

Inclusive Chemistry Teaching Strategies for Upper Secondary Students with Dyscalculia

A Review of Innovative Practices

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01

Specific Learning Disorders

Definition, classification & Italian legislation

What are Specific Learning Disorders?

"Specific" = affects one skill domain while leaving general intelligence intact (IQ ≥ average)



Dyslexia

Specific reading disorder (F81.0)



Dysorthographia & Dysgraphia

Writing disorders (F81.1 / F81.8)



Dyscalculia

Arithmetic skills disorder (F81.2)



Comorbidity

Mixed SLD disorder (F81.3) — most common

SLD Diagnosis: Key Criteria

Consensus Conference (AID, 2006–2007) – Discrepancy Model

Affected Ability

Performance $\leq -2SD$
below normative values
for age / grade level

General Intelligence

IQ ≥ 85
(within normal range)
not a non-specific disorder

DSM-5 Severity Levels

Mild

Some didactic measures sufficient

Moderate

Recovery & strengthening activities
needed

Severe

Intensive support required

Italian Law 170/2010: Rights & Obligations

Early Identification

Schools must report suspected SLDs to families for accredited diagnosis

Personalized Didactic Plan (PDP)

Mandatory individualized plan prepared by Class Council each year

Compensatory Tools

Right to adapted tools & dispensatory measures in all subjects

Teacher Training

Mandatory training for teachers and school leaders in SLD support

Healthcare Services

Strengthened diagnostic services for timely assessment

Protection from Exclusion

Law acknowledges risk of frustration & impact on employment

02

Dyscalculia

Neurobiological profile & impact on STEM education

Dyscalculia: Two Distinct Profiles

Neurobiological origin — affects numerical intelligence from birth

Profile A — Cognitive Structure

- Quantification & comparison mechanisms
- Mental calculation strategies
- Number sense & numerosity

Profile B — Executive Procedures

- Reading & writing numbers
- Retrieval of number facts
- Written calculation algorithms

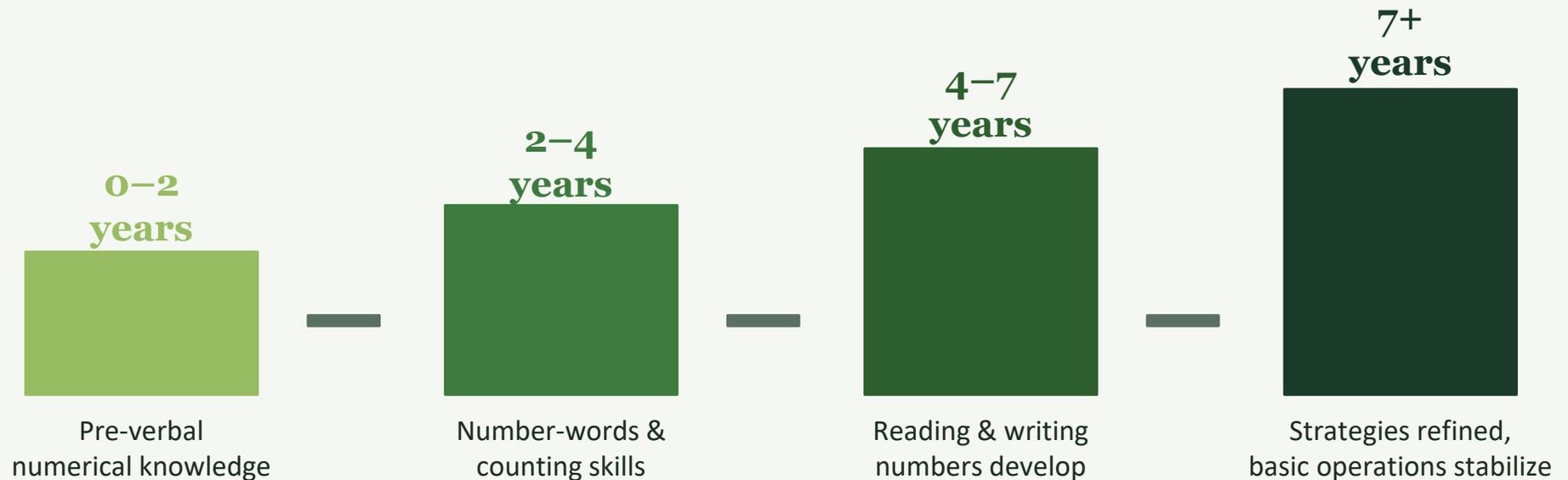
4.9%

of Italian students affected by SLDs
(2018/2019 school year — MIUR data)
Increasing trend: 2.9% (2016/17) → 6.0% (2022/23)

Development of Numerical Intelligence

People with dyscalculia tend to count in units (often on fingers) and struggle to progress beyond foundational strategies.

Common challenges: multiplication tables, carrying in division, transposing digits, unintentional misuse of arithmetic signs, inability to solve complex problems — with obvious consequences on self-esteem.



03

Dyscalculia & Mathematics

Didactic strategies, self-esteem & the low self-esteem spiral

Didactic Strategies for Mathematics

Reasoned Understanding

Avoid mnemonic learning of arithmetic;
favor conceptual reasoning over rote methods

Concrete Materials

Drawings, diagrams, graphs to make learning tangible and visual

Small Steps

Carefully structured sequences;
limit memory load; sufficient repetition

Active Participation

Games where students find their own solutions; varied methodologies

Adequate Time

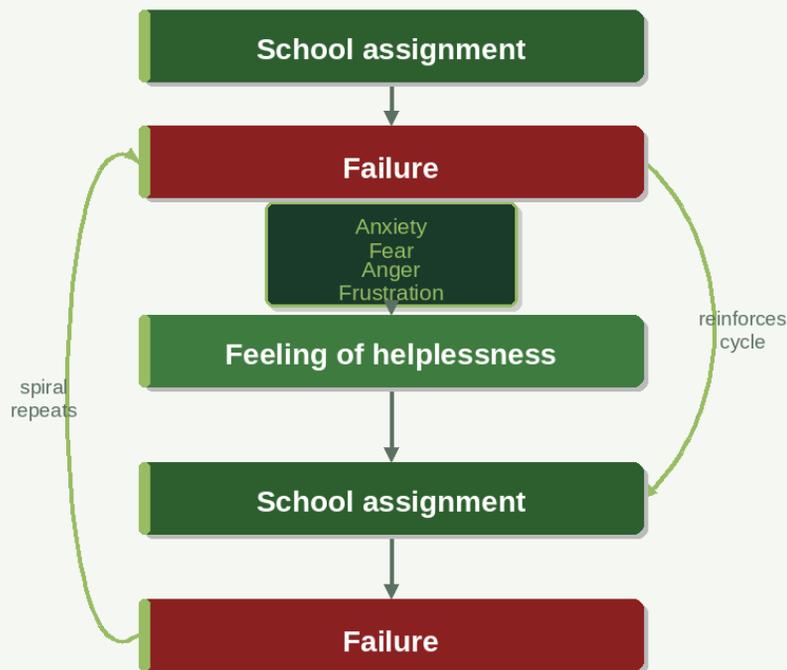
Respect individual rhythms;
flexibility in materials & strategies

Clear Instructions

No ambiguity; adapted font & spacing;
symbol meanings stated explicitly

Self-Esteem & The Low Self-Esteem Spiral

Low Self-Esteem Spiral



Adapted from Donato, C. (2014) — Scuola e Didattica

Counter-strategies

 Biographies of successful scientists with SLDs

 Neurodiversity normalization in the classroom

 Cooperative learning and peer support

 ICT tools for active and autonomous participation

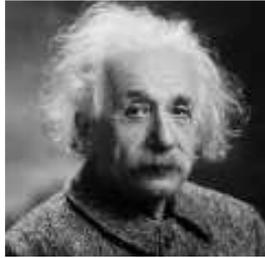
Scientists Who Overcame Learning Difficulties

Presenting these biographies counters the low self-esteem spiral and normalizes neurodiversity

Albert Einstein

Challenge: Late speech development

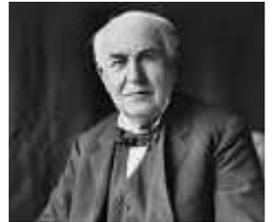
✓ Nobel Prize in Physics



Thomas Edison

Challenge: Spelling & arithmetic difficulties

✓ Inventor of the light bulb



George Gamov

His student Vera Rubin described him so: he couldn't write nor count, yet he understood the universe

✓ Pioneer astronomer



Wernher von Braun

Challenge: Severe difficulties with numbers & mathematics

✓ founder of NASA



04

Dyscalculia & Chemistry

Why chemistry is uniquely challenging — and how to teach it inclusively

Why Chemistry is Especially Challenging

Chemistry requires logical thinking, sequential learning, numerical reasoning, memory of formulas & notation

Formalism Inconsistency — A Key Barrier

Molar Mass | unit: g/mol | symbol: MM or M

Molecular Weight | unit: amu | symbol: PM or Mw

Stoichiometric calculations

Multi-step unit conversions with high memory load

Molar concept

Switching between mass, moles & molecule counts

Ambiguous formalism

Same concept, different symbols across textbooks

Sequential logic

Rules must be applied in exact order — no shortcuts

The Evidence: Kamińska-Ostęp & Gulińska (2008)

400 students (age 13–15) • ~20% with dyslexia/SLD • 4 didactic units • Two groups: Method A (inclusive) vs Method B (traditional)

Computational Chemistry

Proportion method vs equations

**+13%
for SLD
students**

efficacy gain

Chemical Experiments

Video instructions vs written

**+16%
for SLD
students**

efficacy gain

Inorganic Nomenclature

Computer games vs board games

**+12%
for SLD
students**

efficacy gain

Organic Nomenclature

Ball-and-stick models vs animated

**+16%
for SLD
students**

efficacy gain

Innovation 1: Proportion Method for Calculations

Why it works: reduces equation complexity — less working memory load for SLD students

Traditional Equation Method

Requires manipulating multiple algebraic steps simultaneously

High working memory demand

Proportion Method (Inclusive)

One step at a time using ratios:

$$A : B = C : D$$

Breaks complexity into manageable proportions

+13%

efficacy gain for SLD students

Innovation 2 & 3: Video Instructions & Manipulative Models

Video Instructions for Experiments

Why effective:
Multi-sensory input; students can
pause, rewind, repeat at own pace

*Effective for ALL students —
not just those with SLDs*

**+16% for SLD
students**

Ball-and-Stick Models for Nomenclature

Why effective:
Direct physical manipulation
outperforms animated computer models

*Promotes meaningful learning
over rote memorization*

**+16% for SLD
students**

Chemistry & Self-Esteem: Notable Scientists

Nobel laureates and leading scientists who succeeded despite — or because of — their learning differences

Carol Greider

Condition: Dyslexia

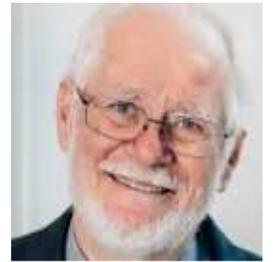
🏆 Nobel Prize — Physiology/Medicine
Discovery of telomerase



Jacques Dubochet

Condition: Dyslexia (diagnosed age 14)

🏆 Nobel Prize — Chemistry
Cryo-electron microscopy



Archer J.P. Martin

Condition: Dyslexia

🏆 Nobel Prize — Chemistry
Partition chromatography



Benjamin Franklin

Condition: Severe mathematical difficulties

🏆 Discovered electrical nature of lightning & invented lightning rod



Disabilities of scientists related with the PT

PERIODIC TABLE of the Elements

Scientists who made extraordinary discoveries — despite their disabilities

1	H																	He		
2	Li	Be											B	C	N	O	F	Ne		
3	Na	Mg													Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
6	Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Rn		
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og		

Wilhelm Bunsen
Blind in one eye

Sir Humphrey Davy
Partially blind
chronic invalid

William Wollaston
Blind — discovered Ru, Rh, Pd

Pierre Janssen
Physical disability
co-discovered He

Joseph Priestley
Speech disability

Ferdinand Reich
Colour blind
co-discovered In

Dirk Coster
Progressive spinal disease

Anders Ekeberg
Deaf, blind in one eye

Eugène Demarçay
Blind in one eye

58	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	112	113

Karl von Welsbach Auer
Hard of hearing

Georges Urbain
Hearing impairment

LEGEND

- Mg** = scientist with disability
- Al** = other element
- Orange box** = group of co-discoverers

Source: Lang & Perkins (2001)
National Technical Institute for the Deaf

05

Inclusive Textbooks & ICT

Zanichelli's approach and the role of technology

Zanichelli: "Chimica: molecole in movimento"

Valitutti et al., 2022 — 2nd edition — uniquely designed with an inclusive approach

Main Text

~25 pages on the mole
Extensive explanations
& exercises



Lab Book

Hands-on experiments
adapted for inclusive
pedagogy

Idee per imparare

7 pages on the mole
Diagrams, mind maps,
visual examples
SLD-optimized



Key Inclusive Features of "Idee per imparare"

- Larger font size for readability
- Concept-activating maps at start of each chapter
- Guided exercises with explicit step-by-step instructions
- Color-coded units of measurement
- Everyday analogies (eggs → Avogadro's number)
- Summary concept maps at end of each chapter

Zanichelli: "Chimica: molecole in movimento"

Valitutti et al., 2022 — 2nd edition — uniquely designed with an inclusive approach

6 CAPITOLO
La quantità di sostanza in moli

L'ATOMO

- ha una massa
- possiamo stabilire la sua massa
- se usiamo grandi quantità di materia, possiamo stabilire la sua massa

COSA TROVERAI NEL CAPITOLO

- La massa atomica
- La massa atomica relativa
- La mole
- La massa molare

GUARDA!

Possiamo misurare la massa di un atomo?

Misurare la massa di un atomo è impossibile, perché è troppo piccola per fare misurazioni dirette: NON esiste una bilancia che possa rilevare la massa di un atomo!

Come misuriamo «per confronto»?

Possiamo stabilire la massa di un atomo solo in modo indiretto: «ricorriamo» la massa atomica relativa di un atomo per confronto con la massa di un atomo di riferimento, che conosciamo. Facciamo un esempio. Dobbiamo conoscere la massa dell'uovo piccolo nella foto.

L'uovo di gallina è la nostra massa di riferimento conosciuta. Dobbiamo calcolare quante volte la massa dell'uovo piccolo «pesa» rispetto alla massa dell'uovo di gallina. Grazie al principio di Avogadro, possiamo scoprire quanti atomi ci sono in una quantità di sostanza che possiamo pesare con una bilancia. Questa regola ci serve per fare le nostre misure indirette perché possiamo confrontare tra loro porzioni grandi di materia.

Dividiamo la massa di una quantità di sostanza per il numero di atomi che contiene: così stabiliamo la massa di un singolo atomo.

Cosa è la mole?

In laboratorio, è scomodo usare una unità di misura piccola come l'unità di massa atomica (così come è scomodo usare i millimetri per misurare la distanza dalla Terra alla Luna).

Per risolvere questo problema, usiamo un'unità di misura che ci permetta di stabilire un collegamento tra il mondo macroscopico e quello microscopico, cioè tra ciò che vediamo (un campione di materia abbastanza grande) e ciò che è talmente piccolo che non possiamo vederlo (gli atomi). Questa unità di misura è la mole.

La mole (simbolo mol) è l'unità di misura della quantità di sostanza, che contiene un numero di particelle uguali al numero di atomi presenti in 12 grammi di carbonio-12.

La mole è una delle sette unità di misura fondamentali del SI.

Una mole di alcune sostanze. Una mole di ogni sostanza ha lo stesso numero di particelle, anche se il volume è diverso.

RICORDA!

La mole, come altre unità di misura, indica sempre lo stesso numero di particelle (atomiche o molecolari), così come per esempio la decina indica sempre 12 unità (come 12 uova), o il paio indica 2 unità (come un paio di calze).

Quante sono le particelle contenute in una mole?

Ricorriamo il dato con questa formula:

$$1\text{g mol}^{-1} = 6,022 \cdot 10^{23} \text{ mol}^{-1} = N_A = \text{costante di Avogadro}$$

$$1,661 \cdot 10^{-27} \text{g}$$

La costante di Avogadro (N_A) è un numero di particelle diviso per una quantità di sostanza. È un numero enorme.

Una mole di qualsiasi sostanza contiene sempre $6,022 \cdot 10^{23}$ mol⁻¹ particelle (che possono essere atomi, molecole o ioni).

Per esempio, una mole di...	corrisponde a...	... e contiene:
H	1,008 g	$6,022 \cdot 10^{23}$ atomi di H
O ₂	32,00 g	$6,022 \cdot 10^{23}$ molecole di O ₂
Na ⁺	22,99 g	$6,022 \cdot 10^{23}$ ioni di Na ⁺

Come possiamo convertire in moli la massa in grammi?

Se di una sostanza dividiamo la massa del campione, m , per la massa molare, M , di quella sostanza otteniamo la quantità di sostanza in moli, n :

$$n = \frac{m}{M}$$

massa del campione (g) / massa molare (g/mol) = quantità di sostanza in moli (mol)

MASSA DEGLI ATOMI

MASSA ATOMICA RELATIVA (MA)

MA = $\frac{\text{massa di un atomo (g)}}{\text{unità di massa atomica (g)}}$
= numero adimensionale

UNITÀ DI MASSA ATOMICA (u)

u = 1/12 della massa di ¹²C = $1,661 \cdot 10^{-24}$ g
valore scelto come riferimento

MA u = massa di un solo atomo (in grammi)

MASSA MOLECOLARE (MM)

somma delle masse atomiche

MOLE (mol)

quantità di sostanza che contiene lo stesso numero di atomi presenti in 12 g di ¹²C

$6,022 \cdot 10^{23} = N_A$ (costante di Avogadro), numero di particelle contenute in una mole

serve per esprimere

MASSA MOLARE (M)

uguale alla MA o MM espressa in g/mol

massa di una mole di particelle

NH_3

$14,01 + 3 \times 1,008$

$MM = 17,03$ $M = 17,03 \text{ g/mol}$

RIPASSA

- Scegli la risposta corretta.
 - La mole è l'unità di misura:
 - della quantità di sostanza
 - dell'atomo
 - delle molecole
 - Esprimiamo la massa molare di un elemento:
 - in unità di massa atomica
 - in grammi/mole (g/mol)
 - in adimensionali
 - La costante di Avogadro esprime:
 - un numero piccolo;
 - sempre 1 o 2
 - un numero enorme

Una mole di palline da baseball occupa lo stesso volume della Terra.

Key Inclusive Features of "Idee per imparare"

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- Summary concept maps at end of each chapter

06

Conclusions & Recommendations

Bridging research-practice divides in inclusive science education

Key Findings

Chemistry teaching for students with dyscalculia requires an evolution of methodologies — not a revolution of content

Proportion method

+13% efficacy vs equations for SLD students in computational chemistry

Video instructions

+16% efficacy vs written instructions for lab experiments

Computer games

+12% efficacy vs board games for inorganic nomenclature

Ball-and-stick models

+16% efficacy vs animated models for organic nomenclature

Inclusive textbooks

Color-coding, larger fonts, concept maps & everyday analogies reduce cognitive load

Self-esteem interventions

Biographies of scientists with SLDs counter the low self-esteem spiral

Recommendations & Research Gaps

Recommendations

1. Teacher training in multisensory pedagogies for secondary STEM
2. Policy advocacy for equitable access to STEM subjects
3. Systematic use of PDPs with chemistry-specific adaptations
4. Integration of ICT tools as standard inclusive practice

Research Gaps

- ⚠️ Few studies on dyscalculia in upper secondary chemistry
- ⚠️ Most research focuses on primary mathematics
- ⚠️ Limited chemistry-specific SLD interventions
- ⚠️ Need for longitudinal efficacy studies in STEM

Thank You

"Teaching chemistry for students with dyscalculia does not require a revolution of content, but an evolution of methodologies."

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