Getting up to SpEED: Special Education Embodied Design for Sensorially Equitable Inclusion

Sofia Tancredi[*], *Rachel Chen*[**], *Christina Krause*[***], *Dor Abrahamson*[****], *Filippo Gomez Paloma*[*****]

Abstract
We present the implications of a novel approach to design-based research, Special Education Embodied Design (SpEED), for inclusive education. SpEED is a new way of thinking about how Special Education students can learn through whole-body participation (Tancredi *et al.*, in press). The goal of SpEED is to update our thinking about special education and inclusion based on the latest developments in cognitive science. We illustrate the utility of embodied design to teaching and research on issues affecting learners in Special Education through examples centering different Special Education populations, including Deaf learners, learners on the autism spectrum, and sensory-seeking learners. Each project focuses on deepening the learning opportunities we offer students by using learners' existing embodied resources. We conclude with a commentary on considerations for implementing SpEED within the Italian educational system.
Keywords: embodied cognition, design, special education, inclusion, accessibility

First submission: 04/05/2021, accepted: 19/05/2021
Available online: 28/06/2021

[*] PhD student in the Joint Doctoral Program in Special Education at University of California Berkeley and San Francisco State University, California, United States. E-mail: sofiatancredi@berkeley.edu.

[**] PhD candidate in the Joint Doctoral Program in Special Education at University of California Berkeley and San Francisco State University, California, United States, and Nanyang Technological University, Singapore. E-mail: rachel.chen@berkeley.edu.

[***] Postdoctoral Marie Skłodowska Curie fellow at University of California Berkeley, United States and University of Duisburg-Essen, Germany. E-mail: christina.krause@berkeley.edu.

[****] Professor at University of California Berkeley, United States. E-mail: dor@berkeley.edu.

[*****] Full Professor of Teaching and Special Education, University of Macerata, Italy. E-mail: filippo.gomezpaloma@unimc.it.

Doi: 10.3280/ess1-2021oa11818

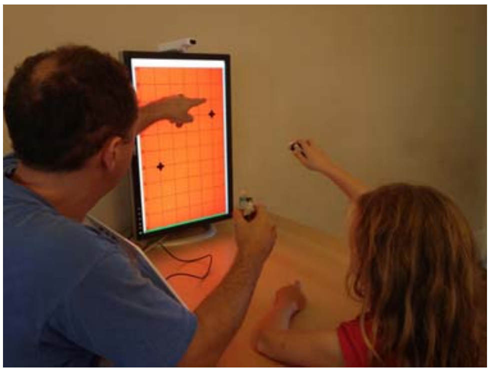
1. Introduction

The separation of mind and body in Western scholarship tracing back to Descartes has long implied a separation of mind and body in education. In this view, a math teacher must focus on the mind, and a sports teacher on the body. Recent developments in cognitive science, however, challenge this neat divide. Embodied models of cognition (Newen *et al.*, 2018) establish the body as *participating in* the activity of the mind. Rather than just manipulating abstract symbols in the head, thinking happens with and through learners' bodies and objects in the world. Perception and action unfold together, and cognitive structures emerge through repeated patterns supporting perceptually-guided action (Varela *et al.*, 1991). Growing evidence supports such embodied accounts of cognitive activity (Fincher-Kiefer, 2019).

This emerging perspective on the mind in turn affects how teaching and learning are conceptualized; the body becomes a central participant in learning even in disciplines usually considered abstract, such as mathematics. Embodied views of cognition have already begun to influence education, from literacy (Glenberg *et al.*, 2004) to science (Scherr *et al.*, 2013). In mathematics, they have inspired a range of innovative educational approaches and designs, from novel technologies (e.g., Nemirovsky *et al.*, 1998; Ottmar *et al.*, 2015; Sinclair and Heyd-Metzuyanim, 2014) to whole-body collaborative activities (Kelton and Ma, 2018, Vogelstein *et al.*, 2019).

Embodied design is a design framework that aims to crystalize the implications of embodied cognition for teaching and learning, with an emphasis on the field of mathematics (Abrahamson *et al.*, 2020; Abrahamson, 2009, 2014). Embodied designs create the conditions for learners to learn to move in new ways that ground the concepts they are intended to learn. Embodied design starts from what learners can already do and perceive and sets things up so that learners can explore target concepts using these resources. Once students have learned to move in a new way, disciplinary forms like numbers and measurement are brought in to serve the students as useful tools that help them control, evaluate, and explain what they are doing. A classic example of embodied design is the Mathematics Imagery Trainer for Proportion (MIT-P) (Abrahamson and Trninic, 2015), a digital interface for math instruction. The learner holds two sensors that manipulate the heights of dots on a screen in front of them (Fig. 1). The screen turns green when the heights of the two dots are in a secret ratio with each other: here, when the left dot is half the height of the right dot. Through this activity, the student learns to move in a new way that keeps the screen green, such that the gap between her hands gets larger as she moves them up the screen. This design shows how learners' capacity to learn new movement patterns can become the basis for learning mathematical concepts like proportional reasoning. Embodied design is the practical arm of embodied models of cognition, such as *enactivism*, that is, the philosophical theory that all thinking is embodied doing (Hutto *et al.*, 2015). We will revisit this example shortly from the perspective of inclusive design for learners with different sensory experiences.

Fig. 1 - The Mathematics Imagery Trainer for Proportion



1.1. An Embodied View of Accessibility

An embodied perspective doesn't just inspire new ways of approaching educational design; it also changes how we define and design for accessibility. Accessibility is often defined as allowing full and equitable participation in activity. In educational settings, accessibility is often thought of as presenting information in an alternate format. For example, this could look like providing blind students with auditory descriptions of visual images, or Deaf students with sign-language interpreters at a spoken lecture. With the old view of cognition, such experiences might be considered equivalent, that is, the plausible assumption would be that "at the end of the day, all students are actually learning the same math, regardless of *how* they learn it." However, from an enactivist point of view, it becomes clear that because diverse learners' bodily engagements with these different educational resources differ dramatically, their respective engagements engender different qualities of learning. Moreover, embodied views of disability can help highlight learners' existing *capabilities,* as well as barriers imposed on them through instructional environments and practices (de Freitas and Sinclair, 2014; Lambert, 2019; Toro *et al.,* 2020; Yeh *et al.,* 2020).

An embodied view of learning can enrich existing inclusive educational design frameworks like Universal Design for Learning (UDL). UDL seeks to accommodate learners' differences through teaching with multiple modes of representation, expression and action, and engagement (CAST, 2018; Meyer *et al.* 2014; Rose and Meyer, 2002). Bringing together UDL and embodied design, Abrahamson *et al.* (2019) reimagine the MIT-P design as a context for blind and visually impaired students to learn together with sighted students by introducing audio and haptic feedback to the design. Learners stand on opposite sides of a board featuring knobs in parallel tracks. Peers on either side of the board slide the knobs together. When the ratio of the left knob's height to the right knob's height fulfills the secret ratio, the knobs vibrate, and a sound is produced. This design designates proportions with visual and haptic–tactile feedback such that blind and sighted learners can achieve equitable independence in their learning together. Both learners' sensorimotor resources are actively and continuously engaged. This version of the MIT-P assures students equal participation in self-guided and coordinated movements, offering an equivalently rich learning experience to all students. This design surpasses common teaching tools like tactile diagrams and text-to-speech that do not give blind learners full and equivalent access to spatial exploration[1].

SpEED (Tancredi *et al.*, in press) – Special Education Embodied Design – takes up the spirit of this project by integrating UDL's commitments to proactive, adaptive education and embodied design's commitment to designing for students' specific embodied resources. SpEED applies embodied-cognition theory to Special Education design. The goal of SpEED is to develop tools that improve accessibility to offer all students equitable access to deep engagement with peers and conceptual learning. To serve every learner in the inclusion classroom, it is necessary to consider how each brings different sensory and motor experiences into learning, and how instructional designs differentially give them opportunities to use that experience.

The principles of SpEED are:

1. **Learning happens through the body's sensorimotor engagement with the world.**
2. **Learning begins from learners' existing embodied resources.** These include prior sensorimotor experiences, practices, processes, and abilities.
3. **Instruction must flexibly adapt to learners' sensorimotor diversities.** This principle calls for an embrace of human variation. Learners' sensorimotor differences can change how they interact with what they are learning.

SpEED uses an iterative approach called design-based research (Cobb *et al.*, 2003). In design-based research, theory informs design, whose evaluation then

[1] For an accessible version of the MIT-P inspired by this design, see https://phet.colorado.edu/en/simulation/ratio-and-proportion.

comes back to inform theory, and over again through iterated cycles of development efforts. With this approach, it is possible to study types of learning that do not yet exist (Bakker, 2018).

We share four examples of SpEED design in action to show how this framework can apply to a range of applications. Each of the four projects uses an embodied approach to design learning technologies that are more equitable. Each focuses on a different population: learners with ADHD, learners on the autism spectrum, and Deaf signers[2]. We describe each example project's rationale and design, list their key implications for practice, and conclude with a set of guiding questions for anyone seeking to implement SpEED in teaching or research. Following these guidelines, we include a commentary on applying SpEED in the Italian educational context.

2. SpEED Projects

2.1 The Magical Musical Mat[3]

The Magical Musical Mat (MMM) is a domain-general platform that allows people to interact using the non-speaking modalities of touch and sound by integrating haptic exploration and music with social interaction (Chen *et al.*, 2020). The MMM is motivated by a drive towards surfacing the very core of human connection: co-presence and affective attunement. Although this project centers non-speaking learners on the autism spectrum, it touches something that is fundamentally human to all of us: the ability to connect with another human being. The MMM creates communicative symmetry between diverse communicators – for example those who have verbal speech and those who don't – by embracing communicative modalities accessible to everyone.

In Vygotsky's words (1962), learning is inherently situated in social practice, whether teacher-to-student or peer-to-peer. Social participation also creates a sense of belonging, an important factor in successful classroom learning (Osterman, 2010). Although everyone has the capacity to engage in interaction, participation in typical social communication usually occurs through talk, and is not readily accessible to some populations. How then can

[2] We are using the terms "blind", "on the autism spectrum", and "Deaf" to respect preferences expressed by people with these identities (Gernsbacher, 2017; Liebowitz 2015). In the US, we use Deaf with a capital D to emphasize sociocultural identity.

[3] This project is led by Rachel Chen. The Magical Musical Mat was funded by the Barbara White Bequest, and the Jacobs Institute Innovation Catalysts grant, and supported by the Humanities International PhD Scholarship.

we design for inclusive participation of students with diverse interactional modalities?

The very label of Autism is clinically characterized by a difference in social communication. Autistic students, especially those who are minimally-verbal or non-speaking, may realize the desire for social interaction differently than neurotypical individuals, through non-dominant sensory modalities, attunements, and practices. The dominance of referential spoken language in educational practices misses opportunities to identify and thus develop multisensorial means of engaging in social interaction.

Previous solutions for non-speaking students involve *Alternative and Augmentative Communication (AAC)* systems that serve as an alternative to, or an augmentation of an individual's speech. For example, AAC solutions include speech generating devices or picture cards for the expression of specific requests. Although the implementation of AAC systems has had much success in furthering language development and linguistic production in many populations, there remains some challenges with these devices. AAC solutions are designed around referential linguistic form. As such, because AAC systems focus on indexical language structures geared towards generating speech, AAC user interfaces are constrained to an array of symbols and grids, whose use is predicated on effective sequencing skills, excellent memory, and motoric dexterity, thus imposing high cognitive and motor demand. The AAC user must accommodate their interlocutor's communicative modality (speech), and their bodily movement is recruited for the purpose of linguistic output. But what if the body's significant role in interactional engagement could instead be forefronted? What if both interactants communicated in the same modality?

This design solution draws upon embodied cognition and other theories of embodiment that take the body as a point of departure. Stemming from phenomenology, this project draws from Merleau-Ponty's concept of intercorporeality, where the human body is seen as the active center of cognition, social understanding, and culture making. This work also draws upon research that has microgenetically examined touch in social interaction, such as Marjorie Goodwin's work on haptic sociality (Goodwin, 2017), where touch is empirically demonstrated to communicate close attunement and trust. By designing for touch-based interaction, this project forefronts developmental antecedents of effective communication that are rooted in the body.

The MMM is an embodied-design platform (Abrahamson, 2014) that positions students' dynamic bodies as the nexus of social interaction. This platform is designed to foster collaborative interaction as a dyad's emergent solution to the situated problem of enacting musical improvisation. When two people stand on the mat and touch hands, they close a circuit (Fig. 2). The fluctuations in resistance levels between both bodies are mapped onto musical sounds, such that different touch-based gestures produce different sounds.

Fig. 2 - *The Magical Musical Mat (Images adapted from Chen et al., 2020)*

We introduced the MMM to an autism clinic that runs Integrated Play Groups (IPG), an interventional form that facilitates students' play-based interactions (Wolfberg *et al.*, 2016). The practitioners presented the MMM in two different classes with different age groups (5-8 y/o and 9-12 y/o) comprising of both autistic and neurotypical students. With little guidance, the students interacted with one another in various ways. They played rhythmic hand-games, explored a variety of sounds by touching hands and feet, and took turns pretending to be musical instruments. The clinic's directors, teachers, and therapists expressed surprise at the creativity of the games the students played and the sounds they explored. They also observed a behavioral change in some students, who were at first hyperactive in interacting with each other but had calmed down through using the mat in ways that facilitated other learning activities. Lastly, they stated that the students thereafter continued to express interest in using MMM: they asked the teachers to play with it and mentioned it in later clinic sessions.

In our current work, we are using this platform as a musical improvisation tool for children on the autism spectrum. We are examining repetitive movement – rocking, tapping, flapping – of autistic children, and how this can emerge into social interaction through musical interventions.

Implications for practice:

1. Beyond the dominant modality of speech, modalities such as tactility can allow diverse communicators to connect with one another.
2. Interacting with modalities other than speech allows for communicative symmetry, especially with minimally-speaking / non-speaking children.

3. Facets of social interaction such as rhythmicity and musicality can encourage creative and inventive play.

2.2 Balance Board Math[4]

Balance Board Math is a new way of interacting with mathematical concepts using a rocking balance board. This project is motivated by improving instructional accessibility for learners who crave movement stimulation. This tends to include many children with ADHD (Shimizu *et al.*, 2014) as well as children on the autism spectrum (Tomchek and Dunn, 2007). Balance Board Math introduces a range of mathematical concepts including functions, angles, and ratio using embodied design activities on a balance board. We'll focus here on one Balance Board Math configuration, the *Balance Number Line (BNL)*, a balance-based way of interacting with the number line to experience absolute value and negative numbers.

A key feature of Balance Board Math is that it reconciles two ways of thinking about movement in learning: sensory regulation and embodied cognition. Theories of *sensory regulation* in the psychology and occupational therapy literature (e.g., Dunn, 1997) posit that movement operates as a means to maintain optimal levels of alertness through sensory stimuli that are of an adaptive intensity for one's sensory profile. This project focuses on a particular kind of sensory input: the vestibular system in the inner ear. The vestibular system supports balance and coordination. It includes three semicircular canals in different orientations that detect movement. Sitting in class provides minimal stimulation to the vestibular system. Students who need more vestibular stimulation might seek it through movements such as rocking in their chair or walking around, which may look to their teacher like they are distracted. There is evidence for the impact of sensory experience on academic learning: sensory differences have been found to explain 47% of variance in academic performance for children on the autism spectrum (Ashburner *et al.*, 2008), and self-directed movement like fidgeting is positively correlated with performance for children with Attention Deficit Hyperactivity Disorder (ADHD) (Sarver *et al.*, 2015). This project sets forth from the perspective that having a learning task and environment that meets one's sensory regulation needs is a question of accessibility. In parallel, embodied cognition dictates that movement plays a central role in cognition. The vestibular system plays a central role in movement. Not surprisingly then, the vestibular system has been implicated in cognitive development, and even abstract conceptual reasoning (Hitier *et al.,* 2014; Antle *et al.*, 2013).

[4] This project is led by Sofia Tancredi. The Balance Board Math project is supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. 1938055.

Existing solutions in the United States for supporting sensory regulation typically meet sensory needs separately from academic learning, either by providing sensory accommodations to students in the classroom such as specialized seating, or through therapeutic sensory programs conducted outside of the classroom. But according to embodied cognition, sensory activity is part of cognition, not separate from it. This project differs from previous solutions by treating sensory regulation as *part of* mathematical activity. The design conjecture of this project is that directly incorporating vestibular stimulation into learning activities will improve their efficacy. The aim is to combine the sensory regulation tool of a balance board with number line tools from math instruction. The resulting design makes rocking on a balance board central to a series of mathematics learning tasks. Students sit on the board and rock by moving their hands along a number line. Hand positions affect the board's balance (Fig. 3), providing stimulation to the vestibular system that serves as feedback about the number line movements. The design builds upon learners' natural engagement with vestibular stimulatory behavior. Rocking becomes a resource for conceptual learning. The BNL is designed not only to support sensory regulation, but also to use vestibular stimulation to enhance the perceptual salience of learning-relevant stimuli.

Fig. 3 - The Balance Number Line

An example BNL activity is to find a way to move both hands along the number line while staying in balance. The solution consists of moving both hands apart at the same rate, keeping them equidistant from the origin (for example, at -2 and 2, -4 and 4, etc.). If and only if the hands move in this way, the board will remain in balance. Solving this problem develops a sense of number-line symmetry. Negative numbers are defined as the counterbalancing point to their positive counterparts. The number line becomes a tool to be able to refine, control, and talk about movements. In BNL activities, magnetic arrows of different lengths are also used to document, plan, and discuss movements on the board.

When tested with a 13-year-old male on the autism spectrum, the pilot participant effectively identified mathematical properties through experiences on the board. He also rocked on the board beyond the formal tasks themselves during tasks such as waiting or visual comparison, suggesting that the board provided an opportunity for sensory regulation. The student's parents shared in a debrief interview that the student's sustained focus for much longer than typical in this context. This supports the hypothesis that meeting students' sensory regulation needs through the activity design can expand their capacity for sustained mathematical investigation.

Current work in Balance Board Math includes testing the activity with a range of participants and building out other configurations that explore other mathematical concepts, each with an eye towards allowing students who are sensory seeking to collaborate with peers who are less sensory seeking and even sensory avoidant.

Implications for Practice:
1. Different learners within the same classrooms will need different levels of sensory stimulation to do their best learning.
2. Students who are moving in non-prescribed ways such as fidgeting or tilting in their chair might be meeting their sensory needs in order to work. Recognizing their sensory regulation needs can help to offer alternatives that are not disruptive to peers.
3. Foundational sensory systems like balance, tactility, and proprioception (body-in-space) provide untapped opportunities for presenting concepts in new and engaging ways.

2.3. SignEd|Math[5]

The aim of SignEd|Math is to develop instructional approaches and methods that make use of the potential of sign language as a special practice and communicational preference of Deaf students. This project builds on the

[5] This project is led by Christina Krause. The project SignEd|Math receives funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska Curie Grant Agreement No 842487.

assumption that learning math in the medium of sign language changes how learning content is approached and structured, from both an individual-embodied and a social-constructivist perspective.

Sign languages are not mere word to word translations of spoken languages into gestural signs; they are languages with their own syntactic rules, steadily and naturally growing in the Deaf communities in which they are used. Signs are more or less conventionalized and vary in handshape, performance location, trajectory, direction, speed, orientation, and facial expression (Stokoe, 1963).

The use of a sign language seems to influence Deaf signers' ways of thinking universally, leading to differences in cognitive processing and conceptual organization (Grote, 2013 for an overview). For example, the visual-spatial format and simultaneous articulation afford concept organizations differently than the auditory-sequential articulation of spoken languages. This is considered to influence the ability for serial recall of information to be less distinctive in Deaf signers. This makes it more difficult for them to follow information presented linearly, and simultaneously presented information becomes more accessible for cognitive processing (Hall and Bavelier, 2010). Additionally, sign languages generally show a higher degree of iconicity than spoken languages. Signs often reflect a concept by representing actions or objects. The whole concept cannot be represented, so a certain aspect is chosen to stand for the concept. Research in psycholinguistics found that these foregrounded aspects are more strongly associated with the whole concept than those that are not represented (Grote, 2013).

Instead of acknowledging these differences in cognitive processing and conceptual organization, Deaf students are still mainly treated as "hearing students that cannot hear" (Marschark *et al.*, 2011, p. 4) That is, the main concern addressed in Deaf students' education, especially in mainstream schools, is the access to information and instruction, problems supposedly solved through easier written language and sign language interpreters. While these approaches lower the barrier for learning, they underestimate the role of language in learning mathematics and miss out on using sign language as a medium and a resource for learning mathematics (Krause and Wille, to appear).

Conventionalized mathematical signs do often not exist, especially for higher mathematical concepts. This can be seen as an obstacle, but it also bears a unique opportunity for making mathematical language meaningful (Kurz and Pagliaro, 2020) through actively establishing iconic meaning in the sign as grounded in the activity through which the mathematical concept is introduced (Krause, 2019).

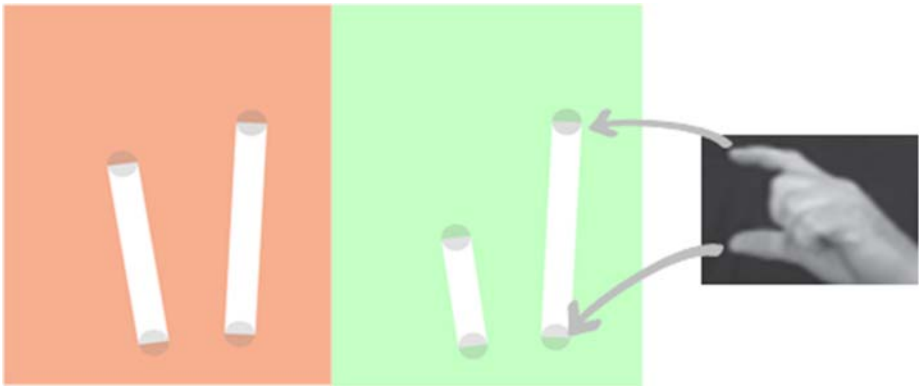
Mathematical signed language hence bears the potential of capturing enactive or depictive features of source sensorimotor forms as schematized enacted experience of the learner (Krause, 2019). As this encompasses the manual action, idiosyncratic gestures as proto-signs arising from this action, and eventually signed mathematical discourse integrating such gestural expression, we refer to this as *modal-continuity* (Krause and Abrahamson, 2020). Iconicity thus becomes part of the modal hybrid of gestures and signs in signed discourse and thereby shapes the development of socially negotiated mathematical meaning.

The SignEd|Math design takes advantage of the potential of sign languages to allow for modal continuity to model embodied experience that fosters the emergence of conceptually and linguistically fruitful signed mathematics discourse about a specific topic (Krause and Abrahamson, 2020). It accordingly involves two phases: one designed to establish individual embodied experience through solving a dynamic interaction problem, and a second fostering the negotiation of mathematical meaning through signed discourse.

We focus here on the first phase: an adaptation of the MIT-P design (Abrahamson and Trninc, 2015) implemented on a multi-touch interface to allow for bridging from action to signed mathematical discourse in a conceptually meaningful way. Instead of using the height of two reference points on a vertically oriented screen, learners manipulate the lengths of two bars on a touchscreen, each spanned by the thumb and index finger of one hand (Fig. 4). Just as in the original design, the screen turns green when the lengths of the two bars stand in a certain ratio. Manipulation with the thumb and index finger mimics a handshape called ‘bent L’, in American Sign Language used as a classifier to refer to the idea of number or quantity. The classifier is not the actual sign for the idea itself but rather a representation of the idea in context and can be varied depending on the context. For example, Kurz and Pagliaro (2020) use it to stand in for the numerator and the denominator in a conceptually meaningful sign for improper fraction in which the numerator is indicated as larger in quantity as in the denominator. The SignEd|Math MIT-P redesign integrates the classifier handshape as a feature in the tablet action attempting to link action, concept, and language in a meaningful way.

The main objective of the second phase is to allow for an occasion to negotiate mathematical meaning through collaborative problem solving on a transfer problem. For this, pairs of students are invited to collaboratively solve a problem that elaborates on the idea of proportion as encountered when working with the digital interface. Following socio-constructivist theories, shared mathematical meaning might then develop as constructed among peers, together with shared gestural signs as a preconventional means to address the new mathematical knowledge in development. This transfer problem can deepen the engagement with the proportion concept as encountered when working with the digital interface. For example, the students can be asked to solve a similar problem that uses another ratio as an underlying rule with each student controlling one bar such that the students need to negotiate the coordination of their movement. The transfer problem can also go beyond the original interaction problem and widen the conceptual involvement by linking to related concepts like fractions.

Fig. 4 - SignEd|Math App



Note. The two bars move dynamically and change their length. The screen turns green when the right bar is twice as long as the left bar.

Implications for practice:

1. In lesson design, we can plan approaches and activities in ways that facilitate links between language, gestural expression, and other visual representations to foster meaning making in and through the social interaction.
2. More specifically, we can plan embodied activities with the idea in mind that they match the corresponding mathematical signs to also build a representational bridge to facilitate communication between hearing and Deaf students.

3. Getting Up to SpEED: A Starter Kit

These ongoing projects illustrate the traction of embodied cognition on design problems across different populations and learning goals. Although each population's needs are distinct, embodied cognition sheds useful light on learning for all of them. As these designs are tested and iterated, they can also help to develop and refine theories of embodied learning.

We conclude with lessons learned across these diverse projects for prospective SpEED designers. SpEED relies upon careful differentiation of the factors affecting learners' interactions with peers, objects, themselves, and their environment. Three parameters can help to specify and reimagine these relations: modality, semiotic mode, and media. *Modality* refers to the sensory and motor systems recruited by a task. Examples include visual, auditory, tactile, proprioceptive (body-in-space), and vestibular (balance) systems, as well manual (hands), oral (speech), or whole-body motor systems (Edwards and Robutti, 2014). *Media* are materials, like pen-and-paper, a tablet interface, or the body (Kress, 2001). *Semiotic modes* are systems of meaning-making involving any kinds of signs (Kress, 2001). These include, for example, spoken or signed language, gesture, and mathematical symbols. The interactions among these three parameters – modality, media and semiotic modes – create the conditions for what kinds of learning can take place. For example, SignEd|Math resists replicating the semiotic modes of spoken language in sign language, appreciating that the practice of signing changes the way Deaf learners structure their experiences and their knowledge. The media is designed to give learners access through manual action ground conceptual learning through the modality of manual kinesthesia and encourage collaborative meaning making through the semiotic mode of signed language.

Special education populations frequently engage the world in ways that differ from neuromajority individuals, through modalities that are not traditionally privileged as ways of learning. Just because vision and hearing are common modalities does not mean they deserve to be the only ways that concepts are represented for students. A SpEED approach combats what we call *modalism*: the over-reliance on dominant modalities like vision and hearing. Greater learning opportunities might be found through engaging other modalities like touch and movement to explore concepts. Using shared modalities means that learners can work together and talk about what they are doing; this creates rich opportunities for inclusive learning.

To teachers and researchers seeking to undertake SpEED, we offer the following guiding questions:

1. **Embodied resources:** What kinds of sensorimotor activities, strengths, and practices do these learners already have in their repertoire? How might these be related to focal content?
2. **Modalities:** What modalities are traditionally used to teach this content? How does this shape the way the concept is thought about? How might this content be presented and experienced through modalities accessible to this learner? What other modalities could be engaged?
3. **Media:** What media is traditionally used to teach this content? What modalities are used to engage with this media? What kind of media could give students opportunities to interact *dynamically* through other modalities?

4. **Semiotic modes:** What semiotic modes are traditionally used to teach this content? Are these modes accessible to the learner? Are these modes necessary for the content, or incidental? Could these modes be replaced or transformed so that this student might fully access them?
5. **Interaction loop:** What kind of interaction do I want to enable in this design? How will the learner get ongoing feedback from their activity?
6. **Peer interaction and discourse:** How are learners interacting with peers during this activity? Can we create shared sensorimotor experiences that allow peers to collaborate and discuss? Can we embrace social interaction beyond the dominant modalities of speech and the linguistic system?

The SpEED framework can bring a fresh perspective to longstanding challenges in education and help imagine ways to deepen disciplinary and peer engagement for diverse learners. We offer these questions as an invitation to teachers and researchers to join us in SpEEDing towards a more equitable classroom.

4. Commentary by Filippo Gomez Paloma: SpEED in an Italian Context

This commentary reflects upon the potential application of SpEED in the Italian context. A brief excursus about legislative history and pedagogical inclusion is necessary to understand how fertile and ready he Italian educational system is to welcome this new inclusive approach.

The Italian regulations, starting with the Falcucci document (1977), highlight the evolution of the inclusive pedagogical model of schooling. In recent decades, there have been numerous legislative interventions (Legge 5 febbraio 1992, n. 104 sulla disabilità; Legge 8 ottobre 2010, n. 170 sui Disturbi Specifici di Apprendimento, DSA; D.M. del 27 dicembre 2012 e la C.M. n.8 del 6 marzo 2013 sui Bisogni Educativi Speciali, BES; D. Lgs. 13 aprile 2017, n. 66; D. Lgs. 7 agosto 2019, n. 96; D.I. 29 dicembre 2020 n. 182) that went from the mere insertion of disabled people into normal classrooms to inclusion of people with Special Educational Needs (*Bisogni Educativi Speciali:* disabilities, specific learning disabilities, specific developmental disabilities, as well as socio-environmental, linguistic and cultural disadvantages).

This evolution has led the school system to pursue full inclusion of Special Educational Needs students, offering equal opportunity and dignity to all the students in the class, regardless of disability. Inclusion is an objective that the school autonomously pursues through intense and organized planning, valuing internal professionalism as well as local resources. Furthermore, the current national and international legislative framework with the issuing of the ICF, *International Classification of Functioning, Disability and Health* (WHO, 2001; 2007), and of the New Individual Educational Plans promoted by the Interministerial decree n. 182 and by the related Guidelines (2020), has shifted the attention from the clinical problem of the single individual to the bio-psycho-social variables that affect a subject's growth of their potential in life.

So far, it would seem that the legislative framework and the current and innovative pedagogical pathways offer high hope for implementing SpEED in Italy; yet the scientific approach that spearheads the Embodiment paradigm (Glenberg, 2008; Barsalou, 2010; Paas and Sweller 2012; Wilson and Golonka, 2013; Gallese, 2003; 2005; 2014) has been slow to take off. The scientific principles recommended by the Italian pedagogic community, although well aligned with the legislative norms (MIUR, 2012; 2018), run into difficulty due to an educational culture that does not yet widely value differences and consider learning as a situated not standardized process, that is directly connected to the subjective potential of each student and strongly dependent on the sensorimotor system, hence embodied (Gomez Paloma, 2020).

In my brief reflection, I will attempt to suggest some aspects and requirements to take into consideration for the SpEED model in the context of the Italian educational system.

The first requirement is the cultural transformation of the teachers' mindset. To this day, considering how the entry and service training courses for teaching professionals are organized and proposed, it is understandable, as well as reliable, that the mentality of educators actually limits the development potential of the Embodiment phenomenon in all forms of schools including inclusive ones. It is indispensable, therefore, to build a formative system, scientifically supported and conducted methodically with the same *Embodied* approach, which aims to raise awareness of educators as people, beyond the job description, as well as to favor the acquisition of integrated, Embodied-Centred (Gomez Paloma and Damiani, 2015) theoretical, practical, and experiential skills. This system, albeit ideal, is challenging because it clashes with the deep roots of Italian culture that tends to orient the population (legislators, directors, educators, families and students), both cognitively and socially to give more weight to words than actions, to external appearance than internal substance. The advancement of the book *Manuale delle Scuole ECS. The Neuroeducational Approach* (Gomez Paloma and Damiani, 2021) shows how much work is still necessary, but also proves that initial steps have already been taken and that a preliminary experimentation of the Embodied approach has been realized in several schools in Italy.

The second requirement is tied to the partial, if not nonexistent, compliance with the rules on inclusion which, as mentioned above, offer teachers maximal opportunity to enjoy SpEED's inclusive approach. The presence of disabled people in normal classrooms, despite being implemented for decades, does not result in the fullest and most significant concept of inclusion. This concept is understood as a phenomenon in which the context (educators, classmates, resources, and supports) adapts to facilitate the learning pathways of the student and yields a double positive effect: catering to the subject's potentials, emphasizing and recognizing them in their unique complexities, and teaching classmates to accept their peers' differences, taking on the human value of sharing for the future, and to avoid operating socially in a discriminatory manner. Too often, instead, the resources provided by the Italian school system – to special needs teachers – go towards an approach of assistance (to fill the gaps) and of pity, risking offending the student's dignity; this approach not only limits full participation in group activities but also deprives the subject of the active protagonism so emphasized in the Embodied approach.

As stated by Abrahamson (2014), embodied design – and with that also SpEED – focuses on what the students can already do and perceive and promotes activities that allow them to explore the target concepts, using their own resources. This allows the introduction of active disciplinary forms that help students understand and explain concepts through participation that is active and processed by the body.

Therefore, in Italy, the application of SpEED meets a second obstacle; here too, there is work to be done academically and institutionally to train teachers to value differences, and to improve and focus on the challenged subject's strengths.

The third requirement is the schools' institutional setup and their architectural limitations and affordances. For many years, Italy has been trying to promote an innovative form of urban planning (whether new construction, renovation, or retraining) that allows for more open spaces, and less physical and spatial restraint. This aims to shift didactics towards a more embodied approach, as to allow students to be more involved, in a collaborative way, in the planning of their school activities. The legislation itself (Legge 13 luglio, 2015, n. 107), with the Scuole Innovative del MIUR project, created the possibility of a dialogue between Pedagogy and Architecture, aware of the strong necessity to implement a structural change of the educational space (Gomez Paloma *et al.*, 2019; Vanacore and Gomez Paloma, 2020). This structural revolution is directly connected to SpEED, since many of the propositions here described include the use of specific spaces and supports, surpassing the traditional desk and chair classroom configuration, and opening the way for new forms of accessibility and use of space and objects in order to make learning sustainable and supportive of the students' well-being.

In conclusion, without repeating the validity of the propositions promoted by the SpEED working group established in the lab of my colleague Abrahamson – taking for granted the value of the constructs now known and evident to the entire international pedagogic community – it would be quite functional to apply this model to the demands and needs of disabled students.

Blind children who through vibration and sound can perceive the rules of mathematical proportions (Mathematics Imagery Trainer for Proportion) (Abrahamson *et al.*, 2014), fostering Deaf students' mathematical meaning making by grounding individual concept learning and signed mathematical discourse in manual action (Signed Math) (Krause and Abrahamson, in press), integrating sensory regulation and embodied cognition to benefit students with ADHD in the study of number lines (Balance Board Math), the exploration through touch and sound of music integrated with social interaction for autistic students (Magical Musical Mat), are four excellent ideas that, as stated by my colleagues, aim to surpass the common use of what Gardner called the canonical channels (sight and hearing), opening new horizons and sensors (touch, movement), as recognized by Berthoz (1998). Thus, the concepts for students with special education needs will actually be explored, and not decoded with often-compromised abstract cognitive processes.

We are aware, however, that, as previously mentioned, in order for SpEED to take shape and become applicable in the Italian educational system, we must take the responsibility of setting in motion regulatory and planning actions, both academically and institutionally, to face the consolidated barriers (structural and mental) that do not allow the above-mentioned requirements to be satisfied.

These steps matter because SpEED applies the theory of Embodied Cognition to the design of Special Pedagogy, which we support as, we are convinced, it will leave a deep mark on education of the next generations.

References

Abrahamson D. (2014). Building educational activities for understanding: An elaboration on the embodied design framework and its epistemic grounds. *International Journal of Child-Computer Interaction, 2*(1): 1-16. Doi: 10.1016/j.ijcci.2014.07.002.

Abrahamson D., & Trninic D. (2015). Bringing forth mathematical concepts: Signifying sensorimotor enactment in fields of promoted action. *ZDM Mathematics Education, 47*(2): 295-306. Doi: 10.1007/s11858-014-0620-0.

Abrahamson D., Flood V. J., Miele J. A., & Siu Y.-T. (2019). Enactivism and ethnomethodological conversation analysis as tools for expanding Universal Design for Learning: The case of visually impaired mathematics students. *ZDM Mathematics Education, 51*(2): 291-303. Doi: 10.1007/s11858-018-0998-1.

Abrahamson D., Nathan M. J., Williams-Pierce C., Walkington C., Ottmar E. R., Soto H., & Alibali M. W. (2020). The future of embodied design for mathematics teaching and learning [Original Research]. *Frontiers in Education, 5*(147). Doi: 10.3389/feduc.2020.00147.

Antle A. N., Corness G., & Bevans A. (2013). Balancing justice: Comparing whole body and controller-based interaction for an abstract domain. *International Journal of Arts and Technology*, *6*(4): 388-409. Doi: 10.1504/IJART.2013.058285.

Ashburner J., Ziviani J., & Rodger S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with Autism Spectrum Disorder. *American Journal of Occupational Therapy*, *62*(5): 564-573.

Bakker A. (2018). *Design research in education: A practical guide for early career researchers.* London: Routledge. Doi: 10.4324/9780203701010.

Barsalou L.W. (2010). Grounded cognition: Past, present, and future. *Cognitive Science, 2*(4). Doi: 10.1111/j.1756-8765.2010.01115.x.

Berthoz A. (1998). *Il senso del movimento*. Milano: McGraw-Hill Companies.

CAST (2018). *Universal Design for Learning Guidelines version 2.2*. http://udlguidelines.cast.org.

Chen R. S. Y., Ninh A., Yu B., & Abrahamson D. (2020). Being in touch with the core of social interaction: Embodied design for the nonverbal. In M. Gresalfi & I. S. Horn (Eds.). *The Interdisciplinarity of the Learning Sciences, Proceedings of the 14th meeting of the International Society of the Learning Sciences (ICLS 2020)* (Vol. 3, pp. 1681-1684). International Society of the Learning Sciences.

Circolare Ministeriale n. 8, *Indicazioni operative sulla Direttiva ministeriale "Strumenti d'intervento per alunni con bisogni educativi speciali e organizzazione territoriale per l'inclusione scolastica"*. prot. 561/6.3.2013, Roma, marzo 2013.

Cobb P., Confrey J., diSessa A., Lehrer R., & Schauble L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1): 9-13. Doi: 10.3102/0013189X032001009.

D. Lgs 13 aprile 2017, n. 66, Norme per la promozione dell'inclusione scolastica degli studenti con disabilità, a norma dell'articolo 1, commi 180 e 181, lettera c), della legge 13 luglio 2015, n. 107, *Gazzetta Ufficiale* n.112 del 16-5-2017 - Suppl. Ordinario n. 23.

de Freitas E., & Sinclair N. (2014). *Mathematics and the body: Material entanglements in the classroom.* Cambridge University Press. Doi: 10.1017/CBO9781139600378.

Decreto Legislativo 7 agosto 2019, n. 96 Disposizioni integrative e correttive al decreto legislativo 13 aprile 2017, n. 66, recante: «Norme per la promozione dell'inclusione scolastica degli studenti con disabilità, a norma dell'articolo 1, commi 180 e 181, lettera c), della legge 13 luglio 2015, n. 107». *Gazzetta Ufficiale* n.201 del 28-8-2019.

Decreto Interministeriale 29 dicembre 2020, n.182, *Adozione del modello nazionale di piano educativo individualizzato e delle correlate linee guida, nonché modalità di assegnazione delle misure di sostegno agli alunni con disabilità, ai sensi dell'articolo 7, comma 2-ter del decreto legislativo 13 aprile 2017, n. 66.*

Direttiva Ministeriale 27 dicembre 2012, *Strumenti d'intervento per alunni con bisogni educativi speciali e organizzazione territoriale per l'inclusione scolastica.*

Dunn W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants and Young Children, 9*(4), 23-35. Doi: 10.1097/00001163-199704000-00005.

Fincher-Kiefer R. (2019). *How the body shapes knowledge: Empirical support for embodied cognition.* American Psychological Association. Doi: 10.1037/0000136-000.

Gallese V. (2003). The manifold nature of interpersonal relations: The quest for a common mechanism. *Philosophical Transactions of the Royal Society of London B, 358 (1431):* 517-528. Doi: 10.1098/rstb.2002.1234.

Gallese V. (2005). Embodied simulation: From neurons to phenomenal experience. *Phenomenology and the Cognitive Sciences, 4*: 23-48. Doi: 10.1007/s11097-005-4737-z.

Gallese V. (2014) Bodily selves in relation: embodied simulation as second person perspective on intersubjectivity. *Philosophical Transactions of the Royal Society of London B, 369*: 20130177. Doi: 10.1098/rstb.2013.0177.

Gernsbacher M.A. (2017). Editorial perspective: The use of person-first language in scholarly writing may accentuate stigma. *Journal of Child Psychology and Psychiatry, 58*(7): 859-861. Doi: 10.1111/jcpp.12706.

Glenberg A.M. (2008). Embodiment for education. In: Calvo P. & Gomila A. (Eds.). *Handbook of Cognitive Science: An Embodied Approach*. San Diego: Elsevier.

Glenberg A. M., Gutierrez T., Levin J. R., Japuntich S., & Kaschak M. P. (2004). Activity and imagined activity can enhance young children's reading comprehension. *Journal of Educational Psychology*, *96*(3): 424-436. Doi: 10.1037/0022-0663.96.3.424.

Grote K. (2013). *'Modality Relativity?' The Influence of Sign Language and Spoken Language on Semantic Categorization*. Dissertation. Retrieved 01/15/2017 from: http://publications.rwth-aachen.de/record/211239/files/4546.pdf.

Goldsmith S. (1997). *Designing for the disabled: The new paradigm.* London: Routledge.

Gomez Paloma F., Damiani P. (2015). *Cognizione corporea, competenze integrate e formazione dei docenti. I tre volti dell'Embodied Cognitive Science per una scuola inclusiva*. Trento: Erickson.

Gomez Paloma F., Borrelli M., Buondonno E. (2019). *Scuole innovative. L'Embodied Cognition Design come paradigma dei nuovi spazi scolastici.* Roma: Nuova cultura.

Gomez Paloma F. (a cura di) (2020). *Embodiment & School.* Lecce: Pensa Multimedia.

Gomez Paloma F., & Damiani P. (2021). *Manuale delle Scuole ECS. The Neuroeducational Approach*. Brescia: Scholè.

Goodwin M. H. (2017). Haptic sociality. *Intercorporeality: Emerging socialities in interaction*, 73-102. Doi: 10.1093/acprof:oso/9780190210465.003.0004.

Hall M. L., & Bavelier D. (2010). Working memory, Deafness, and sign language. In: M. Marschark, P. E. Spencer (Eds.). *The Oxford handbook of Deaf Studies, language, and education,* Vol. 2. (pp. 457-472). Oxford University Press. Doi: 10.1111/j.1467-9450.2009.00744.x.

Hitier M., Besnard S., & Smith P. (2014). Vestibular pathways involved in cognition. *Frontiers in Integrative Neuroscience*, *8*(59). Doi: 10.3389/fnint.2014.00059.

Hutto D. D., Kirchhoff M. D., & Abrahamson D. (2015). The enactive roots of STEM: Rethinking educational design in mathematics. In: P. Chandler & A. Tricot (Eds.). Human movement, physical and mental health, and learning [Special issue]. *Educational Psychology Review, 27*(3): 371-389. Doi: 10.1007/s10648-015-9326-2.

Hutto D. D., & Myin E. (2012). *Radicalizing enactivism: Basic minds without content*. Cambridge: M.I.T Press.

Kelton M. L., & Ma J. Y. (2018). Reconfiguring mathematical settings and activity through multi-party, whole-body collaboration. *Educational Studies in Mathematics, 98*(2): 177-196. Doi: 10.1007/s10649-018-9805-8.

Krause C.M. (2019). What you see is what you get? – Sign language in the mathematics classroom. *Journal for Research in Mathematics Education, 50*(1): 84-97. Doi: 10.5951/jresematheduc.50.1.0084.

Krause C. M., & Abrahamson D. (2020). Modal continuity in Deaf students' signed mathematical discourse. In: A. Isabel Sacristán & J. Carlos Cortés (Eds.). *"Entre Culturas / Across Cultures" – Proceedings of the 42nd annual meeting of the North-American chapter of the International Group for the Psychology of Mathematics Education (PME-NA)* (pp. 1448-1449). PME-NA.

Krause C.M. & Wille A. M. (to appear). Sign language in light of mathematics education: an exploration within semiotic and embodiment theories of learning mathematics. *American Annals of the Deaf - Special Issue on 'Critical Topics in Mathematics Education: Research to Practice with Deaf/Hard-of-Hearing Students'.*

Kurz C. & Pagliaro C.M. (2020). Using L1 sign language to teach mathematics. In: R. S. Rosen (Ed.). *The Routledge handbook of sign language pedagogy* (pp. 85-99). Routledge. Doi: 10.1093/deafed/enp015.

Lambert R. (2019). Political, relational, and complexly embodied; experiencing disability in the mathematics classroom. *ZDM Mathematics Education*. Doi: 10.1007/s11858-019-01031-1.

Legge 5 febbraio 1992, n. 104, Legge-quadro per l'assistenza, l'integrazione sociale e i diritti delle persone handicappate, *Gazzetta Ufficiale* Serie Generale n.39 del 17-02-1992 - Suppl. Ordinario n. 30.

Legge 8 ottobre 2010, n. 170, Nuove norme in materia di disturbi specifici di apprendimento in ambito scolastico, *Gazzetta Ufficiale* N. 244 del 18 Ottobre 2010.

Legge 13 luglio 2015, n. 107, Riforma del sistema nazionale di istruzione e formazione e delega per il riordino delle disposizioni legislative vigenti, *Gazzetta Ufficiale*, Serie Generale n.162 del 15-07-2015.

Liebowitz C. (2015, March 2015). *I am disabled: on identity-first versus people- first language.* The body is not an apology. https://thebodyisnotanapology.com/magazine/i-am-disabled-on-identity-first-versus-people-first-language/.

Marschark M., Spencer P. E., Adams J., & Sapere P. (2011). Evidence-based practice in educating deaf and hard-of-hearing children: Teaching to their cognitive strengths and needs. *European Journal of Special Needs Education, 26*(1): 3-16. Doi: 10.1080/08856257.2011.543540.

Meyer A., Rose D.H., & Gordon D. (2014). *Universal design for learning: Theory and practice.* CAST.

Ministero della Pubblica Istruzione (1975). *Relazione conclusiva della commissione Falcucci concernente i problemi scolastici degli alunni handicappati.* Consultato il 12.01.2011 su http://www.edscuola.it/archivio/didattica/falcucci.html.

Ministero dell'Istruzione dell'Università e della Ricerca (2012). *Indicazioni Nazionali per il Curricolo della Scuola dell'Infanzia e del Primo Ciclo d'Istruzione.*

Ministero dell'Istruzione dell'Università e della Ricerca (2018). *Indicazioni Nazionali e nuovi scenari.*

Nathan M. (2014). Grounded mathematical reasoning. In L. Shapiro (Ed.), *The Routledge handbook of embodied cognition* (pp. 171-183). Routledge.

Nemirovsky R., Tierney C., & Wright T. (1998). Body motion and graphing. *Cognition and Instruction, 16*(2): 119-172. Doi: 10.1207/s1532690xci1602_1.

Newen A., Bruin L.D., & Gallagher S. (Eds.). (2018). *The Oxford handbook of 4e cognition*. Oxford: Oxford University Press.

Ottmar E. R., Landy D., Weitnauer E., and Goldstone R. (2015). Graspable mathematics: using perceptual learning technology to discover algebraic notation. In: M. Meletiou-Mavrotheris, K. Mavrou, and E. Paparistodemou (Eds.). *Integrating Touch-enabled and Mobile Devices into Contemporary Mathematics Education* (pp. 24-28). IGI Global.

Paas F., & Sweller J. (2012). An evolutionary upgrade of cognitive load theory: Using the human motor system and collaboration to support the learning of complex cognitive tasks. *Educ Psychol Rev, 24*: 27-45. Doi: 10.1007/s10648-011-9179-2.

Rose D. H., & Meyer A. (2002). *Teaching every student in the digital age: Universal design for learning.* Association for Supervision and Curriculum Development.

Sarver D. E., Rapport M. D., Kofler M. J., Raiker J. S., & Friedman L. M. (2015). Hyperactivity in attention-deficit/hyperactivity disorder (ADHD): impairing deficit or compensatory behavior?. *Journal of Abnormal Child Psychology*, *43*(7): 1219-1232. Doi: 10.1007/s10802-015-0011-1.

Scherr R. E., Close H. G., Close E. W., Flood V. J., McKagan S. B., Robertson A. D., et al. (2013). Negotiating energy dynamics through embodied action in a materially structured environment. *Phys. Rev. Special Topics Phys. Educ. Res.*, 52: 291-294. Doi: 10.1119/1.4872412.

Shapiro L. (Ed.). (2014). *The Routledge handbook of embodied cognition.* London: Routledge.

Shimizu V. T., Bueno O. F. A., & Miranda M. C. (2014). Sensory processing abilities of children with ADHD. *Brazilian Journal of Physical Therapy, 18*(4): 343-352. Epub July 25. Doi: 10.1590/bjpt-rbf.2014.0043.

Sinclair N., & Heyd-Metzuyanim E. (2014). Learning number with TouchCounts: The role of emotions and the body in mathematical communication. *Technology, Knowledge and Learning, 19*(1-2): 81-99. Doi: 10.1007/s10758-014-9212-x.

Stokoe W. C. (1963). Sign Language structure. *Annual Review of Anthropology, 9*: 365-390. Doi: 10.1146/annurev.an.09.100180.002053.

Tancredi S., Chen R. S. Y., Krause C., & Siu Y. T. (in press). The need for SpEED: Reimagining accessibility through Special Education Embodied Design. In: S. L.

Macrine, & J. M. Fugate (Eds.). *Movement matters: How embodied cognition informs teaching and learning*. Cambridge: MIT Press.

Tomchek S. D., & Dunn W. (2007). Sensory processing in children with and without autism: a comparative study using the short sensory profile. *American Journal of Occupational Therapy, 61*(2): 190-200. Doi: 10.5014/ajot.61.2.190.

Toro J., Kiverstein J., & Rietveld E. (2020). The Ecological-Enactive model of disability: Why disability does not entail pathological embodiment [Hypothesis and Theory]. *Frontiers in Psychology, 11*(1162). Doi: 10.3389/fpsyg.2020.01162.

Varela F. J., Thompson E., & Rosch E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge: M.I.T. Press.

Vanacore R., Gomez Paloma F. (2020). *Progettare gli spazi educativi. Un approccio interdisciplinare tra architettura e pedagogia.* Anicia.

Vogelstein L., Brady C., & Hall R. (2019). Reenacting mathematical concepts found in large-scale dance performance can provide both material and method for ensemble learning. *ZDM Mathematics Education, 51*(2): 331-346. Doi: 10.1007/s11858-019-01030-2.

Wilson A.D., Golonka S. (2013). Embodied cognition is not what you think it is. *Frontiers in Psychology, 4*(58): 1-13. Doi: 10.3389/fpsyg.2013.00058.

World Health Organization (2001). *The International Classification of Functioning, Disability and Health (ICF).* WHO.

World Health Organization (2007). *The International Classification of Functioning, Disability and Health, Children and Youth version (ICF-CY)*. Geneva: WHO.

Vygotsky L.S. (1962). *Thought and language*. Cambridge: MIT Press (original work published 1934).

Yeh C., Ellis M., & Mahmood D. (2020). From the margin to the center: A framework for rehumanizing mathematics education for students with dis/abilities. *The Journal of Mathematical Behavior*, *58*, 100758. Doi: 10.1016/j.jmathb.2020.100758.