions like fast heartbeat or sweating are interpreted by the students as proof of their incompetence. The emotional burden from math anxiety makes things worse, creating a bad loop where anxiety decreases performance and strengthens the idea that math cannot be understood (Bandura, 1997).

Together, these four factors—mastery experiences, vicarious experiences, social persuasion, and physiological response—form a powerful set of influences that shape a student’s belief in their ability to succeed in mathematics.

2.5 Where should mathematics change?

Students' difficulties in mathematics are not solely due to some cognitive deficits but rather reflect deeper systemic problems in mathematics education.

The heavy reliance on symbolic representation, abrupt transition from concrete to abstract, decontextualization, and low self-efficacy make math unreachable for many learners. Additionally, the teaching practices of most countries tend to facilitate mechanistic and systemizing-like minds, leaving many students - both with and without learning disabilities - in a disadvantaged position.

Changing the teaching and representation in mathematics, not changing the students, is what the reform is about. That means decreasing the cognitive load by smoothing the transition from concrete to abstract, using manipulatives and real-life illustrations to contextualize symbolic learning, and implementing teaching methods inclusive of a wider range of learners.

By recognizing cognitive divergence in the classroom, educators can make the class a place where math problems are within the reach of all kinds of learners.

CHAPTER 3 – Rules and narratives: the double nature of language

Humans acquire language early in life, supported by structured learning and social interaction. According to the universal grammar theory of Chomsky, an inner grammatical set of rules guides humans in their innate capability for language (Chomsky, 1965). In contrast, Vygotsky's social development theory highlights the interaction of humans with their environment, which is also their main teacher (Vygotsky, 1962). These dual aspects reflect the tension between learning language as a rule-based system and as a tool for social communication.

3.1 Reading and writing in schools

In educational settings, reading and writing engage both rule-based and social dimensions of language. Phonics instruction focuses on the rule-based aspect, teaching children to decode words through letter-sound relationships (Ehri, 2005). Reading also involves comprehension, requiring students to infer characters’ intentions and emotions, which engages the social communication aspect of language (Nation & Snowling, 1999). Understanding texts demands both cognitive and emotional effort, as readers navigate complex social interactions and mental states.

Mar et al. (2006) divided a sample of two groups of readers based on whether they were fiction and nonfiction readers and tested them on measures of social cognition using the Reading the Mind in the Eyes test and the Interpersonal Reactivity Index. Nonfiction readers received a lower score on these tasks, while fiction readers scored higher, especially in the areas of empathy or providing reasons from others' perspectives. This study controlled for several such possible confounding variables by administering tests of narrative comprehension and general cognitive ability besides the social cognition measurements. The study of Mar et al (2006) does control for a casual relationship, as it is possible to conclude that individuals with better social cognition are keen fiction readers, but it does not prove the effect of fiction..

Other researchers searched for a causality effect of reading fiction on social cognition. A meta-analysis of 14 experimental studies conducted by Dodell-Feder and Tamir in 2018 demonstrated that participants who, through random assignment, read fiction outperformed those who either read nonfiction or did not read at all on a variety of social cognitive tasks. These investigations involved complete control over experimental design: participants were randomly assigned either to read or not to read, thus establishing a cause-and-effect relationship between fiction and social cognition. Any rise in social cognition post-reading also could not be due to some pre-existent differences in social skills, since the random assignment controlled for those. The authors concluded that reading fiction can improve the ability to understand others' emotions and perspectives through repeated engagement with narratives of social events that mimic real-life interactions.

Kidd and Castano (2013) came to a similar conclusion. The authors conducted five experiments in which participants who had read literary fiction performed significantly better on the Reading the Mind in the Eyes test, a task considering the ability to infer the state of others from subtle social signals, compared with participants who had read non-fiction or popular fiction. This represents a temporary but statistically significant gain in social perception right after reading, indicating that even brief exposure to fiction enhances social cognition. Because the researchers compared different types of reading material, they showed it is the complex, character-driven narratives in literary fiction that produce this cognitive effect, not merely any reading material. This design controlled for other potential confounding factors, such as pre-existing reading preference, by making sure that all participants shared similar baseline characteristics.

Writing is an additional exercise for social communication. Structured writing, like essays, is rule-based learning, but creative writing frees the student to explore emotions, thoughts, and experiences. This practice nurtures empathy and ToM by placing the writer in a position to understand his audience, use appropriate tone, and convey meaning in a way that reflects both the rule-based and social components of language, according to Svensson (2018). Creative writing also commonly invites students to engage with either character or reader roles, thereby encouraging social cognition by engaging in mock social environments.

Gender differences in reading preferences reflect broader cognitive patterns. Boys tend to prefer nonfiction, focusing on factual content, while girls are more drawn to fiction (Clark & Foster, 2005). This difference aligns with Baron-Cohen’s (2002) empathizing-systemizing theory, suggesting that boys are generally more inclined toward systemizing and girls toward empathizing. These preferences perhaps impact the development of social skills since boys who preponderantly read non-fiction would have fewer opportunities for engaging in the types of complex social interaction fiction enables. However, Roberts et al. (2015) reported that in those instances in which boys did engage in fiction, there was an improvement in their social cognition, suggesting that changes in social cognition are driven by reading material and not pre-existing social ability.

These studies point to a causal relationship between reading fiction and the improvement of social cognition. Fiction exposes readers to elaborate, character-driven storylines that mirror real-world social interactions, offering opportunities to practice and develop social skills (Dodell-Feder & Tamir, 2018; Kidd & Castano, 2013; Mar et al., 2006).

3.2 Reading and Social Communication Disorders

While dyslexia primarily manifests as a reading disorder with underlying deficits in phonological processing and semantic memory, hyperlexia is characterized by an early and often precocious ability to read, sometimes without comprehension. Both conditions provide valuable insights into how specific cognitive processes, particularly semantic memory and symbolic reasoning, can vary widely among individuals, often aligning with either mechanistic or mentalistic cognitive styles.

3.2.1 Sister reading disorders: dyslexia and hyperlexia

Students with dyslexia typically experience difficulties in word recognition, connecting letters to sounds, and spelling. These difficulties impair reading fluency and comprehension significantly, affecting academic performance in different subjects. As with mathematics, semantic memory is important in connecting written symbols - letters and words – with sounds and meanings. Dyslexic learners typically have difficulties in that respect, particularly when rapid retrieval of verbal information is required (Moll et al., 2014).

This may lead to being slow when reading and analyzing sentences and paragraphs. At the same time, dyslexia impacts connectivity between new and prior knowledge, especially for such domains as history and literature in general (Snowling & Hulme, 2012).

While dyslexic readers struggle to decode, hyperlexic readers do the opposite, developing precocious reading skills that sometimes exceed age expectations (Aram & Healy, 1988). However, this exceptional decoding ability is frequently accompanied by deficits in comprehension and social communication, as hyperlexia is often associated with autism (Ostrolenk et al., 2017) and is considered by Badcock to be a disorder connected to paternal imprinting. This creates a disconnect: hyperlexic readers excel at interpreting text but find it hard to grasp its deeper meaning. Their strength lies in recognizing patterns and symbols, while understanding context and meaning remains poor (Grigorenko et al., 2003). Thus, hyperlexia challenges the assumption that decoding alone equates to full literacy.

3.2.2 Semantic-pragmatic disorder and communication in ASD

While dyslexia reveals a disruption in the rule-based component of language—primarily affecting decoding and phonological processing—semantic-pragmatic disorder (SPD) exposes deficits in the communicative aspect of language. Individuals with SPD face challenges in using language appropriately in social contexts, despite having relatively intact grammatical and structural abilities. This disorder primarily affects the pragmatic use of language, which includes understanding and adhering to the social rules of communication, interpreting indirect or non-literal language, and adjusting speech according to social cues and contexts (Adams et al., 2018). Pragmatic difficulties often include issues with turn-taking, understanding sarcasm, or recognizing social intent within interactions (Ellis Weismer et al., 2021). Although they can construct grammatically correct sentences, people with SPD cannot use these sentences effectively in specific social contexts. These individuals often miss the subtleties of social interaction, such as body language, tone of voice, and the contextual nuances underlying conversations, all of which are fundamental to effective communication. SPD frequently co-occurs with ASD, though this is not always the case (Hage et al., 2021).

3.3 When in Rome, read as the Finnish do. Worst and best PISA performers

Literacy, social skills, and the ability to engage deeply with written texts are key aspects of education worldwide. In the 2018 PISA survey, Finland performed exceptionally well, with an average reading literacy score of 520, well above the OECD average of 487 (OECD, 2019). Japan's education system, known for its rigor, scored 504, while Italy recorded a score of 476 (OECD, 2019).

In Finland, most of the literature classes entail discussions, role-playing, and even creative writing to encourage students to delve into the thoughts, feelings, and motivations of characters. The method ensures that along with the development of cognitive abilities, students reflect upon human relations and social roles. Finnish teachers try to make literature personally relevant and connected to children's lives and experiences and thereby, to make learning more appealing (Lähdemäki, 2019)

In Japan, the stress is on precision and factual recall. In the PISA, Japanese demonstrate strong skills in reading comprehension and decoding (OECD, 2019). Literature teaching in schools is inclined more toward the memorization of plots, historical contexts, and rhetorical devices rather than analyzing underlying emotional or social themes. Education in Japan is designed to prepare students for university entrance exams, which heavily favor factual knowledge. As a result, Japanese students excel in tasks requiring accuracy but may find it challenging to connect with texts that demand empathy, creativity, or an understanding of social context (OECD, 2019).

Italy's education system relies on traditional approaches. Students study a wide range of classical literature, focusing on authors such as Dante, Petrarch, and Manzoni. Teaching, however, tends to be content-oriented; this oftentimes means that instead of developing critical or personal relationships, students will be required to memorize facts about the authors and historical contexts. This more rigid approach limits students' engagement with literature, as classes focus on covering content rather than delving into its meaning. This may explain Italy's lower score, as students are often not allowed to critically reflect on or relate to the literature they study (OECD, 2019).

3.4 Barriers to learning social communication skills: difficulty in practice, traditional literature teaching, decline of literature

3.4.1 Dangerous exercises

Social communication in real-life interaction is associated with risks and penalties. While in math or reading, one can make mistakes and learn from them in a controlled setting, mistakes in social communication may be immediately followed by negative consequences and social exclusion, embarrassment, or conflict that precludes any possibilities for constructive feedback (Ellis Weismer et al. 2021). This is particularly challenging for students with conditions such as autism spectrum disorder or social (pragmatic) communication disorder, who have a hard time inferring social rules or understanding the implicit cues that guide conversations (Adams et al., 2018).

3.4.2 Barriers to traditional approaches to teaching language and literature

In many educational systems, the teaching of language and literature is done largely through a mechanistic approach, laying strong emphasis on grammar, syntax, and technical reading comprehension. Students in countries such as Japan and Italy are expected to learn facts about literature, sentence structure, and rhetorical devices by rote rather than being asked to engage with the emotional or social dimensions of texts (OECD, 2019). Japan and Italy are just two examples of countries where students are asked to memorize facts about literature, sentence structure, and rhetorical devices rather than engaging the emotional or social dimensions of texts (OECD, 2019).

Whereas the mastery of the technical rules of language is essential, this preoccupation overshadows its communicative and empathetic functions, with evident limitations in students' ability to apply their language competencies within social contexts.
One drawback of such a systematic approach is that the learning of the language becomes divorced from the social skills. In natural life, social communication depends not only upon linguistic correctness but also upon an understanding of the situation; in other words, a knowledge of the literal meaning of words and their social significance. In schools, these are often divided. A shortcoming of this approach is its separation of language learning from the development of social skills. Social communication, in everyday life, apart from accuracy in language, includes a sense of context: understanding the literal meaning of words and their social implications. In schools, however, these elements tend to get isolated. Language is taught as a technical subject with an emphasis on grammar and syntax, while social skills—if covered at all—are generally relegated to character education (Adams et al., 2018).

3.4.3 Strengths and limitations of literature

Literature provides a unique platform for teaching both rule-based language skills and social understanding. Through stories, students can observe how characters interact, how misunderstandings arise, and how social cues shape communication. In this way, literature offers a model of social communication within a controlled environment, allowing students to practice their Theory of Mind and empathy skills without the real-world consequences that often accompany social missteps (Mar et al., 2006).

Literature can, however, be limited in its capacity to serve as a tool for teaching social skills. A book can reveal wide insight into human interaction but is, in essence, static against the dynamic nature of real-world socialization. Readers may watch the interactions of the characters but cannot participate or respond to their behavior regarding social timing. This makes literature less effective as a practical tool for developing social communication, especially for students who have trouble interpreting social cues and require more interactive learning.

Additionally, for students who have difficulties with reading—such as those with dyslexia—engaging with written texts can be an exhausting process, making it less effective as a tool for enhancing social skills. For these students, the symbolic and semantic challenges of reading can detract from their ability to connect with the material in a meaningful way.

3.4.3.1 The declining engagement with literature

Another major barrier to using literature as a tool for teaching social communication is the declining interest in reading among younger generations. As students spend more time on digital media and less time with books, their exposure to narrative-driven, character-focused stories has diminished (OECD, 2023). This issue is worsened by how literature is often taught—through memorization and technical analysis—making it feel like a dry, mechanical subject rather than a rich exploration of human relationships and emotions. For students who face challenges with reading or who are more visually or practically inclined—such as boys, who tend to prefer nonfiction or visual media—this can further distance them from the social learning that literature can provide (Hicks, 2023).

Schools must reconsider the way both language and social communication are taught to overcome these barriers. Rather than being treated as separate components, the two need to be integrated. Literature represents an ideal platform for this integration, blending linguistic content with social narratives and modeling real-world interactions through its characters and stories. One way to achieve this is through more interactive, student-centred approaches in the teaching of literature. Instead of focusing solely on plot structure or identifying literary devices, teachers can guide students to explore ways through which characters' interactions mirror real-life social dynamics.

Role plays, group discussions and creative writing are some activities that will help students in their social use of language for both technical and effective communication skills. Furthermore, technology like virtual reality could be used to simulate social situations, offering students with social communication challenges a safe, controlled space to develop these skills interactively.The next chapter will explore interventions and strategies aimed at improving social communication skills through narrative-based media.

CHAPTER 4 – Rethinking math and literature education: icons and games are not (only) for children

4.1 Addressing mathematical difficulties

Mathematics is generally perceived to be out of reach for many. In this respect, different interventions have been designed to make math more accessible and interactive. These would generally fall into the categories of (1) changing learners' attitudes and improving their skills to better perception and ability in mathematics and (2) modifying how mathematics is taught and presented to adapt it to a wider range of learners. This chapter will discuss the success and potential of both approaches.

4.1.1 Changing attitudes and Skills: anxiety, growth, and stereotypes

4.1.1.1 Math anxiety: addressing emotional barriers

One of the most common stumbling blocks to math success is math anxiety. Math anxiety invariably lowers performance, particularly in those students who already have difficulties with the subject (Ashcraft, 2002). Interventions directed at math anxiety often target emotional regulation strategies such as mindfulness or systematic desensitization.

For instance, mindfulness programs instruct students in using breathing exercises and grounding techniques to maintain a cool head while solving problems, rather than letting stress derail them. In a discursive-analytic review, Victor-Aigbodion (2023) examined several mindfulness-based interventions, including mindfulness-based stress reduction and mindfulness-based cognitive therapy, and their impact on students with math anxiety. One study revealed a 13.8% reduction in math anxiety levels following a series of mindfulness-based stress reduction sessions, in which breathing and grounding techniques were taught to the students to help them overcome stress and anxiety during math class (Pinthong, 2018).

A limitation of mindfulness interventions is that they do not intervene in mathematical skills. They can reduce the fear and avoidance of math, but without working on math skills, the risk is for their positive effects to be short-termed, especially for students with working memory deficits and other underlying cognitive difficulties (Victor-Aigbodion, 2023).

4.1.1.2 Growth mindset: promoting persistence in math learning

Growth mindset interventions are based on the work of Dweck (2006) and aim to instill the belief that maths ability can be developed through effort and persistence. These programs aim to counteract in students the mindset that math talent is innate and cannot be acquired. Encouraging students to treat mistakes as opportunities for learning and growth, growth mindset interventions encourage greater persistence and a desire to commit to challenging problems. Students with a growth mindset are more resilient when facing difficulties and tend to show better long-term outcomes in mathematics (Boaler et al., 2021).

In a study by Blackwell et al. (2007), seventh-grade students learned about neuroplasticity—the brain's ability to grow and strengthen through effort and practice, much like a muscle. Over a series of workshops, students were taught that intelligence is not fixed but can be developed through hard work. In these sessions, it was explained to the students how the brain makes new connections when we learn, and how effort leads improvement.

Students exposed to the intervention showed better grades and greater motivation compared with the control group. The growth mindset group, viewing effort as the key to progress, was more willing to persist through difficulties and view mistakes as part of the learning process. Yet just as with the interventions for math anxiety, the growth mindset programs have their limits.

While these programs do improve attitudes and persistence, they do not directly impact the cognitive strategies or content knowledge of mathematics. For students who are missing foundational skills or the development of mathematical reasoning, simply having a positive mindset will not ensure their success..

4.1.1.3 Gender stereotypes and socio-economic disparities

Efforts to reduce gender stereotypes and improve access to STEM fields for underrepresented groups have also shown promise. Programs that focus on increasing female participation in math by providing mentorship, scholarships, and role models have had positive effects in many contexts. For example, Norwegian programs aimed at combating stereotypes have led to a higher number of women entering STEM fields (Silander et al., 2022). These initiatives seek to convince girls that mathematics is not a boys' domain and encourage them to explore their interest in STEM subjects.

Paradoxically, however, some countries such as Norway, with less strong gender stereotyping, have some of the lowest rates of women participating in the STEM fields (Stoet & Geary, 2018). This is what has been referred to as the gender-equality paradox, suggesting the possibility that reducing stereotypes alone cannot change the dynamics of gender representation in mathematics.

Instead, the problem may well lie with the pedagogy of math itself and the way that it interfaces with different cognitive styles. Subjects that, in the way they are currently taught, require a mechanistic thinking style may be more naturally appealing to someone who is more STEM-oriented, whereas someone who is more mentalistic, according to Crespi and Badcock (2008), would find mathematics too symbolic and relying on semantic memory.

Interventions targeting students with low socioeconomic status, including after-school tuition and access to technologies, have also been shown to benefit the math attainment of pupils (Dietrichson et al., 2019). However, these programs generally focus on short-term gains, like better test scores, and do not delve into deeper cognitive issues. Students from low-income backgrounds usually lack the resources as well as the cognitive support necessary to understand abstract mathematical concepts (Pensiero et al., 2019). Therefore, although these interventions may close the attainment gap for a short time, they seldom lead to long-term gains in mathematical achievement.

4.1.2 User-friendly mathematics: narrative approaches, embodied learning and visual representations

Another major approach to improving math education focuses on presenting mathematical ideas in easier ways to understand and work with. This includes methods like embodied learning, using stories to teach concepts, and visual techniques that help students see abstract math more concretely. These approaches are especially helpful for students who find traditional math instruction difficult, offering new ways to connect with the material.

4.1.2.1 Narrative-based Instruction: teaching math with stories

A promising approach to making math more relatable One effective strategy is narrative-based instruction, where math concepts are explained through stories and real-life examples. This approach helps with a common challenge: many students struggle to connect abstract math with their everyday lives. By embedding math within stories, teachers give students familiar, engaging contexts. For example, Heath et al. (2017) examined how a story about building a treehouse could teach measurement, area, and perimeter. Students' understanding was tested with practical tasks, like designing blueprints or solving problems within the story. Results showed that students taught through stories not only performed better but could also see how math applies to real situations.

This method builds on the theories of Vygotsky and Piaget. Vygotsky believed that learning happens through social interactions, while Piaget emphasized that young learners need concrete experiences. In line with these theories, Capraro and Capraro (2006) found that using children's stories in middle school geometry improved students' grasp of math vocabulary and helped them use geometric concepts in different situations. Students in narrative-based classrooms could explain formulas and apply math more flexibly in real-world contexts, achieving better test scores than their peers in traditional classrooms.

Narrative-based learning is especially beneficial for students with mentalistic cognitive styles, who thrive when learning is framed in social or contextual terms. According to Badcock (2009), these students find it easier to absorb information when it engages their emotional and episodic memory. In classrooms where math concepts are presented through stories, students with this cognitive style can better understand abstract ideas. By adding a social dimension to math, narratives make it more relatable and connect it to personal experiences.

Using literature to teach math offers another advantage: it reduces math anxiety. Furner (2018) found that students who learned through storytelling experienced lower anxiety levels and greater confidence. This was measured through surveys conducted before and after lessons, along with assessments of their performance. The familiar structure of stories creates a less intimidating environment, allowing students to approach math without the fear often associated with abstract topics. By lowering anxiety, narratives help students engage more comfortably with math, especially those who struggle with traditional methods (Furner, 2018).

However, while narrative-based instruction is effective for introducing foundational concepts like geometry or arithmetic, it can be more challenging to apply to advanced topics such as calculus or trigonometry. Even after engaging with math through narratives, students would find algebraic symbols difficult to master. While stories can math concepts and applications more accessible and clearer, they cannot entirely replace the need for abstract representation in higher-level mathematics, and neither can they intervene on strains with symbols.

4.1.2.2 Embodying math in physical experiences

Embodied learning is a teaching method that brings physical movement and gestures into math teaching, helping students connect abstract math ideas to physical experiences, which can make complex concepts easier to get. For instance, students might use hand gestures to represent algebraic functions or work with physical objects to explore shapes and their properties (Tran et al., 2017).

Research has shown that embodied learning can improve students' understanding of math, especially at the elementary level (Abrahamson & Sánchez-García, 2016). By connecting abstract ideas to physical activities, students develop a deeper understanding before moving on to more symbolic or theoretical work. For example, students who learn geometry by handling physical shapes are better able to understand those shapes when they see them in symbolic form later on (Abrahamson et al., 2020).

However, embodied learning's effectiveness drops as students get into higher-level math. While it works well for topics like basic arithmetic and geometry, it is tougher to apply to more advanced subjects like calculus or algebra. So, while embodied learning is a valuable tool in early math education, it doesn't completely address the needs of advanced math (Goldin-Meadow, 2018).

4.1.2.3 Introduction to icons

Following embodied learning, another approach that employs alternative methods for presenting mathematical concepts is the use of icons.

An icon, as Peirce describes, "is a sign which refers to the object it denotes merely by virtue of characters of its own, and which it possesses, just the same, whether any such object exists or not" (Peirce, 1955). Essentially, icons are direct visual representations that closely resemble the object or concept they are intended to signify. For example, a visual depiction of fractions as pie charts provides an iconic representation of division and parts of a whole, offering a concrete image that mirrors the abstract idea of numerical fractions. In contrast, symbolic representations, such as the number ½, have no visual or physical connection to the concept of a fraction, relying entirely on abstract notation. Figure 1 is an example of an icon, a combination of symbols and what they represent.

Figure 2. A mouse, an icon representing a mouse, and the symbols in the Latin alphabet form the word "mouse".

The use of icons in education serves to bridge the gap between concrete experiences and abstract reasoning. When students first encounter mathematical concepts, introducing these concepts through icons allows them to build mental models that can later support symbolic reasoning. By connecting an intuitive, visual form with an abstract idea, icons offer a scaffold that helps learners engage with the material without being overwhelmed by the cognitive demands of processing complex symbols.

4.1.2.3.1 Iconic mathematics

Kramer (2022) pushes the idea of icons in math even further, proposing a fully iconic system for representing mathematical ideas. He argues that traditional math symbols add unnecessary mental strain, especially for learners who have issues with abstract reasoning or have cognitive styles that make working with symbols difficult, like mentalistic thinkers. Building on Bricken's earlier work, Kramer suggests that math could be represented entirely through icons, reducing or even eliminating the need for traditional symbols.

In Kramer's model, mathematical operations are shown through visual structures, like "mighty dice" and "depth-value notations," which give a more intuitive way to grasp numbers and operations. Instead of using symbols like 'x' or 'y,' Kramer uses dot patterns—similar to dice—so learners can *see* quantities without needing to interpret symbols. In Figure 2 there is an illustration of the "mighty dice" and the dots next to their symbolic equivalents; in Figure 3, addictions and subtractions using the "mighty dice".

For larger numbers, the depth-value notation uses “containers” where numbers are nested, kind of like an abacus. This setup makes it easier to understand place value, as each container shows how smaller quantities fit into larger ones (Kramer, 2022).

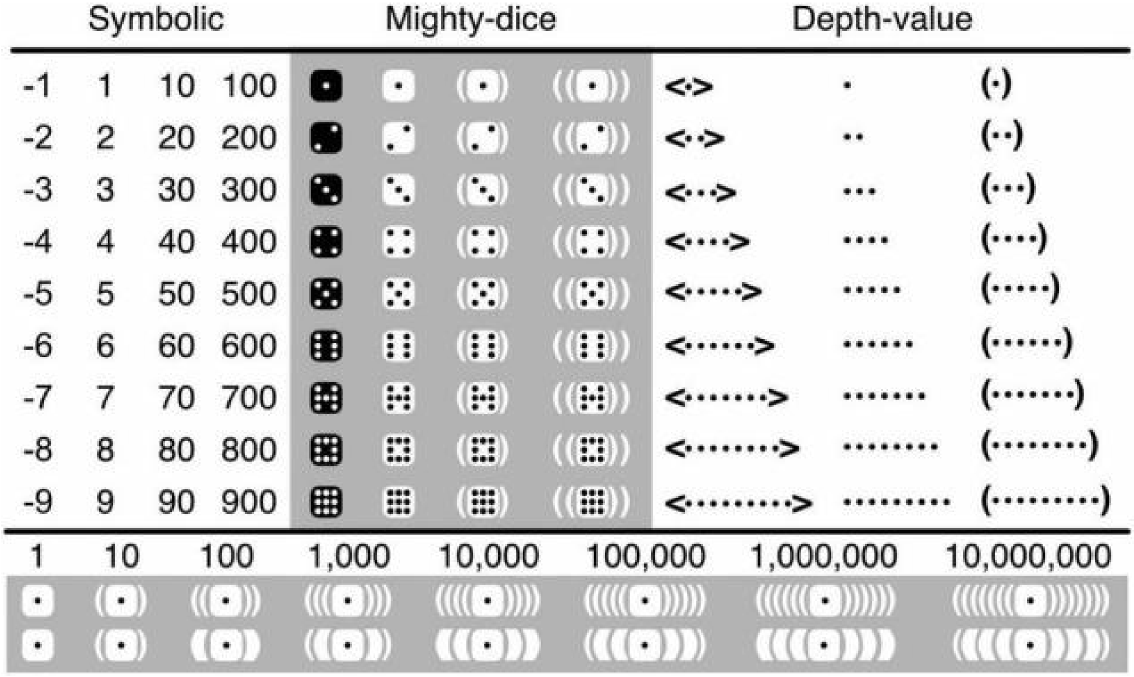


Figure 2. Symbolic numbers, "mighty dice" and depth-value dots. From Kramer (2022).

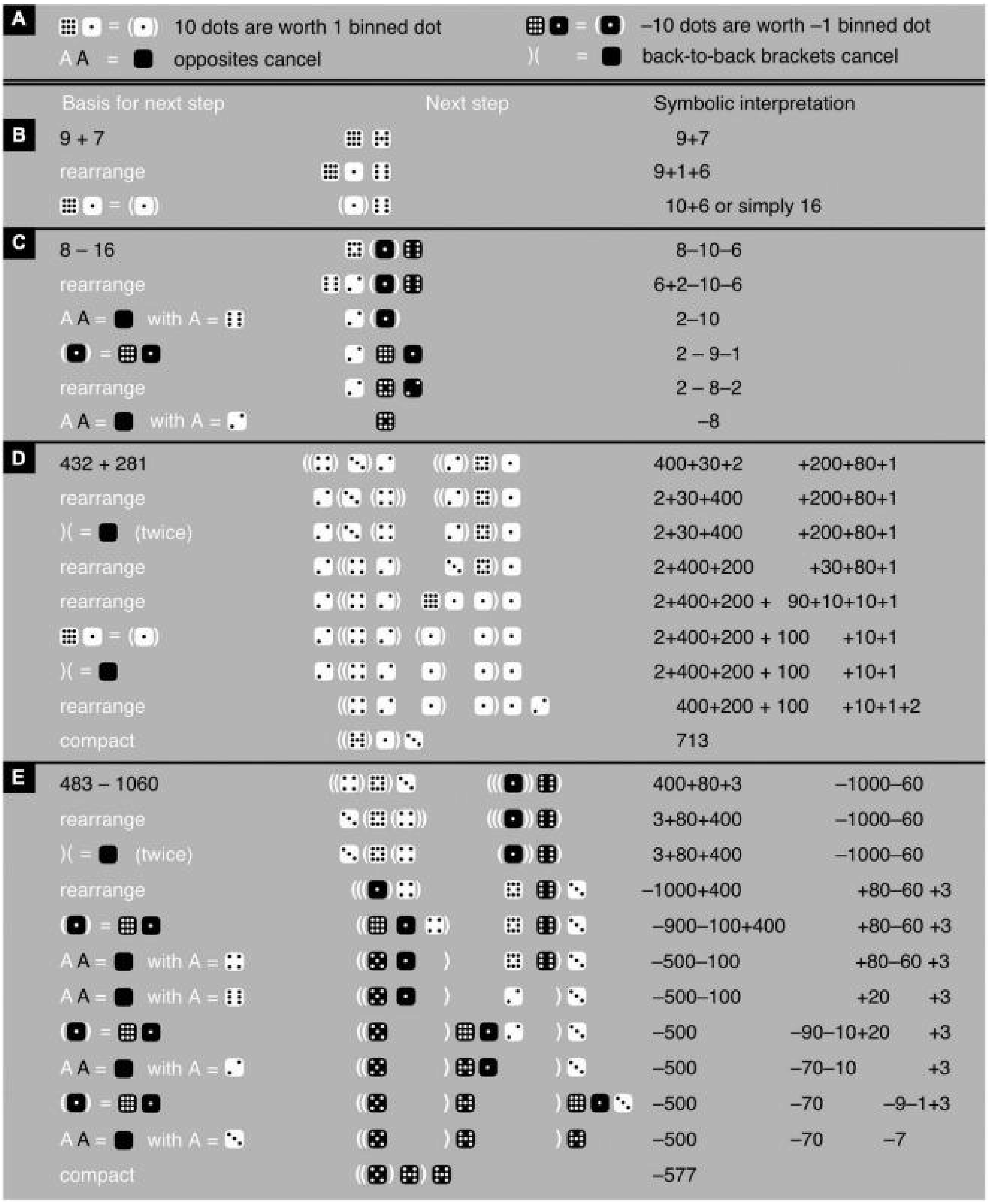


Figure 3. Addictions and subtractions in symbols and iconic "mighty dice". From Kramer (2022).

For example, addition is shown by grouping dots, while subtraction involves removing dots, making changes in quantity visually clear without needing symbols. A number like 10 could be shown as a single bead in a larger container, and subtracting would mean physically removing beads, showing a decrease in quantity similar to how we perceive it with concrete objects.

According to Kramer, this method makes math more intuitive, matching how people naturally understand quantities in the physical world. By reducing the cognitive load, this approach aims to make math more accessible to a wider range of learners. (Kramer, 2022).

4.1.2.3.2 Educational advantages of iconic representations

One of the main benefits of using an iconic approach in math is its ability to make abstract concepts more concrete and accessible to a wide range of learners. Icons serve as visual anchors, giving students a clear, concrete image that directly represents the concept being taught. This approach can be especially helpful for students with dyslexia since it reduces the need for reading and decoding complex symbols, providing a more straightforward, visual path to understanding.

Research by Tran et al. (2017) backs this up, showing that interacting physically with visual representations can improve students' conceptual understanding of math. In one study, students who used gestures or physically handled geometric shapes to model algebraic relationships performed better on later tasks requiring abstract thinking than those who learned only through symbolic methods. These results suggest that icons not only lessen cognitive load but also encourage a deeper, more instinctive understanding of mathematical principles.

Similarly, a study by Bronkhorst et al. (2021) looked at the role of visual and formal representations in the classroom. They found that students who worked with iconic representations were more successful at transitioning to symbolic reasoning compared to those who only used abstract symbols. The study pointed out the importance of allowing students time to explore and interact with visual representations before moving on to formal symbols. This gradual transition, a process called "concreteness fading," helps students develop a solid grounding in visual reasoning, which better prepares them for handling abstract symbols later (Bronkhorst et al., 2021).

4.1.2.3.3 Limitations of iconic representations

While icons in math have clear benefits, they also bring certain challenges to education. One main issue is that many teachers may not be very familiar with these alternative methods. Math education has traditionally focused on symbolic manipulation, so introducing icons would mean a significant shift in both curriculum and teacher training. Teachers might find it challenging to integrate icons effectively, especially if they lack the resources or support to learn these new tools.

Another potential drawback is that a sudden switch to iconic representations could be confusing for students who are used to symbols. If icons are introduced too quickly, they might feel unfamiliar and could lead to frustration instead of making things clearer. Bricken (2017) also points out that non-standard approaches, like those suggested by Kramer, might not fit neatly within the modern algebra framework, which could make it harder to incorporate them into the current curriculum.

There's also the risk that students might rely too much on icons, which could limit their development of symbolic reasoning skills. While icons offer a helpful foundation, they're ideally a bridge toward more abstract thinking rather than a full replacement for symbols. Bronkhorst et al. (2021) suggest that students need time and practice to connect concrete, iconic, and symbolic forms to fully understand mathematical ideas.

4.1.2.4 Enactive-Iconic-Symbolic: embodiment and icons as ladders

In contrast to Kramer (2022) and Bricken (2017), who claim that icons can work as fully independent tools for understanding math concepts, Jerome Bruner's (1966) Enactive-Iconic-Symbolic (EIS) theory sees icons as essential but still a transitional part of learning. According to Bruner, learning develops through three stages: enactive, iconic, and symbolic, each offering a different way of interacting with knowledge.

In the enactive stage, which is the most concrete, learning happens through hands-on actions with objects. For instance, when a child learns fractions, they might physically cut an apple into halves or quarters to see the fractions in real life. Teachers often use manipulatives like blocks or counters to teach basic math concepts, such as numbers or operations. These activities provide a base for more abstract thinking because they root learning in physical, and sensory experiences.

Once learners become comfortable with enactive experiences, they move to the iconic stage, where knowledge is shown through visuals like images or diagrams. Rather than cutting up objects, students might work with fraction bars or pie charts that visually represent fractions. This stage builds on the concrete understanding they gained earlier, letting students explore more complex ideas without yet needing symbols. Diagrams and graphs at this point help form a bridge to abstract thinking.

Finally, students reach the symbolic stage, where abstract symbols like numbers or algebraic expressions are used. In this stage, students would write fractions as ½ or ¼ without needing any visual aids. This level represents the highest form of abstraction, where learners use symbols to solve problems and perform advanced reasoning, skills that are crucial for higher-level math like algebra and calculus.

Bruner’s EIS model can be illustrated in how multiplication is taught. In the enactive stage, a teacher might arrange blocks in rows and columns to show "3 x 4," allowing students to count the blocks to find the total. In the iconic stage, the concept could be shown with an array of dots or pictures. Finally, in the symbolic stage, students would express this as "3 x 4 = 12," using only symbols.

In a study by Erbilgin and Gningue (2023), students’ algebra understanding was tested using pre-and post-tests, along with problem-solving exercises over five weeks. One group of sixth-grade students was guided through the enactive and iconic stages, working with physical objects and visual aids, before moving on to symbolic algebra notation. Another group went straight to symbols. The scaffolded group showed a 15% greater improvement in problem-solving skills and demonstrated a deeper understanding of algebra during classroom activities and discussions.

In another similar study, Abrahamson and Bakker (2016) looked at middle school students learning algebra through embodied gestures. Students modeled algebraic variables and equations using hand movements before switching to symbols. Analysis of video recordings and follow-up interviews showed that students who used gestures had a 20% higher success rate in solving algebra equations than those taught only with symbols. The physical representation of algebraic ideas helped students form an intuitive understanding of these abstract concepts.

4.1.2.4.1 The limitations of the linear EIS Model

While the linear EIS framework provides valuable support, it does not fully address the "four horsemen" of math anxiety: symbolic formalism, cognitive overload, test anxiety, and fear of failure. These challenges become especially noticeable when students are expected to move quickly through stages without enough flexibility or time.

Bruner’s EIS model emphasizes symbolic reasoning as the final goal, but this can become problematic for students who find abstract symbols difficult to understand. Lakoff and Núñez (2002) argue that higher-level reasoning is deeply connected to sensory experiences, meaning that many students do not fully transition from the iconic to the symbolic stage without feeling significant cognitive strain. For these students, shifting from enactive and iconic stages to symbolic reasoning creates cognitive overload, as they are expected to understand abstract relationships without the physical or visual aids they are accustomed to.

A study by Bronkhorst et al. (2021) explored this issue in a high school logic course where students were introduced to symbolic representations too early. Students who had not developed strong enactive and iconic foundations found it challenging to manage the cognitive load required for symbolic reasoning. The researchers assessed cognitive load and anxiety levels using performance tests and self-reported surveys, showing that students who transitioned to symbolic reasoning too quickly experienced higher levels of stress and cognitive overload. This demonstrates that the EIS model may not be suitable for students who need more time in the earlier stages to build strong mental models.

The shift to symbolic reasoning can provoke anxiety independently from the understanding of quantities. To explore this, Zaleznik et al. (2023) recruited 92 participants, who completed a math anxiety survey, two working memory tasks, a timed symbolic arithmetic test, and a non-symbolic "approximate arithmetic" task. The hypothesis was that, if difficulties in performing operations contribute to math anxiety, then math anxiety would correlate with both symbolic and approximate arithmetic abilities. Conversely, if math anxiety is more closely related to issues with precise or symbolic representation, then only symbolic arithmetic would show a relationship. The results demonstrated no significant link between math anxiety and the ability to perform operations with approximate quantities, indicating that perceptual arithmetic skills may not be a core number ability associated with math anxiety, but rather with the use of symbols. This study suggests that while Bruner's model is effective for some, it may lack the flexibility needed to support students who feel anxiety with symbolic reasoning.

4.1.2.5 A non-hierarchical approach to cognitive development

In Bruner's framework, symbols are viewed as the highest form of cognitive understanding, with the enactive and iconic stages serving as mere stepping stones toward this ultimate goal. Lotz, however, critiques this view, arguing that symbols are not necessarily the apex of cognitive development for all learners. Instead, his EIS-Palette promotes a non-hierarchical model, in which each stage of representation—whether enactive, iconic, or symbolic—can be valuable in its own right and can serve as the final stage for certain learners depending on their cognitive profile.

For example, students with strong visual-spatial skills may find that they can develop a deep, conceptual understanding of mathematical principles through iconic representations such as diagrams, graphs, or models, without ever needing to fully transition to symbolic manipulation. In Lotz's (2022) framework, the emphasis is not on forcing learners to abandon earlier stages but rather on empowering them to use the tools that work best for them at any given moment. This adaptability contrasts sharply with Bruner's expectation that students would leave behind the enactive and iconic stages as they advanced in their learning.

One of the most compelling classroom examples that Lotz (2022) provides is a case study in teaching algebraic equations. Rather than beginning with abstract symbols and formal notations, the teacher starts by encouraging students to physically manipulate objects that represent variables in simple equations. The students are free to move between these physical manipulations and iconic representations, such as diagrams of balance scales and drawings of matches in a box, before ever engaging with symbolic notations like "x" and "y." In Figure 3 there is an example of these exercises.

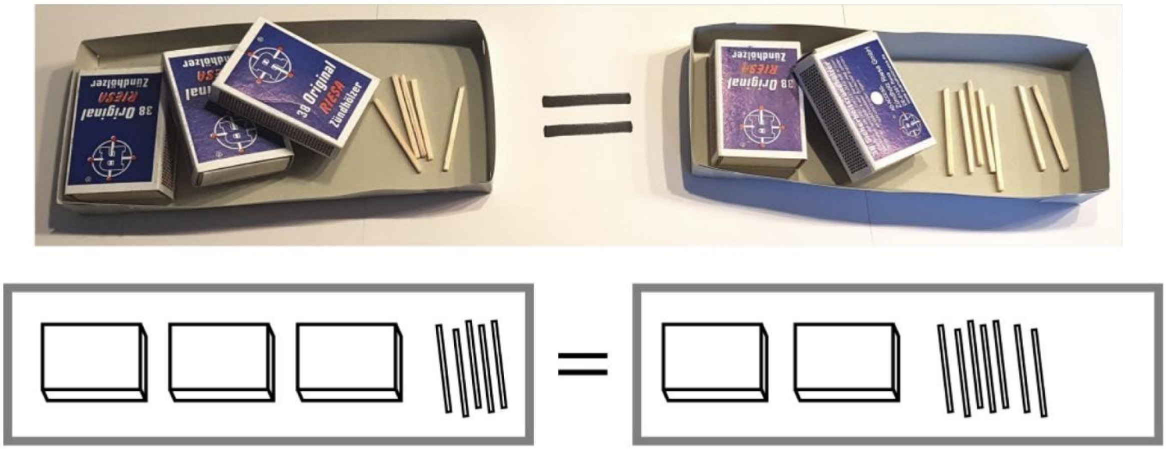


Figure 4. Matches in a box. In the EIS system, students manipulate matches in a box (embodiment) and later draw them to understand equations. From Lotz (2022).

Importantly, when students encounter difficulties with symbolic representations, they are encouraged to return to physical or iconic stages to reinforce their understanding. The flexibility of the EIS-Palette allows for this cyclical movement, whereas Bruner's model would push students toward abandoning the enactive stage entirely once they had encountered symbolic notation.

4.1.2.5.1 Embodied Cognition in the EIS-Palette

An innovation in Lotz's EIS-Palette is its deep integration of embodied cognition principles. While Bruner's model acknowledges the value of physical manipulation in the enactive stage, it treats this stage as something to be transcended. In contrast, Lotz (2022) argues that the enactive stage is not merely a precursor to abstract reasoning but an ongoing, essential part of learning that can be revisited whenever necessary. This recognition of embodied cognition as a continual resource is a significant difference between the EIS-Palette and Bruner's linear model.

For example, in Lotz's (2022) classroom-based research, students learning about trigonometric functions first explore the concepts enactively by using their arms to model the movement of angles and their bodies to represent the sides of triangles. This kinesthetic experience helps students physically understand the relationships between angles and side lengths before they encounter visual representations like unit circles and graphs, and ultimately formal symbolic expressions. The EIS-Palette allows students to move fluidly between these stages, based on their comfort and understanding, with teachers providing scaffolding as needed.

Importantly, students who find symbolic expressions like "sin(θ)" challenging are encouraged to return to earlier enactive or iconic modes whenever they feel overwhelmed. This cyclical movement is absent in Bruner's model, which aims for progression toward symbols, leaving behind physical and visual aids. By incorporating embodied cognition, Lotz's approach provides a more nuanced and flexible pathway, accommodating the natural flow of learning, rather than enforcing a strict progression toward symbolic abstraction.

4.1.2.5.2 Icons: more than just a transitional tool

In Bruner's original conception, icons were largely viewed as transitional tools—steps along the way to the mastery of symbols. The iconic stage served as a bridge between physical manipulation and abstract reasoning, with the expectation that learners would eventually leave behind visual representations as they progressed into more advanced symbolic thinking. Lotz (2022) rejects this assumption, arguing that icons can serve as endpoints for some learners, especially those who struggle with symbolic abstraction.

For instance, in a classroom study focused on teaching geometry, students were given the option to represent transformations (such as rotations and reflections) through a variety of mediums, including physical models, diagrams, and algebraic notations. While some students successfully transitioned to the symbolic stage, others found that they were able to grasp the underlying concepts just as well by sticking with visual representations such as diagrams and graphs. Rather than forcing these students to move toward symbols, Lotz's approach validated their use of iconic reasoning as a legitimate form of understanding. This is particularly beneficial for students with learning disabilities such as dyscalculia or those with little visuospatial skills who have difficulties visualizing mathematical concepts without a visual anchor.

Lotz’s (2022) case studies in teaching fractions also illustrate how the iconic stage can serve as a long-term mode of reasoning for certain learners. In this context, students were encouraged to use fraction bars and pie charts as visual representations of fractional relationships. Some students found these visual aids so effective that they were able to develop a deep understanding of fractions without ever needing to transition fully to symbolic notation (e.g., 1/2, 1/4). The flexibility of the EIS-Palette allowed these students to continue using iconic representations as their primary means of understanding, which would not have been permitted in Bruner’s model.

4.1.2.5.3 A palette of possibilities

The EIS-Palette The EIS-Palette provides a more flexible, non-linear approach to learning, which contrasts with the stricter progression in Bruner’s EIS model. Bruner’s framework suggests that learners move in a specific order—first enactive (hands-on), then iconic (visual), and finally symbolic (abstract) reasoning—with each stage acting as a step toward the next. But Lotz (2022) argues that learning is not always so straightforward and that many learners move between stages in a cyclical or non-hierarchical way.

A clear example from Lotz’s (2022) research is in teaching systems of equations. In a traditional Bruner-based class, students would start by solving equations with physical objects, then move to visual aids like graphs, and finally work with algebraic notation. In the EIS-Palette, however, students are encouraged to move back and forth between stages depending on their needs. If a student finds symbolic manipulation challenging, they can go back to working with physical objects or graphs to clarify their understanding. This back-and-forth process highlights that learning is not necessarily linear but more of a dynamic interaction between various modes of reasoning.

Lotz (2022) also notes that some students may not need to fully move on to symbolic reasoning to develop a deep understanding of certain concepts. For instance, students with strong visual-spatial skills might find systems of equations easier to work with through graphs, without needing symbolic equations. This approach differs from Bruner’s model, where symbolic reasoning is often seen as the ultimate goal. The EIS-Palette promotes an inclusive learning environment by allowing students to choose a learning path that fits their strengths instead of forcing them into a fixed order.

The EIS-Palette has been tested in classrooms with positive outcomes. For example, in a lesson on the rate of change, students began with enactive activities—physically moving objects along a track and measuring their speed. This hands-on experience gave them a concrete sense of the rate of change. Next, they created visual representations, like graphs, to show speed over time. Only after they were comfortable with these enactive and visual tools were they introduced to symbolic equations representing rates of change. If students found the symbolic forms difficult, they could return to the physical or visual models to reinforce their understanding. This flexibility is a key aspect of the EIS-Palette, which lets students move between learning modes without having to follow a strict sequence.

Another example from Lotz’s research involved teaching area and perimeter. In Figure 4 there is an example of an enactive tool used to teach the calculation of the area and perimeter of triangles.

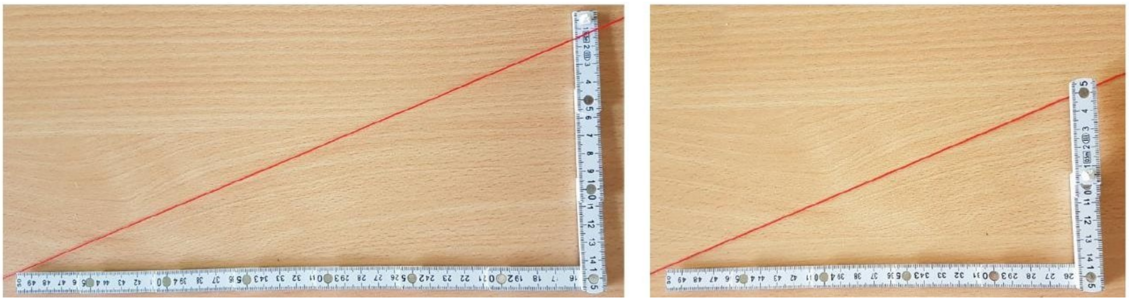


Figure 5. Triangles of different sizes to give a physical demonstration of perimeter and area measurement. From Lotz (2022).

Traditionally, students might start by physically measuring objects (enactive), move to use diagrams (iconic), and eventually learn symbolic formulas like A = l x w. In the EIS-Palette classroom, however, students who found symbolic formulas difficult were allowed to continue working with visual models and manipulatives as long as necessary. This approach helped students build a solid conceptual foundation before moving to abstract formulas. In some cases, students did not need the formulas at all, as they were able to solve problems using only visual representations.

4.1.2.5.4 Addressing the four horsemen of math anxiety with the EIS-Palette

The EIS-Palette offers an effective solution to the challenges of math anxiety, particularly by addressing the rigid linear progression that can increase anxiety for many learners. The traditional EIS model, with its focus on moving from enactive to symbolic stages, often leaves students feeling overwhelmed if they cannot progress as expected. This sense of failure can lead to anxiety and disengagement, especially when students are forced to abandon visual or physical representations prematurely.

The EIS-Palette alleviates cognitive overload by allowing students to remain in the enactive or iconic stages for as long as necessary. For those who experience cognitive strain when transitioning to symbolic notation, the option to return to visual or physical representations provides relief and ensures they are not overwhelmed by abstraction too early in the learning process.

The non-hierarchical structure of the EIS-Palette directly addresses the anxiety caused by symbolic formalism, which is often seen as the primary form of mathematical reasoning in traditional education. By recognizing icons and physical models as equally valid modes of reasoning, the EIS-Palette removes the pressure to conform to abstract symbolism, allowing students to choose the representational form that suits them best.

In traditional models, students who do not progress quickly through the stages of the EIS model may feel left behind, contributing to performance anxiety. The EIS-Palette, however, promotes individualized pacing, enabling students to spend as much time as needed in each stage, without the expectation that learning must proceed at a predetermined speed.

The flexibility of the EIS-Palette challenges traditional assessments that prioritize symbolic reasoning. By incorporating assessments that recognize multiple modes of understanding, including enactive and iconic reasoning, the EIS-Palette reduces the anxiety often associated with high-stakes testing focused solely on symbolic manipulation.

The EIS-Palette represents a significant shift in mathematical education, prioritizing flexibility, inclusivity, and student-centred learning. By rejecting the rigid linear progression of the traditional EIS model, it empowers students to navigate their learning paths in a way that suits their cognitive profiles, addressing many of the barriers that contribute to math anxiety.

4.2 Iconic language and visual novel games: images aiding communication

4.2.1 Introduction

Literature has always served a dual role: it not only helps people improve their reading skills but also allows them to step into the lives of others, fostering empathy and exposing them to different realities. However, the decrease in novel reading, often influenced by the growing use of technology, is sometimes viewed as a threat to the development of interpersonal and language skills. Additionally, new technologies are often seen as being at odds with humanistic culture, leading to a divide between digital progress and the values found in traditional literature.

But this divide does not have to exist. Rather than replacing humanistic practices, technological tools can complement and enhance them. In this chapter, various approaches that combine literature and the humanities with technology to improve social skills are explored, along with new ideas for reshaping how we write and engage with stories. While traditional literature remains a valuable tool for developing literacy and empathy, modern alternatives like iconic language systems and visual novels offer expanded access, especially for those with reading challenges or social-cognitive difficulties. These technologies can make reading easier and provide immersive, engaging storytelling experiences that combine both humanistic and digital strengths.

This chapter also examines how these tools address the limitations of traditional, text-based learning, with a focus on their potential benefits for learners with dyslexia, hyperlexia, and Theory of Mind (ToM) deficits.

4.2.2 The cognitive foundations of iconic language

Iconic language uses visual symbols, or icons, to represent concepts directly, bypassing the abstract nature of phonetic languages (Kramer, 2023). Traditional text-based systems require readers to decode symbols, like letters, to understand meaning. For individuals with phonological processing difficulties, such as dyslexic readers, this decoding process can be a real obstacle to comprehension. Iconic language offers an easier alternative by presenting information in a direct, visual way.

Kramer (2023) introduced "Icono," a language system that uses icons to represent complex ideas visually. In Figure 5 there are Icono words and their translation in the Latin alphabet.

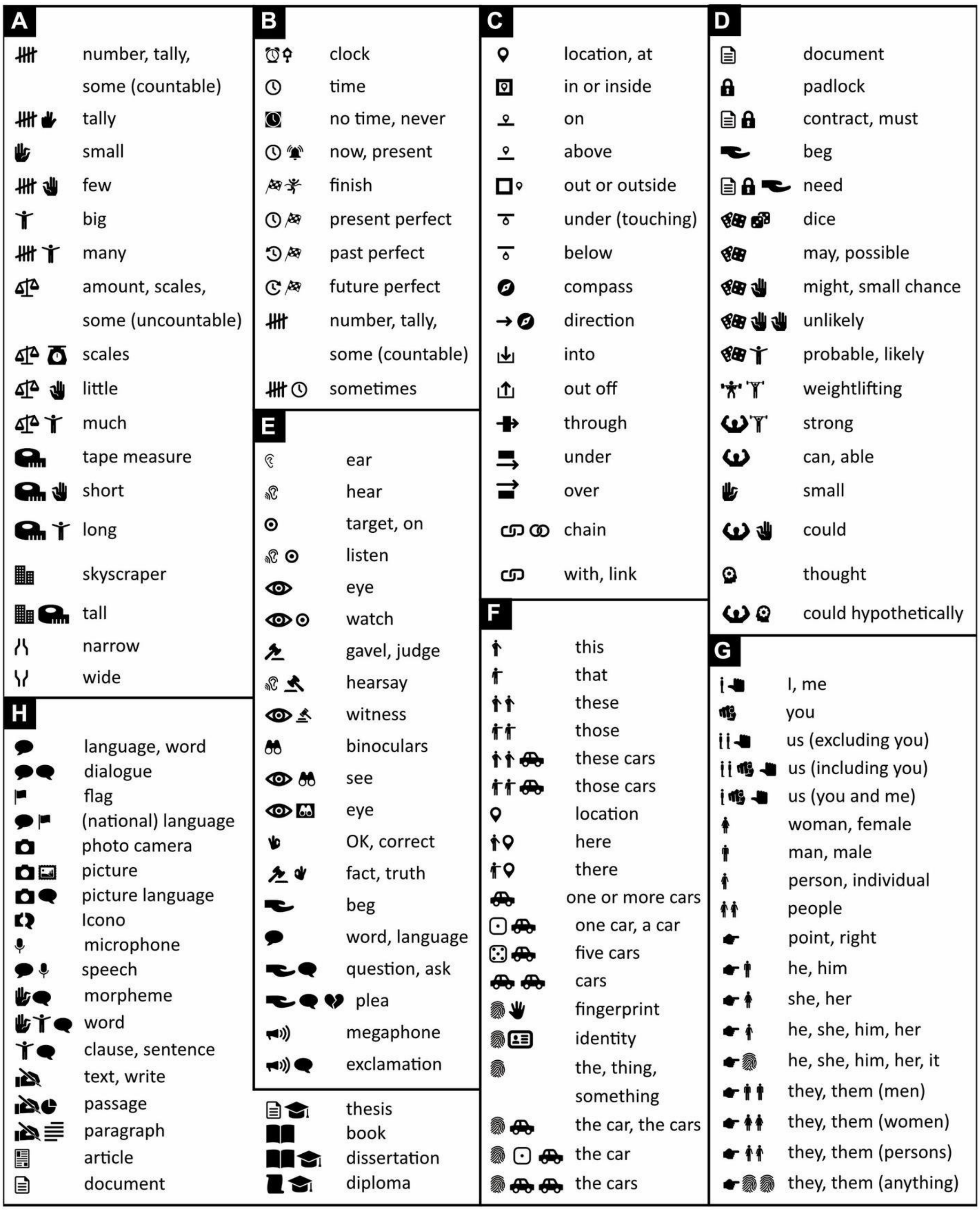


Figure 6. Common words in Icono that represent abstract concepts. From Kramer (2023).

While Kramer mainly explored the theory behind iconic language, other researchers have tested its applications. For example, Lamy et al. (2008) conducted a study in medical settings to examine the effectiveness of iconic symbols in professional communication. They split medical professionals into two groups: one used an iconic system to answer clinical questions, while the control group used traditional text. They measured both speed and accuracy in responses.

The results showed that the group using the iconic system responded almost twice as fast and with greater accuracy compared to the control group. This improvement was linked to the direct nature of the visual icons, which reduced the need for complex semantic and phonological decoding. These findings suggest that iconic systems could boost comprehension and efficiency in high-stakes settings like medicine, with potential for educational applications as well.

Sidhu et al. (2021) studied the role of iconicity in language learning. They analyzed four large datasets of speech directed at young children and the early words used by infants, focusing on words with strong links between sound and meaning, like onomatopoeic words (“buzz” or “woof”). They discovered that iconic words were more common in early language than abstract words, indicating that iconic words are easier for infants to learn. Sidhu et al. concluded that iconicity provides a cognitive bridge between language form and meaning, helping with early language acquisition. This finding has significant implications for education, suggesting that visual representations could similarly aid language learning for dyslexic learners and others who find abstract symbols challenging.

Zhao et al. (2016) tested the use of iconic language with dyslexic students. They divided students into two groups: one group used traditional text materials, while the other used materials with iconic symbols for key concepts. For several weeks, students completed reading exercises that measured fluency, comprehension, and retention. Zhao et al. found that the group using iconic materials improved by 22% in reading fluency and 30% in comprehension compared to the control group. They concluded that iconic symbols reduce cognitive load, allowing dyslexic students to focus more on understanding rather than on decoding. These results suggest that iconic language provides important cognitive support for dyslexic learners, offering them a more accessible path to literacy.

Hyperlexic learners, who often decode text at advanced levels but have trouble grasping broader context and emotional meanings, may also benefit from iconic language. In a study by Hinojosa et al. (2020), hyperlexic students read narrative texts supplemented with iconic symbols that represented social and emotional concepts. The researchers hypothesized that these visual cues would help students connect the mechanical reading process with a deeper understanding of the story's emotional elements.

Over several weeks, students completed reading comprehension tests that measured their ability to understand the emotions and motivations of characters. Results showed a 25% improvement in the group using iconic symbols. Hinojosa et al. concluded that iconic symbols helped hyperlexic learners engage with the social and emotional layers of narratives, providing a visual guide that enhanced comprehension. This study demonstrates the potential of iconic language to address not only decoding challenges but also the difficulties hyperlexic learners face in understanding social and emotional content.

4.2.2.1 Limitations of iconic language

The use of icons in language, similar to their role in mathematics, faces several challenges. Although iconic representation shows potential in supporting people with reading and language disorders, as well as aiding the general population, the idea of a widely adopted global iconic language is still a distant goal. Advances in technology, however, are making it possible to create writing systems that prioritize ease for the reader instead of the writer. This shift opens new possibilities for making written language more accessible, particularly for individuals who have difficulties with reading. Systems could be developed to simplify complex text by using icons or visual aids, making language easier to understand at a glance.

This potential has special importance in education, where the focus could shift from traditional formalism and rigid standardization to more user-friendly ways of presenting knowledge. By reducing the reliance on strictly standardized language, technology can help build flexible and accessible methods for people to engage with written content. Such approaches could help bridge gaps in learning, making both literature and mathematics more inclusive for a diverse range of learners.

4.2.3 Stories and social skills interventions

An effective approach for developing social skills, especially for children with autism, is the use of social stories. This method involves short, structured narratives that describe specific social situations like sharing, taking turns, or greeting others. In a review by Alhwaiti (2022), six studies were analyzed to see how well social stories improve communication in children with ASD. Results showed positive changes in behaviors like turn-taking, starting conversations, and staying engaged with peers. This intervention included daily, personalized social stories over several weeks, with progress tracked through observations and structured behavior analysis. Longer, more individualized approaches seemed to give the best results in social interactions.

A related study on children with high-functioning autism combined Theory of Mind (ToM) training with social skills lessons. This method was meant to help children read social cues like facial expressions and tone of voice to better understand their peers' emotions and intentions. Waugh and Peskin (2015) conducted this study over several weeks, looking for changes in social responsiveness and friendships. Observations and peer reports showed significant improvement in the children's ability to connect with peers, especially in situations that needed empathy or emotional understanding. This suggests that cognitive skills like ToM play a big part in building social connections.

Literature-based interventions also show potential for building social skills, especially when mixed with group discussions. In a study by Dogan and Kaya-Tosun (2020), literature circles were used with fourth-grade students to improve reading comprehension and peer interactions. Students discussed their reading, looking at different viewpoints and thinking about the characters' emotions and choices. Over time, both reading comprehension and peer cooperation improved, as measured by reading tests and peer interaction reports. These structured discussions allowed students to practice social behaviors such as listening actively and participating thoughtfully, bringing together social and academic learning.

Similarly, narrative-based language interventions help both language development and social skills. Spencer and Petersen (2020) studied how students improved vocabulary and grammar by telling and retelling stories, while also working on social skills like understanding inferences and social cues. This intervention included guided storytelling followed by group discussions, with improvements in language comprehension and social relations measured through pre- and post-assessments. Observations in the classroom showed that students became more comfortable in group settings, suggesting that narrative-based interventions can work well for both language and social skills.

Another helpful approach is video self-modeling combined with social stories, which has been used to improve social skills in children with autism. Litras et al. (2010) conducted a study where children were videotaped performing desired social behaviors, like starting play or responding to greetings. The children then watched these videos of themselves, reinforcing the positive behaviors. Progress was tracked through direct observation and behavior checklists, showing notable improvements in social initiations and peer interactions, especially in areas like greetings and staying socially connected. This mix of visual feedback and social stories worked well in teaching social skills through a multi-sensory approach.

In regular school settings, adding social skills training within small-group reading sessions has also worked well. Lysaker et al. (2011) studied how combining social skills lessons with guided reading sessions helped both reading comprehension and social behaviors like cooperation and communication during group activities. Students practiced literacy skills while also learning social techniques like turn-taking and active listening. Results, measured through reading assessments, teacher observations, and peer feedback, showed that students in the combined social skills and reading group did better than those in the control group, highlighting the value of merging academic and social learning.

Project-based learning (PBL) also shows good potential for improving both language and social skills. Almulla (2020) looked into how PBL encourages collaboration, communication, and academic learning through group tasks. Students worked together on projects that required both subject knowledge and problem-solving skills. Progress was tracked through self-reports, teacher evaluations, and peer assessments, showing that students involved in PBL had more positive social interactions and better communication skills. This method not only supports social growth but also helps students use their academic knowledge in real-life scenarios.

Lastly, giving students choices in reading has been linked to better social interactions and greater interest in learning content. Cambria and Guthrie (2010) examined how allowing students to choose their reading materials, combined with peer discussions, affected motivation and comprehension. Over the intervention, students who picked their books and discussed them with classmates showed big improvements in reading motivation and understanding. These gains were tracked through reading assessments and classroom observations, showing increased cooperation and closer connections with peers. Talking about shared reading experiences led to better communication skills and more engagement with both the reading material and classmates..

4.2.3.1 Addressing the limits of traditional social skills training

Traditional language and social skills development interventions have relied extensively on books and narratives, each with some limitations. While such traditional approaches are certainly valuable in teaching foundational skills, many are inadequate to address the needs of students with language-based learning disabilities or challenges related to social communication.

In this regard, the most preferred kind of training was narrative-based, in which children go through literature to enrich language and social skills. This is based on assumptions that the stories will help learners identify with the characters, understand social situations, and develop empathetic responses. While literature will indeed provide a complex and contextualized way to link learners to emotional and social content, all too often, the benefits are confined to learners who already possess the competencies in language comprehension. For example, children with autism or dyslexia may have difficulty understanding the abstract language in books and may miss the nuanced social cues or moral lessons they attempt to convey (Alhwaiti, 2022).

Besides, most conventional literature-based interventions do not consider the cognitive load created by complicated text, especially for students who cannot read easily. For example, dyslexic students can be overwhelmed by books rich in text. Berget et al. (2016) reported that dyslexic students showed a 22% increase in reading fluency when their reading was supported by some form of visual assistance, such as icons or interactive features that provide relief from the intense cognitive demands placed on readers in trouble.

Furthermore, interventions that rely solely on books to teach social skills frequently fall short because they do not offer real-time feedback in social interactions. Traditional books, though rich in content, provide only passive learning experiences. Students may read about social situations, but without the ability to actively participate or respond, they miss opportunities to practice and internalize social skills (Waugh & Peskin, 2015).

4.2.4 Visual novels: games or books?

Visual novels are a form of digital storytelling that combines written text with visuals and often sound. Unlike traditional video games, which usually focus on action or strategy, visual novels emphasize reading and making choices. The player moves through the story by reading dialogue and narrative text, occasionally making decisions that influence the plot and its outcomes.

The visuals in visual novels usually include background images and character illustrations, sometimes with animations. The player advances through the story by clicking through the text and making choices at key moments, which can change the storyline and how characters respond. Visual novels often explore themes like relationships and moral decisions, using both text and visuals to engage the reader.

One of the key advantages of visual novels is their multisensory approach to reading. By blending text, visual art, and interactive decision-making, visual novels help reduce the cognitive load involved in phonological decoding, which can be especially useful for dyslexic learners. Students with dyslexia often find the mechanics of reading challenging, especially phonological processing, which makes traditional, text-heavy learning materials less accessible (Shaywitz et al., 2021). Visual novels can help ease this burden by offering features like adjustable font sizes and text-to-speech options, allowing dyslexic learners to engage with the story at their own pace and focus more on understanding the content rather than decoding text.

For hyperlexic learners, who may be very skilled at decoding text but have trouble grasping the emotional and social sides of a narrative, visual novels provide a unique way to engage with these aspects in ways traditional text-based materials often cannot. Hyperlexia is marked by an advanced ability to decode written language, but often without the same level of comprehension, especially when it comes to understanding the emotional context of a story (Healy & , 1996). Visual novels, with their focus on character development and branching narratives, offer hyperlexic learners a structured environment where they can explore social scenarios and observe the effects of different choices.

4.2.4.1 Visual novels: playing real-life scenarios

One of the main strengths of visual novels is their interactive nature, which lets users build empathy in a safe setting. Unlike traditional reading, where readers passively follow the characters' actions, visual novels allow users to make choices for the characters and see the outcomes. This active engagement lets players explore social and emotional dynamics without real-world risks, giving them a chance to think about complex situations and learn from choices with real-time feedback in a safe space.

A study by Smith et al. (2017) looked at how visual novels might improve social understanding and empathy in people with autism. The researchers made a visual novel where players had to navigate social scenarios like conflict resolution or making decisions that impacted relationships. Participants were assessed on their ability to recognize emotions, predict behavior, and respond to social cues both before and after playing the game.

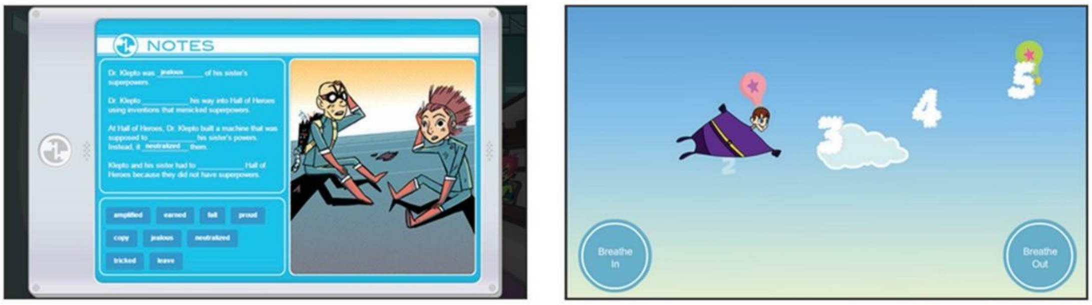
The results showed notable improvements in social understanding, with a 15% increase in recognizing social cues and a 10% boost in emotional reasoning in real-world interactions. Smith et al. attributed these gains to the game's immersive and interactive design, which let participants practice social skills in a low-stress environment. By engaging with social scenarios repeatedly and thinking about the emotional effects of their actions, participants seemed to develop a better understanding of social dynamics.

In another study, DeRosier and Thomas (2019) created *Hall of Heroes*, a superhero-themed visual novel focused on social skills training (SST). The game presented social challenges like resolving peer conflicts and working together to achieve goals.

- We could sit over there at that table. It looks...
- I think I'll go see if I can sit with...
- We could go sit with those kids I had class...
- I don't know who those two kids are over there,

(a) Simulation: players act as the director during a video shoot

(b) Dialog menu: players discuss where to sit during lunch



Dr. Klepto was jealous of his sister's superpowers.

Dr. Klepto ______ his way into Hall of Heroes using inventions that mimicked superpowers.

At Hall of Heroes, Dr. Klepto built a machine that was supposed to ______ his sister's powers. Instead, it neutralized them.

Klepto and his sister had to ______ Hall of Heroes because they did not have superpowers.

(c) Skills application: players demonstrate receptive communication in a notes-taking exercise

(d) Mini-game: players practice deep breathing techniques

Instructions

Step 1: Turn the dial right until you reach the first number of your locker combination.

Instructions

Choose the correct place to stand by dragging and dropping your character onto a circle.

(e) Practice exercise: players practice using a combination lock to open their locker

(f) Practice exercise: players choose where to stand when joining in

Figure 7. Screenshots portraying different gameplay moments and minigames from the visual novel *Hall of Heroes*. From DeRosier and Thomas (2019)

Adolescents who played the game showed significant progress in social-emotional skills, like having better relationships with peers and family members, along with lower levels of anxiety and depression. These findings highlight the potential of visual novels as good platforms for social skills training, especially for young people who may not have access to traditional SST programs due to location or financial limits.

The use of visual novels for prosocial learning has also been tried in early childhood education. Nugraha et al. (2023) developed *PROS-VN*, a digital tool designed to foster prosocial behaviors in young children. The game included story-driven scenarios that encouraged behaviors like sharing, cooperation, and empathy. Children who played the game showed clear improvements in prosocial actions, such as helping others and cooperating with peers. These results suggest that visual novels can teach social values to young children playfully and engagingly, which helps to reinforce positive social habits.

Visual novels also hold a special appeal for boys, who tend to be less drawn to traditional fiction. Research by Clark & Foster (2005) suggests that boys generally prefer interactive media and nonfiction, and visual novels provide a middle ground by combining the interactivity of games with the narrative depth of fiction. This mix makes visual novels an engaging and accessible option for developing empathy, especially for boys who might otherwise shy away from story-based learning..

4.2.4.2 Visual Novels in Educational Contexts

Visual novels offer applications beyond individual literacy and social learning, extending their use to broader educational fields. These interactive stories have been applied to teach complex subjects, from language acquisition to science education. For instance, in language learning, Lai and Chen (2021) compared virtual reality (VR) and computer-based visual novels for teaching vocabulary to second-language learners. Results showed that students who used the VR format had better vocabulary retention, indicating that the immersive qualities of VR provide a more engaging and authentic learning environment. The VR context allowed learners to practice new words within meaningful scenarios, reinforcing both understanding and memory.

In higher education, visual novels have also been used to develop scientific reasoning and analytical skills. Wong et al. (2022) integrated a visual novel into a science course to build skills such as critical thinking, hypothesis formation, and problem-solving. Through its narrative structure, the visual novel created real-life scientific challenges, encouraging students to work together and generate hypotheses. Analysis of student reflections revealed that the visual novel increased engagement and motivation in scientific reasoning, fostering both interdisciplinary thinking and collaboration.

However, visual novels face certain obstacles, particularly in mimicking realistic social interactions. Developing nuanced responses to player choices requires extensive programming and complex branching narratives, adding to both technical difficulty and development costs. Additionally, visual novels need hardware like computers or tablets, making them less accessible than traditional books. Furthermore, unless the artwork is highly detailed, facial expressions and emotional cues in visual novels may lack the subtlety necessary to convey complex emotions effectively, similar to the challenges found in descriptive text in books.

Integrating artificial intelligence (AI) presents a possible solution to these limitations. AI could help generate dynamic responses and social interactions without relying heavily on pre-written scenarios, allowing characters to react naturally to user choices. This would make visual novels more adaptable, offering varied scenarios and outcomes. AI could increase the realism and responsiveness of visual novels, creating richer social simulations that cater to individual learning needs and enhancing user engagement.

Accessibility is also improving, with many visual novels now available on smartphones and other affordable devices. Yet, most widely accessible visual novels are geared toward entertainment rather than education, limiting their potential for teaching social skills or language development. Nonetheless, as AI continues to evolve and developers create more educational content, visual novels could become powerful tools for fostering both language abilities and social skills.

AI could shift visual novels toward balancing immersive storytelling with realistic social scenarios. Currently, visual novels often follow standard plots, like the “new person in town” storyline, sometimes mixed with adventure or supernatural themes (Saito, 2021). While these plots are engaging, they usually emphasize fantasy, which may limit their utility for social skills training. AI could enable storylines with more grounded objectives, such as making friends or preparing for job interviews, while still keeping the immersive appeal. For instance, a scenario could involve a character going on a mission to gain allies in a new town, allowing users to practice persuasion, empathy, and communication in a socially relevant context. AI-driven plot adaptation would make each player's choices feel unique and tailored, offering a more authentic experience.

With AI adapting character responses in real-time, visual novels could simulate realistic social feedback, creating a valuable practice tool for users who find social interactions challenging. Players could test different approaches to building relationships and receiving feedback on their actions in a safe, engaging environment. This blend of real-life challenges and imaginative storytelling could allow users to work on social issues while enjoying the narrative experience.

Lastly, visual novels are not well-known, either as educational tools or even as a form of entertainment. Originally from Japan, the visual novels that have been translated and recognized in the West are often sci-fi, horror, or adult genres, played by a niche audience and typically created by small development teams with limited budgets. Only a small number of visual novels are geared toward younger audiences, and an even smaller fraction has an educational purpose (Saito, 2021).

For visual novels to gain the budget needed to reach the level of complexity required for educational or therapeutic use and to establish themselves as engaging educational tools, they would need increased interest from the gaming public as well as support from developers and researchers.

In conclusion, while visual novels face current limitations, advancements in AI and accessibility hold promise for transforming them into effective tools for social and language learning. When combined with emerging technologies, their interactive and immersive nature could address many of the challenges found in traditional books and current visual novels, making them a powerful resource for education.

CONCLUSION

The central focus of this thesis has been to explore the cognitive profiles of individuals who excel in both mathematical reasoning and literary expression. By understanding how these different types of thinking operate, this work aims to reimagine approaches in both mathematical and literary education. Instead of treating these cognitive abilities as separate or even conflicting, this thesis argues for a more nuanced view of how different minds interact with logic, patterns, language, and narrative. By examining the mechanisms that support success in these areas, it becomes possible to suggest educational approaches that better match these cognitive styles, creating learning environments that are both inclusive and effective.

For instance, individuals with strong mechanistic thinking profiles, such as many with autism, may excel in tasks involving logic and pattern recognition but often face challenges with social communication and literature, areas that rely heavily on emotional insight and social awareness. In contrast, students who lean toward mentalistic thinking—who are strong in empathy, social interaction, and narrative comprehension—may not struggle with abstract thinking itself but instead face challenges when dealing with rigid, rule-based systems. Traditional math education, which focuses on symbolic formalism and procedures, often feels disconnected for these learners. This disconnection doesn’t come from a lack of ability to understand abstract ideas but rather from how these subjects are presented, which may not align with a social or intuitive approach to learning.

This disconnect often leads to limiting stereotypes: students are labeled as either “math people” or “language people.” Such labels not only limit students' potential but also suggest that being strong in one area means lacking in the other. These divisions are not just a reflection of actual ability but also a result of how current educational systems fail to adapt to different cognitive styles.

To address these issues, this thesis introduces the EIS Palette as a flexible educational model, allowing students to interact with content based on their cognitive profiles. Building on Bruner’s enactive, iconic, and symbolic stages of understanding, the EIS Palette lets students move through these stages based on their learning needs. This approach is especially valuable for students who find rule-based systems challenging, as it lets them remain in the enactive or iconic stages as long as needed, bridging their natural strengths with the more abstract reasoning required later.

Embodied cognition is a key concept in this model. Research by Lakoff and Núñez (2002) suggests that even the most abstract reasoning, like mathematical thinking, is closely linked to physical experience. The brain processes concepts more effectively when it can connect them to real-world interactions. This challenges traditional math education, which often prioritizes symbolic manipulation over practical, real-life applications. By integrating physical manipulation, visual aids, and symbolic reasoning, the EIS Palette offers a learning path that aligns with natural cognitive development and allows students to understand in a way that feels intuitive.

This flexibility is particularly important for students with dyscalculia, who frequently struggle with the immediate leap to symbolic reasoning that traditional math education demands. By letting these students first explore mathematical concepts through physical and visual forms, the EIS Palette helps build understanding before transitioning to abstract symbols, potentially reducing math anxiety—a condition affecting roughly 20% of students worldwide (Luttenberger et al., 2018). This method promotes a more inclusive classroom, where all learners can engage at a comfortable pace.

The use of icons as "cognitive anchors" further strengthens the argument for adaptable educational tools. Icons offer an intuitive, visual approach to complex ideas, particularly useful for students who find abstract thinking challenging. Unlike traditional approaches that treat icons as temporary steps toward symbolic reasoning, this thesis suggests retaining icons throughout learning, especially for students who benefit from visual methods. Kramer (2022) found that icons reduce cognitive load, making it easier for students to understand relationships in math and retain information. For learners who find it hard to move from visual to symbolic reasoning, icons provide a practical alternative to abstract symbols, especially in math, where the cognitive load of symbols can often lead to frustration and disengagement.

By redefining icons as permanent tools rather than temporary aids, educators can create a more inclusive environment, allowing all students, regardless of cognitive profile, to access and work with complex ideas at their own pace.

Beyond addressing cognitive diversity in math, this thesis highlights the need for social cognition interventions, especially for mechanistic thinkers. Visual novels—interactive, narrative-driven games—are proposed as a valuable tool for enhancing social skills and empathy in students who struggle with interpersonal communication. These games provide a structured space where students can practice decision-making, interpret social cues, and navigate relationships in a low-pressure, immersive setting.

Visual novels are particularly beneficial for students on the autism spectrum, who may excel in structured systems but face difficulties with social rules and emotional understanding. By engaging with interactive narratives, students can develop Theory of Mind (ToM) skills and practice empathy in a format that is both manageable and engaging.

The multisensory nature of visual novels—combining visuals, sound, and narrative—makes them a valuable alternative to traditional, text-based learning. For students who find traditional literature overwhelming, visual novels offer a structured, flexible way to develop social cognition, bridging the gap between mechanistic and mentalistic cognitive strengths. This provides a path for students to build social skills that are useful in both academic and real-world situations.

In contrast, traditional interventions often focus on changing students' behavior or emotions without adjusting the content itself to suit different cognitive styles. Programs aimed at reducing math anxiety, stereotype interventions, and conventional social skills training tend to focus on altering how students feel about learning, rather than adapting the material to fit their cognitive strengths.

While such programs have benefits, they miss an essential point: instead of merely shifting how students feel about learning, education should focus on adapting content to be more accessible. This thesis suggests that the true solution lies in presenting material—whether in math, language, or social learning—in ways that match cognitive diversity. Mathematics, for example, does not need to rely only on abstract symbols and strict rules; it can become more accessible through icons, visual aids, and narrative elements that appeal to mentalistic learners.

Similarly, social skills do not have to be taught exclusively through conventional methods; visual novels and other interactive tools provide a more engaging way to develop empathy and social understanding. These approaches acknowledge that different cognitive profiles require varied pathways to success and focus on adapting educational content rather than forcing students into rigid learning models.

The cognitive renaissance envisioned in this thesis calls for a rethinking of how education is structured and delivered. The future of education should prioritize adapting content to meet diverse learning needs, ensuring that students encounter material in ways that align with their cognitive strengths.

This cognitive renaissance is more than a push for educational reform; it envisions an inclusive, engaging, and intellectually fulfilling learning environment. By embracing cognitive diversity and offering flexible learning paths, education can become a system that nurtures academic success and fosters social and emotional growth.

While the interventions proposed in this thesis are promising, further research is essential to assess their long-term effectiveness. Longitudinal studies could evaluate the impact of the EIS Palette, visual novels, and other multimodal learning tools across different educational levels and age groups. Effective implementation will also require thorough teacher training and institutional support, equipping educators with the tools to recognize cognitive diversity and effectively apply these methods in classrooms.

In conclusion, this thesis advocates for an education system that not only respects cognitive diversity but actively adapts to meet the needs of all learners. By embracing cognitive diversity and reshaping education to accommodate it, we pave the way for an education that celebrates the full spectrum of human potential and prepares learners for a world that demands not just knowledge, but understanding in all its richness.

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