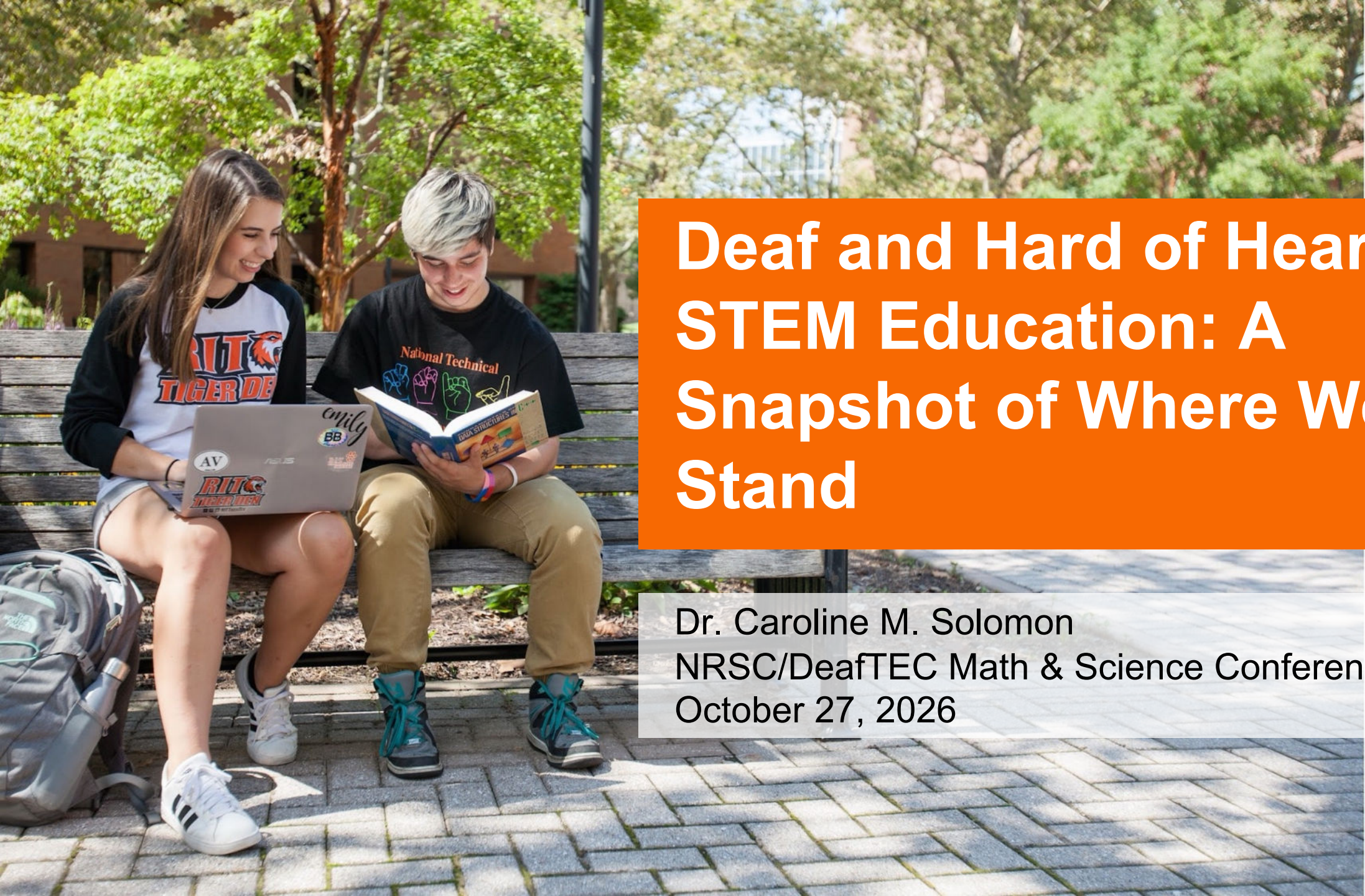
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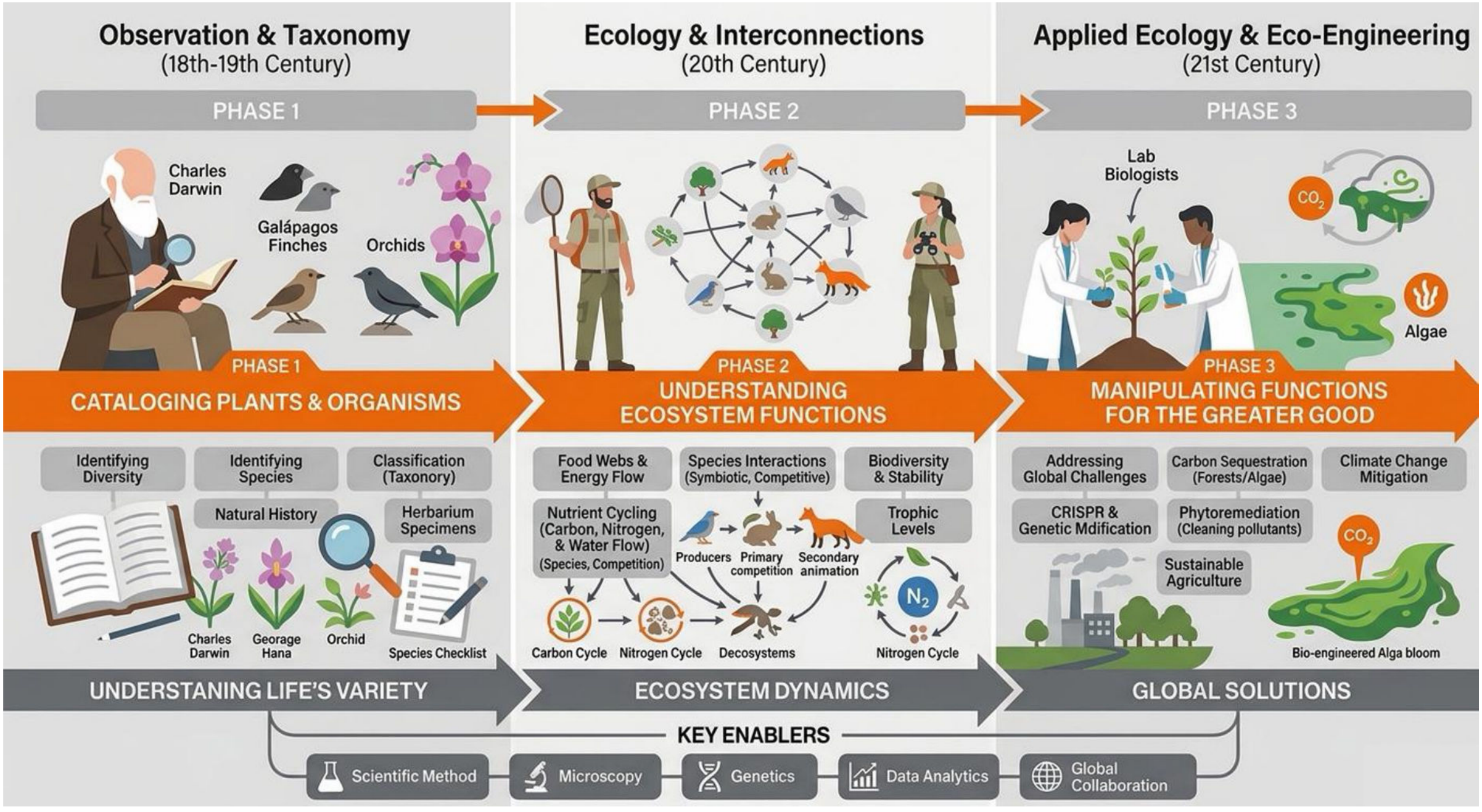


Deaf and Hard of Hearing STEM Education: A Snapshot of Where We Stand

Dr. Caroline M. Solomon

NRSC/DeafTEC Math & Science Conference

October 27, 2026


Observation & Taxonomy
(18th-19th Century)
Ecology & Interconnections
(20th Century)
Applied Ecology & Eco-Engineering
(21st Century)
PHASE 1
PHASE 2
PHASE 3
Charles Darwin
Galápagos Finches
Orchids
Lab Biologists
CO2
Algae
PHASE 1
CATALOGING PLANTS & ORGANISMS
PHASE 2
UNDERSTANDING ECOSYSTEM FUNCTIONS
PHASE 3
MANIPULATING FUNCTIONS FOR THE GREATER GOOD
Identifying Diversity
Identifying Species
Classification (Taxonory)
Natural History
Herbarium Specimens
Charles Darwin
Georage Hana
Orchid
Species Checklist
Food Webs & Energy Flow
Species Interactions (Symbiotic, Competitive)
Biodiversity & Stability
Nutrient Cycling (Carbon, Nitrogen, & Water Flow)
(Species, Competition)
Trophic Levels
Producers
Primary competition
Secondary animation
Carbon Cycle
Nitrogen Cycle
Decosystems
N2
Nitrogen Cycle
Addressing Global Challenges
Carbon Sequestration (Forests/Algae)
Climate Change Mitigation
CRISPR & Genetic Mdification
Phytoremediation (Cleaning pollutants)
Sustainable Agriculture
CO2
Bio-engineered Alga bloom
UNDERSTANING LIFE'S VARIETY
ECOSYSTEM DYNAMICS
GLOBAL SOLUTIONS
KEY ENABLERS
Scientific Method
Microscopy
Genetics
Data Analytics
Global Collaboration

EVOLUTION OF MINDSET IN DEAF STEM EDUCATION RESEARCH

ERA 1: PRE-2000 EVIDENCE BASED RESEARCH



Documenting deficits and gaps

- Educational research focused on basic literacy, language, and English development
- Limited scholarship on deaf STEM education
- Students steered toward hands-on STEM disciplines

ERA 2: 2000–2020 EXAMINING SOLUTIONS TO ADDRESS DEFICITS AND GAPS



Enhancing STEM sign language vocabulary, increasing exposure to STEM, and promoting visual learning

- Solving sign language lexicon gap
- Broadening Participation Programs
- Shift to Inclusive Visual Pedagogy

ERA 3: POST-2020 DEAF-LED INNOVATION IN PEDAGOGY AND INSIGHTS FROM COGNITION



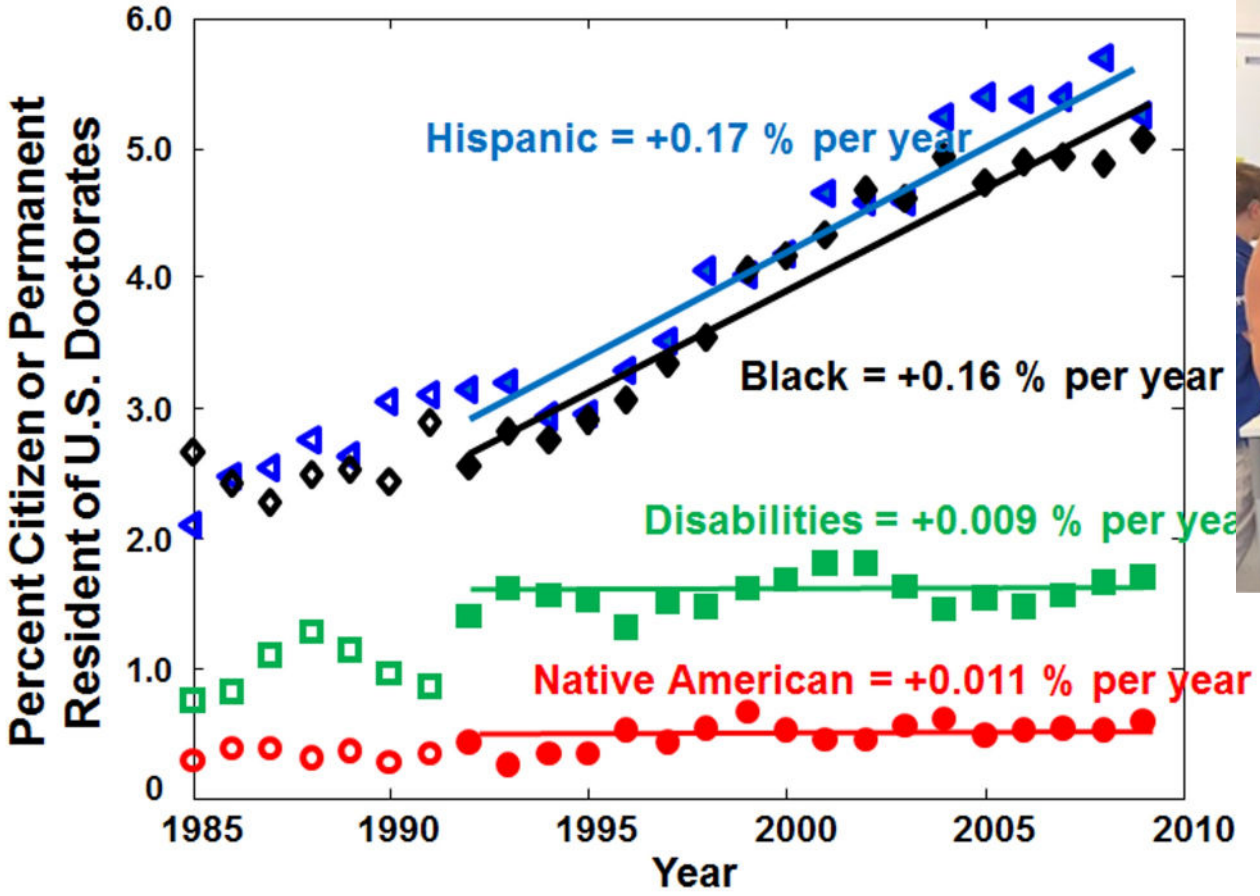
- Deaf Gain & Asset-Based Models
- Global STEM Sign Language and STEMist Collaborations
- Harnessing AI

2000 2020

Pre-2000: Evidence-based research

- Educational research focused heavily on basic literacy, language acquisition, and spoken/written English rather than higher-level critical thinking and analytical reasoning required for STEM (reviewed in C. Kurz, 2006, 2014; Hrastinksi & Wilbur 2016, Marschark & Hauser 2008, 2012)
- Math & Numeracy (Pagliaro 1998, Pagilaro & Marcshark 2010, Pagliaro and Kritzer 2013)
- Early days of deaf STEM education research (Lang 1994, 2002, Marschark, Lang & Albertini 2001)

Modest growth in STEMists with disabilities







The number of DHH aquatic scientists has grown from 3 in 2006 to at least 10 worldwide in 2026.

2000-2020: Examining Solutions to Address Deficits and Gaps

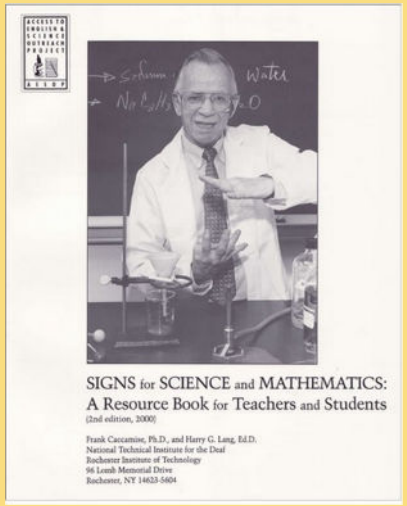
- Growth of DHH STEMists
- Establishment of STEM Sign Language Lexicons (Science Sign Dictionary, Lang et al. 2007; ASL-STEM, Bingham et al. 2008, Cavender et al, 2010; ASL Clear, Reis et al. 2015, Kurz et al. 2020; ASL-CORE; SLICE, Clark et al. 2022)
- Focus on what is happening in the classroom (Kurz et al. 2015, Cameron et al. 2017, Long and Kowalske, 2022, Sarchet-Maher et al. 2026)
- Emphasis on mentoring (Listman, 2013, Listman & Dingus-Eason, 2018, Braun et al., 2016), access (Braun et al. 2018,) and belonging (Gormally & Marchut 2017, Majocha et al. 2018, Renken et al. 2021, Harsh et al. 2025)

Timeline of STEM Sign Lexicons

1970 – 1980s

NTID Technical Signs Project

Videotapes and books (2,200 signs)



1990 – 2000

NTID Science Signs Lexicon

Was developed with the support of three NSF grants to Harry Lang

2000 – 2020

Explosion of STEM Sign Lexicons

TERC/Vcom3D (Vesel)

ASL-STEM (University of Washington)

ASLCORE (NTID)

Texas Math Sign Dictionary (TSD Outreach)

> 2020

Interactions of Deaf STEMists

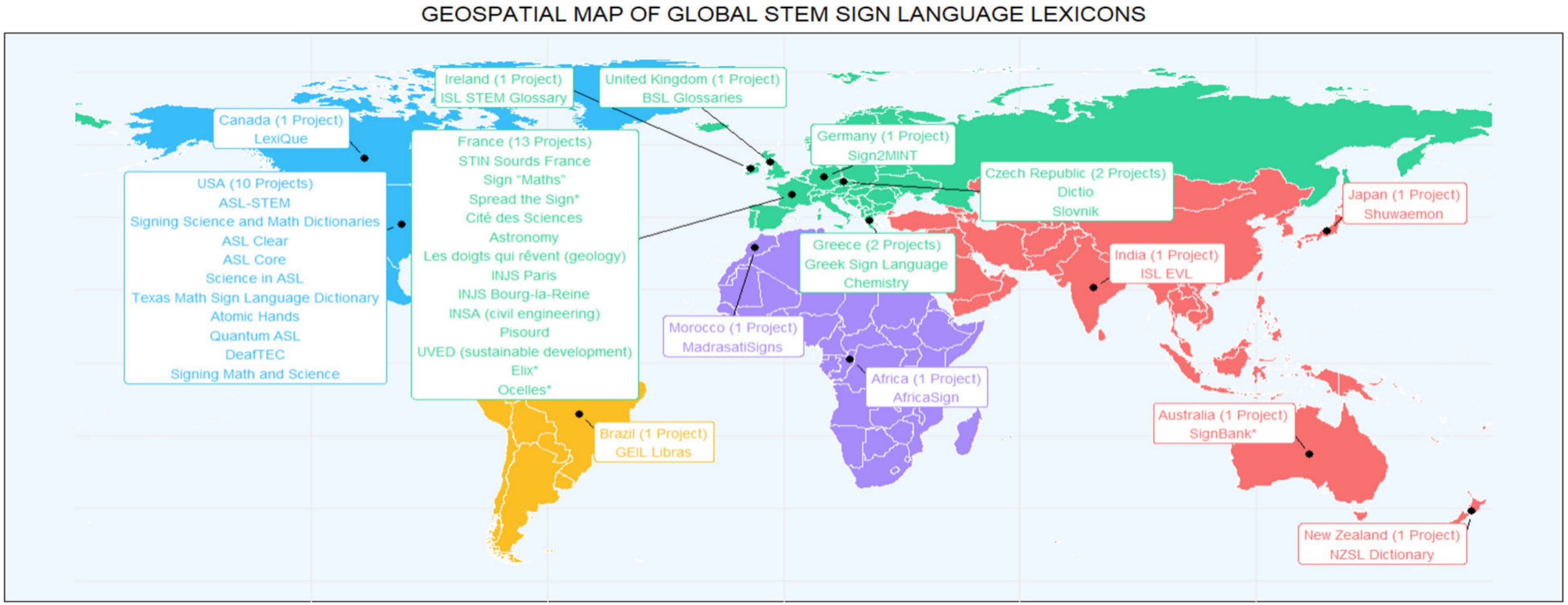
More DHH doctoral students worldwide

Deaf Academics

2023 Global Year of STEM Sign Language Lexicons

Atomic Hands

Explosion of STEM sign language lexicons

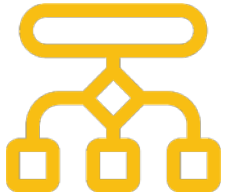


Spatial distribution of STEM Sign Language dictionaries, repositories, and educational projects across geographic coordinates

Taking a look at STEM sign language lexicons brought up questions:



Ethical Considerations



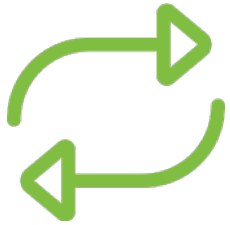
Lexicon Development



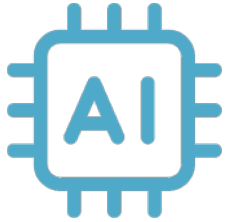
In the Classroom



Multilingual approach



Gaps in Sustainability



Future Technology

Three main areas of discussion emerged:



Ethical Considerations

1. Who develops them?
2. Who decides?



Lexicon Development

1. What is validation?
2. Is standardization okay in some cases?
3. Differences in corpus, lexicon and dictionary



In the Classroom

1. Are there any studies that assess student learning using the signs?
2. Is iconicity so important?

First consideration: Ethics

1. Who develops the lexicons?
2. Who qualifies as a subject matter expert (SME)?
3. Who decides?



INTERPRETERS



DEAF-LED

Signing Math & Science

HEARING EDUCATORS OF THE DEAF OR LINGUISTS



DEAF SME (subject matter experts) TEAMS LED BY CODAS OR ALLIES OF THE DEAF COMMUNITY

Second consideration: **Validation & Standarization**

Linguist's perspective: If a sign enters common use, whether it is 'conceptually correct' or not then it is valid (e.g. covid)

Scientist's perspective: If a sign is vetted by a focus group of educators, scientists, interpreters and other relevant stakeholders then it is valid.

Second consideration: Validation & **Standarization**

1. Do students learn the best if a school or program agree on the same signs?
2. Should some terms that are already universal such as the metric system and some prefixes (ß, μ, Δ) and the periodic table have standard signs worldwide?

Conceptually correct signs

A linguist once asked a group of deaf scientists, *"Why are you so obsessed with creating conceptually correct signs?"*

1. Sociocultural aspect (e.g. Inuits have many terms to define different kinds of snow)
2. Phonological-morphological inventory and rules
3. Iconcity

Third consideration: What do we know about effectiveness and integration of STEM lexicons in the classroom?

Not much.

Vesel and Robillard 2013, Vesel 2016, Cameron et al. 2017, Enderle et al. 2020, Clark et al. 2022, Sortino et al. 2026

World view

https://doi.org/10.1038/s41562-024-01993-7

Challenges in developing STEM sign language for inclusive education



By Caroline M. Solomon

Check for updates

Caroline Solomon is a biological oceanographer and deaf. She discusses how STEM sign lexicon development contributes to inclusive education and which challenges still need to be overcome.

What can be done to make science more accessible to deaf and hard-of-hearing children and to open opportunities for aspiring and current scientists? Part of the answer lies in the development of STEM (science, technology, engineering and mathematics) sign language lexicons, the dictionaries and tools that translate verbal sci-

Global Year of STEM Sign Language Lexicons, much like the International Year of the Ocean or International Year for Basic Sciences for Sustainable Development. We held a series of meetings across the world to discuss the practical and ethical issues regarding STEM sign language development and its effect on education.

One issue that was frequently raised was the composition and methods of the groups who develop the lexicons. If deaf stakeholders are not prominent in the development of the resource, there will be no buy-in from the community as its members question the reliability of the resources. Moving forward, it needs to be recognized that deaf scientists, educators and interpreters must be at the bedrock of these efforts as leaders and

kindergarten-to-12th grade (K–12; 5 to 18 years old) educational settings. Here tools are urgently needed. A recent study that investigated whether sufficient American sign language signs exist to help K–12 educators apply science and engineering practices and nature of science in the next-generation science standards found that STEM dictionaries are lacking. The next-generation science standards framework presents an area of opportunity in inclusive education as more American sign language STEM signs are developed within this framework geared to the conceptual capabilities of different grade levels[2]. It is a model that might serve as an inspiration for initiatives worldwide.

The development of STEM sign lexicons posi-

>2020: Deaf-Led Innovation in Pedagogy and Insights from Cognition

- **Global STEM Sign Language Networking:** 2023 Global Year of STEM Sign Language Lexicons
- **Translanguaging:** Using multiple languages and modalities to foster learning (Scott and Cohen, 2023, Scott et al. 2025)
- **Visual Learning:** Capitalizing on STEM signs to bring distinct visual-spatial perspectives to lab environments, molecular modeling, pattern recognition, and scientific communication (Laudi et al. 2023).

>2020: Insights from Cognition

- **Numeracy & Cognition:** Early access to visual language leads to stronger foundation in numeracy/number concept development; subtle differences in DHH and hearing learners in neutral networks when solving mathematical problems (Berteletti et al. 2021, 2022, 2024, 2026; Langdon et al. 2023, Coppola et al. 2026, Blatto-Vallee, 2026)

What should we be asking ourselves? Where are we going?

- **How does the STEM sign language lexicons align with Next Generation Science Standards (NGSS)? Standarized testing?** (Enderle et al. 2019; Cohen 2025)

An analysis of 6 STEM Sign Resources for 74 target STEM terms (Enderle et al. 2019)

TABLE 3 Quantitative description of data set for science-specific ASL signs

Resources (see Table 1)	Res. #1	Res. #2	Res. #3	Res. #4	Res. #5	Res. #6	Res. #7	Res. #8
Total # of terms in the sources	581	7,377	193	2,100	375	3,265	95	604
# of search terms present	15	29	8	27	2	31	7	18
% presence of search terms in resource	2.58%	0.39%	4.15%	1.29%	0.53%	0.95%	7.37%	2.98%
# fingerspelled	2	3	0	2	1	1	0	2
# Lay term	8	17	7	16	0	17	6	7

What should we be asking ourselves? Where are we going?

- **How are the STEM signs used in the classroom? Does it improve STEM learning? How can we use them to scaffold concepts over different grade levels?** (Clark et al. 2022, Sortino et al. 2026)

Concept-based STEM signs enhance learning

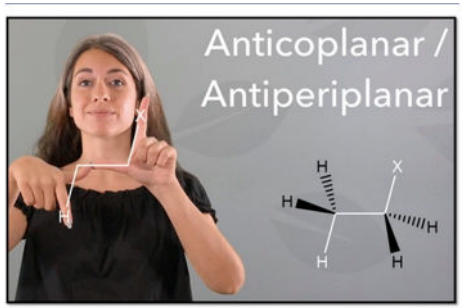


Figure 2. Descriptive sign showing the sign for "anticoplanar".

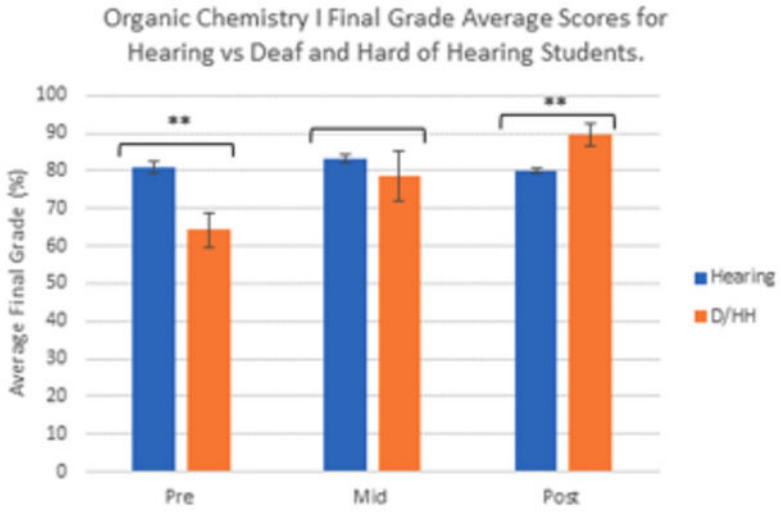
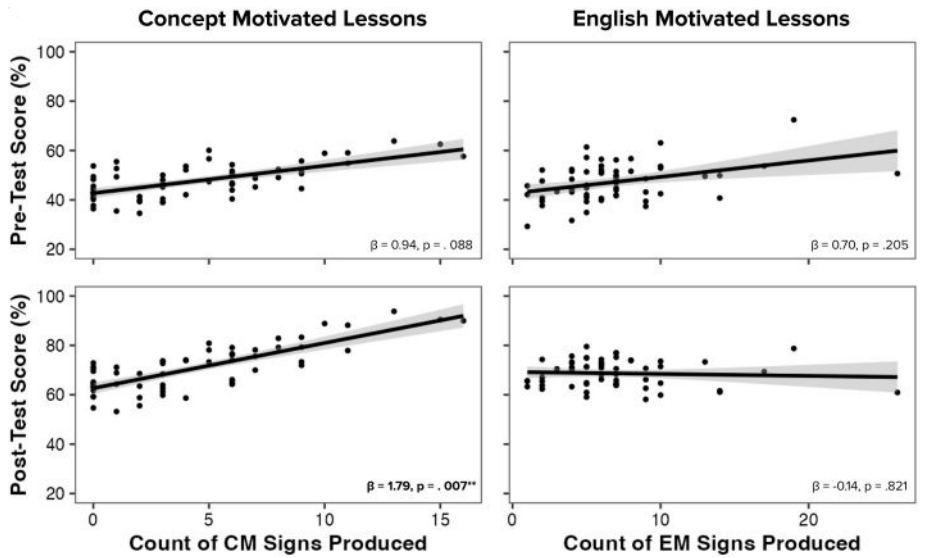


Figure 6. Final grade averages (%) by academic cohort in the first semester of organic chemistry for hearing students and D/HH students requiring an interpreter in the same course. *P*-Values are denoted using *<0.05, **<0.01, ***<0.005.

Clark et al. 2022





Sortino et al. 2026

What should we be asking ourselves? Where are we going?

- **How to provide children with early access to visual language to support numeracy? What is the connection between language and cognition?** (Berteletti et al. 2026, Coppola et al. 2026, Blatto-Vallee, 2026)

Early exposure to visual language increases numeracy

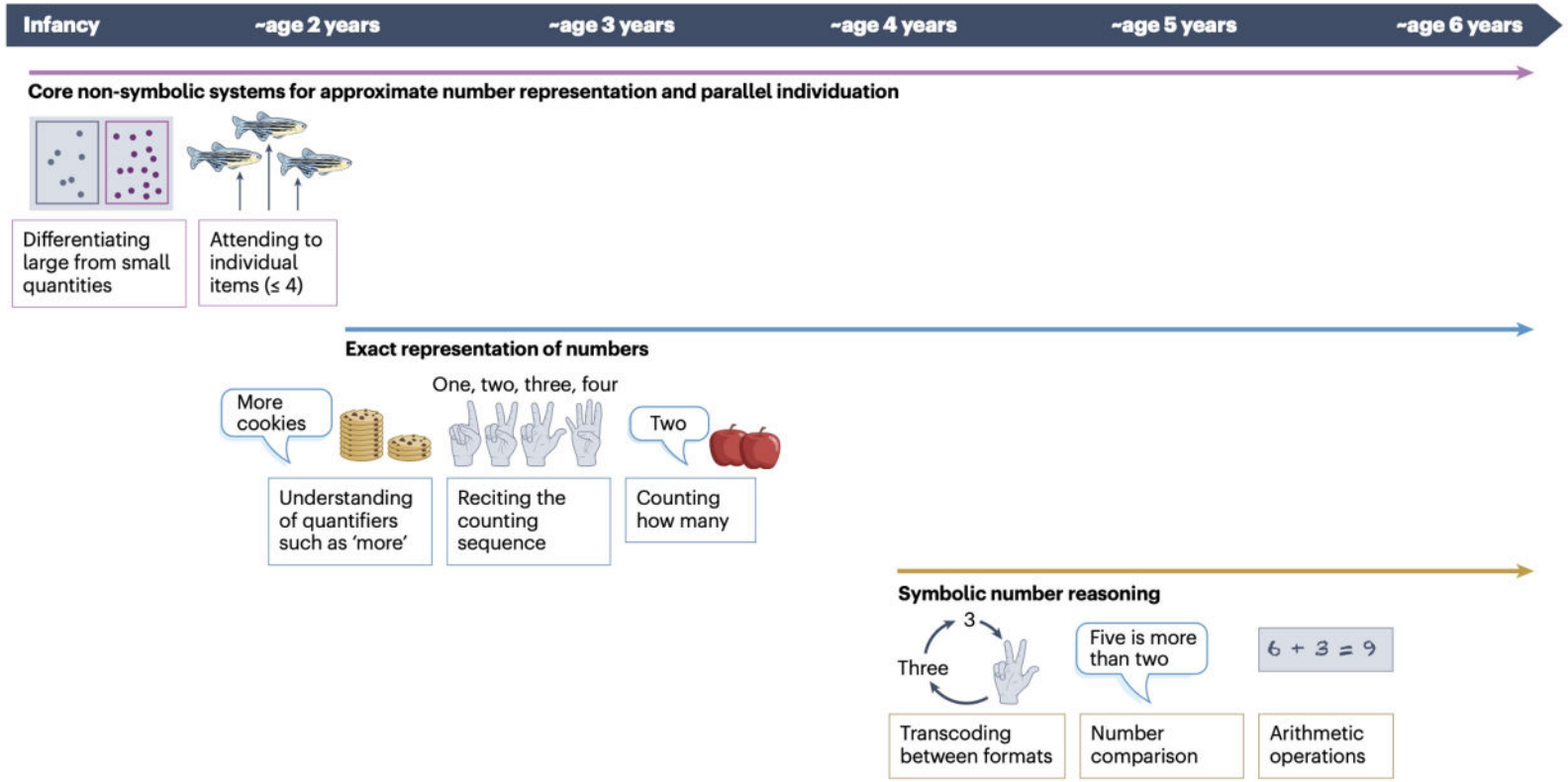
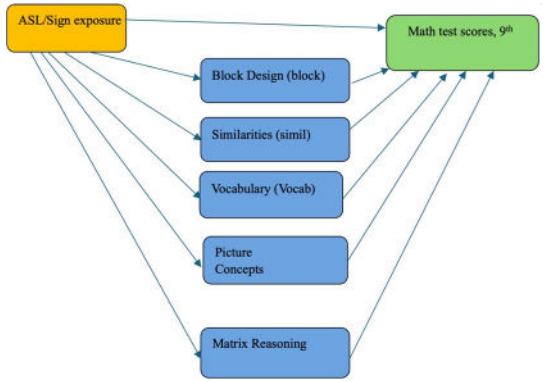


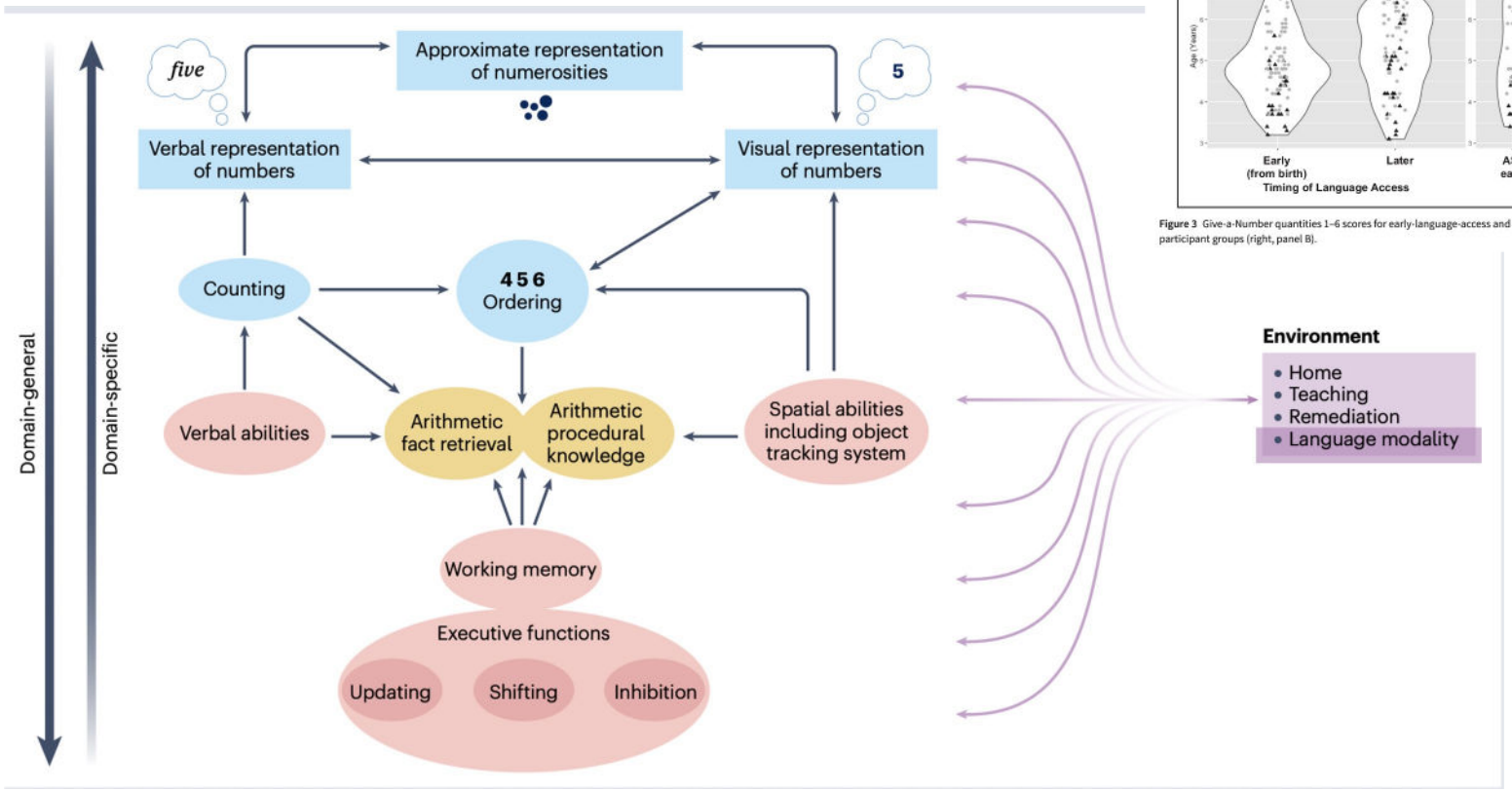
Fig. 1 | Early number skills. The typical developmental progression of children's numerical skills. Children start with core and innate systems that enable them to discriminate sets of non-symbolic quantities (approximate number representation), individuate small collections of objects (parallel individuation), and gradually acquire mental representations of exact quantities denoted by numerical symbols. These new tools then support more sophisticated processes such as symbolic number comparison, transcoding between numerical formats and simple calculations.

Berteletti et al. 2026

Early exposure to visual language increases numeracy



Blatto-Vallee, 2026



Berteletti et al. 2026

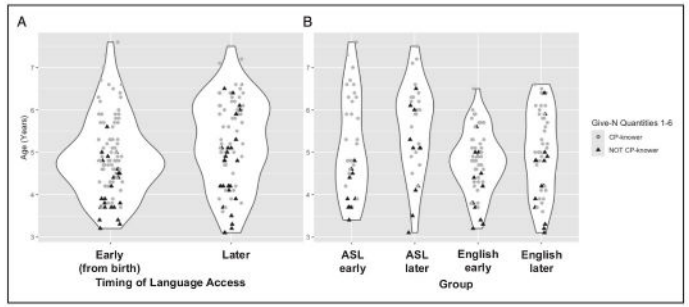


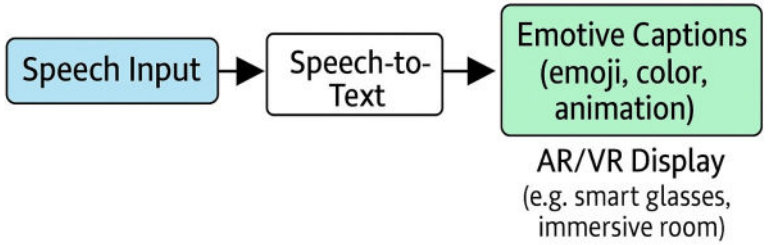
Figure 3 Give-a-Number quantities 1–6 scores for early-language-access and later-language-access groups by age (left, panel A) and for all four participant groups (right, panel B).

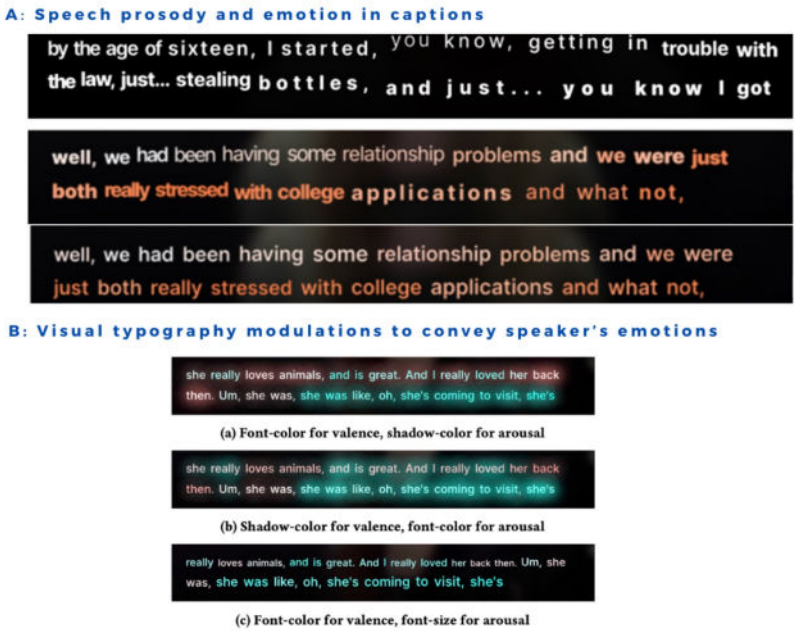
Coppola et al. 2026

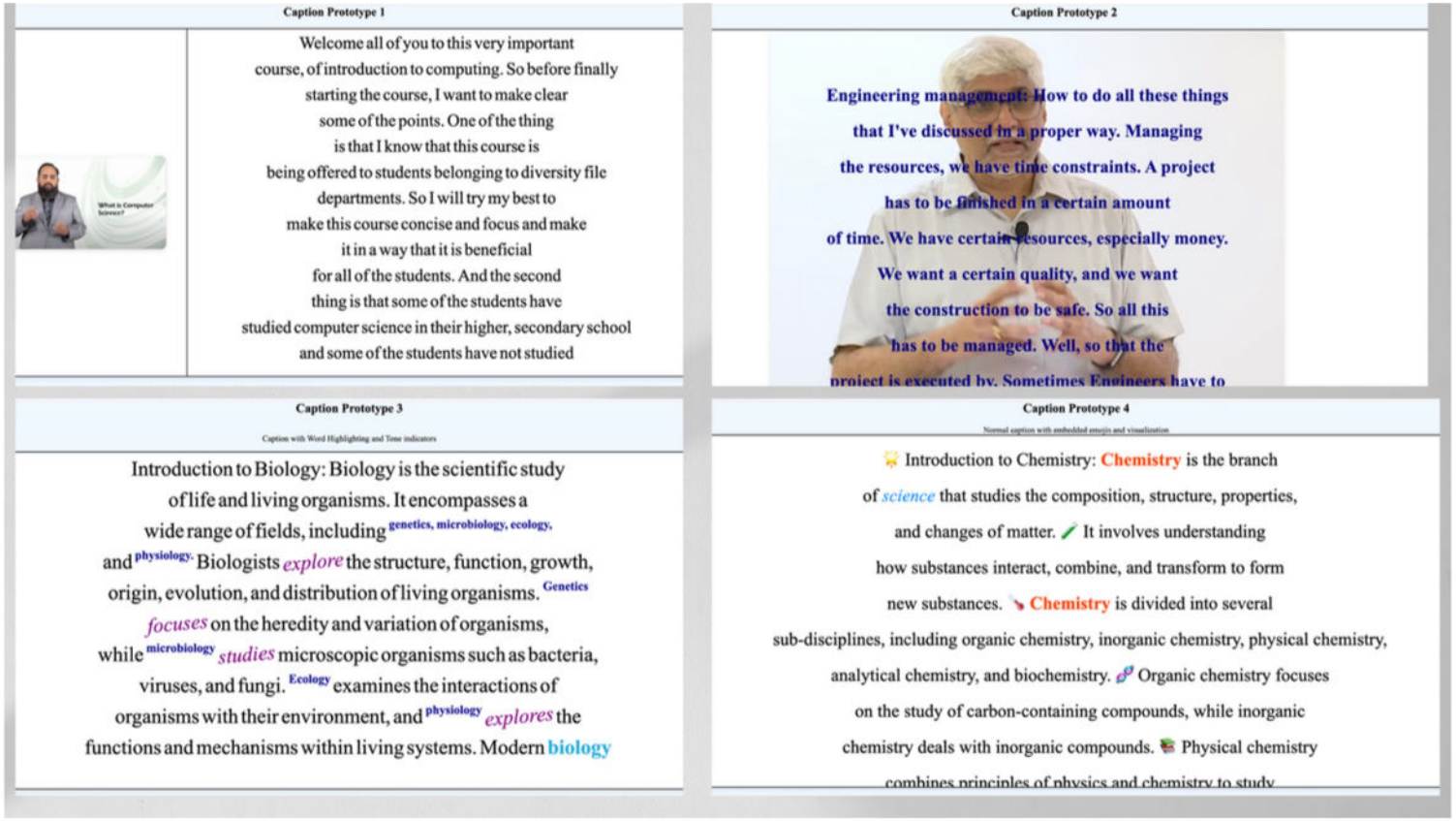
What should we be asking ourselves? Where are we going?

- **How do we leverage AI to learn more about how DHH students learn STEM?** (Mallory 2024, Khandaqi et al. 2025, Ubur, 2026)

Use of AI in Emotive/Expressive Captions







Ubur 2026

We are learning a lot about how DHH students learn and become successful in STEM

- Leverage what we are beginning to understand about language and cognition
- Increase more teachers who are familiar with science
- Take advantage of the STEM sign language lexicon resources
- Increase number of DHH STEMists; stop the leakage from high school → college → graduate school → work

Thank you!

Any questions?

