

How Cognitive Science Can Inform Inclusive Teaching Design for Students with Learning Differences

Ziyan Chen

Sichuan Normal University, Chengdu, Sichuan, China

1181726410@qq.com

Abstract. This essay examines how cognitive science can inform inclusive teaching design for students with learning differences, including dyslexia, ADHD, autism spectrum conditions, and differences in working memory and attention. It argues that inclusive pedagogy can be strengthened by integrating distributed cognition, embodied cognition, and neurodiversity. Distributed cognition shifts attention from individual deficits to the design of tools, peers, and classroom environments that reduce cognitive load. Embodied cognition highlights gesture, movement, and manipulation as integral to meaning-making rather than optional teaching aids. Neurodiversity provides the ethical framework for treating cognitive variation as a natural part of classroom life and for designing multiple routes into learning and assessment. Using a Year 3 fractions lesson as an example, the essay shows how these frameworks can be translated into practical strategies. It also critically examines limitations, including implementation at scale, risks of dependency, uneven evidence for universal design, and the danger of neurodiversity remaining rhetorical without structural change. The essay concludes that cognitive science supports inclusive teaching when theory, evidence, and student agency are held together.

Keywords: cognitive science, inclusive teaching, learning differences, distributed cognition, embodied cognition.

1. Introduction

In contemporary classrooms, student learning differences – such as dyslexia, ADHD, autism spectrum conditions, and variations in working memory and attention – are the norm rather than the exception. Traditional “one-size-fits-all” teaching often attributes difficulties to individual deficits, leading to remedial or segregated approaches. Cognitive science, an interdisciplinary field studying human mental processes, offers a fundamentally different perspective. Instead of asking “what is wrong with this student?”, cognitive science asks “how does this student’s cognitive system work, and how can the environment be redesigned to support it?” This essay argues that three cutting-edge cognitive science frameworks – distributed cognition, embodied cognition, and neurodiversity – can guide inclusive teaching design for students with learning differences. Each framework provides a distinct pathway: distributed cognition focuses on offloading cognitive demands onto tools and environments; embodied cognition engages the body in meaning-making; and neurodiversity reframes cognitive differences as natural variations rather than deficits. Together, they offer a coherent, actionable foundation for inclusive pedagogy.

2. Rethinking Learning Differences: From Labels to Functional Dimensions

Before applying cognitive science theories, it is necessary to reconsider how we understand learning differences. Special education discourse often relies on medical diagnostic labels (e.g., “ADHD child”, “dyslexic student”). While labels may secure resources, they also risk stigmatisation and low expectations. Cognitive science provides an alternative: focusing on dimensions of cognitive function rather than diagnostic categories. Key dimensions include working memory capacity, attentional control, processing speed, long-term memory retrieval efficiency, and metacognitive ability. These dimensions are continuously distributed across the population, with no clear boundary between “typical” and “atypical”. A student with dyslexia may have a weaker phonological loop but stronger visuospatial processing; a student with ADHD may struggle with inhibitory control but excel

in divergent thinking. This dimensional view empowers teachers to identify specific cognitive strengths and weaknesses and adjust instruction accordingly – without needing clinical training.

3. Three Cutting-Edge Cognitive Science Theories and Their Inclusive Applications

3.1. Distributed Cognition: Offloading Cognitive Load onto the Environment

Distributed cognition [1] proposes that cognition is not confined to the individual mind but is distributed across people, tools, artefacts, and the environment, these do not merely augment an individual's existing cognitive capacity, they fundamentally reconfigure the functional organisation of the cognitive system [2]. According to this theory, a student's effective cognitive capacity depends not only on their working memory but also on how well the environment is designed to offload cognitive demands. For example, a checklist for multi-step division problems becomes part of the student's cognitive system, freeing working memory for higher-level reasoning. Translating this to inclusive teaching, three strategies emerge. First, provide permanent external memory supports: visual schedules, anchor charts, graphic organisers, calculators, spell-checkers – made always accessible, not removed after a lesson. Second, design collaborative structures that distribute cognitive tasks: jigsaw activities, think-pair-share with assigned roles, and peer tutoring all allow the group's collective cognitive system to compensate for individual limitations. Third, use environmental cues such as colour-coded folders, transition timers, or a "parking lot" for off-topic questions. These act as external cognitive regulators, reducing executive function load for students with attentional or organisational difficulties. However, simply placing such cues in the classroom does not guarantee their effectiveness. Distributed cognition is not merely a static allocation of tasks across people and tools. Effective inclusive teaching requires designing for productive interaction among students, between students and artefacts, and even between artefacts themselves. A visual timer, for instance, must be interpretable and actionable by the student, not simply present in the room. The key question becomes not "what is wrong with this student?" but "how can we reconfigure the cognitive system – student, tools, peers, environment – for success?"

However, not all cognitive processes can or should be distributed. Higher-order reasoning, creative insight, and metacognitive regulation remain centrally anchored in the individual. Distributed cognition does not imply that the learner's mind is 'empty' or merely a passive recipient of environmental inputs. Rather, the goal of inclusive design is to strategically distribute lower-level or resource-intensive sub-tasks (e.g., memory load, step sequencing) so that the student can free up cognitive resources for the kinds of deep, constructive thinking that only the individual can do. In this sense, the environment supports but never substitutes the learner's own agency and understanding [3].

3.2. Embodied Cognition: Engaging the Body in Meaning-Making

Embodied cognition challenges the Cartesian dualism that has long underpinned traditional cognitive science [4]. Unlike information-processing models that treat the body as a mere input-output device, embodied cognition argues that cognitive processes are constituted by the body's sensorimotor systems, its lived experiences, and its dynamic interactions with the environment. Three key principles emerge from this framework: embodiment (cognition depends on the body's structure and experiences), situatedness (cognition is always embedded in a specific context), and emergence (cognition arises from the self-organising interaction of brain, body, and environment) [5]. Embodied cognition challenges the traditional "computer metaphor" of the mind, arguing that cognitive processes are grounded in the body's interactions with the physical world [6]. Abstract thinking – mathematical reasoning, language comprehension – is built upon sensorimotor experiences. In educational contexts, gestures, manipulations, and whole-body movement are not mere aids but constitutive parts of learning. For students with learning differences, this is powerful. A child with dyslexia may grasp phonics through tracing letters; a student with ADHD may sustain attention when

allowed to stand or gesture; a learner with language impairment may understand narrative through physical re-enactment. However, embodied strategies must be offered as options, not mandates, respecting students who may find movement aversive due to sensory sensitivities or motor difficulties. Three evidence-informed strategies are recommended. First, embed gesture into instruction: teachers using consistent gestures (e.g., sweeping hand for “whole” fraction, pinching for “part”) improve comprehension for all, especially those with language delays [7]. Second, use manipulatives strategically: base-ten blocks, fraction tiles, or number lines students walk along transform abstract symbols into tangible relations [8]. Third, design movement-based activities that externalise cognitive processes: a “human timeline” for historical events, a “gallery walk” with sticky notes. These serve as temporary scaffolds bridging to symbolic understanding. Beyond individual strategies, embodied cognition calls for a fundamental rethinking of teaching as a collaborative, situated, and emergent practice [9]. For students with learning differences, this means that learning is not about passively receiving decontextualised symbols but about legitimate peripheral participation — gradually entering a community of practice through embodied, meaningful activities. A student with dyslexia, for instance, may first understand narrative structure through physical re-enactment before moving to written analysis. This perspective validates the student’s body and experience as legitimate learning resources, not deficiencies to be overcome. Unlike distributed cognition, which focuses on offloading cognitive tasks onto external artefacts, embodied cognition insists that the body is not a passive ‘platform’ for tools but an active, constitutive part of meaning-making. A fraction strip held by a hand is not merely an external memory aid; the act of holding, folding, and comparing creates the very understanding of ‘half’ [10].

3.3. Neurodiversity: Reframing Cognitive Differences as Natural Variation

Neurodiversity is not a cognitive theory in the same sense as distributed or embodied cognition; it is a philosophical and ethical framework that challenges the pathologisation of cognitive differences [11]. It views dyslexia, ADHD, autism, and dyscalculia as natural variations in the human genome – not disorders to be cured. Just as biodiversity strengthens ecosystems, neurodiversity strengthens human communities by bringing different cognitive profiles and strengths [12]. From this standpoint, the goal of inclusive teaching is not to make all students learn the same way nor to “normalise” those with differences, but to design accessible and equitable environments by default. Applying neurodiversity involves several shifts. First, offer multiple means of engagement, representation, and expression – directly from Universal Design for Learning [13]. Allow students to demonstrate understanding via video, drawing, oral presentation, or essay. Second, explicitly value cognitive diversity as a classroom resource: highlight how a student with autism brings attention to detail, a dyslexic student excels at big-picture narrative thinking, and an ADHD student generates creative ideas. Third, redesign assessments to remove artificial barriers: timed tests disadvantage slow processors; dense text excludes those with reading difficulties. Extra time, text-to-speech, or quiet spaces are not “special favours” but reasonable calibrations of a mismatched environment [14]. Fourth, involve students in designing their own supports, affirming their expertise from lived experience.

3.4. Synergy of the Three Frameworks

These three perspectives are complementary. Distributed cognition tells us to externalise cognitive resources. Embodied cognition tells us to engage the body as part of understanding. Neurodiversity sets the ethical direction: differences are not deficits, and environments must change. A lesson using only distributed supports may create dependency on checklists without deep conceptual understanding. A lesson emphasising neurodiversity values without concrete design changes remains rhetorical. Only when all three work together does inclusion become actionable [15].

4. An Integrated Example: A Primary Mathematics Lesson on “Introduction to Fractions”

To illustrate how the three theoretical frameworks can work together in a real classroom, this section presents a Year 3 mathematics lesson on “Understanding halves and quarters ($\frac{1}{2}$ and $\frac{1}{4}$).” This topic marks a critical transition from whole-number thinking to fractional reasoning and is a common point of difficulty for students with learning differences, particularly those with weak working memory or attention difficulties. The learning objective is to understand the concept of “equal sharing” (fair division) and to recognise and represent $\frac{1}{2}$ and $\frac{1}{4}$.

In the introduction and activation phase, a traditional approach might involve the teacher verbally explaining “equal sharing” using a single example, such as sharing a cake. In contrast, an inclusive design based on the three theories asks each student to take a circular or rectangular piece of paper, fold it in half, and tear along the fold so that they can see with their own eyes that the two parts are identical. This hands-on activity reflects embodied cognition. Simultaneously, the teacher displays a visual “equal sharing” diagram and key term cards (numerator, denominator, fraction bar) on the classroom wall, providing permanent external memory support for students with weaker working memory – an application of distributed cognition.

In the concept presentation phase, instead of having all students watch the same slide show or listen to a single teacher explanation, the teacher provides three versions of the learning material: ① an animated video showing a circle split into two equal parts with one half coloured; ② a real-object demonstration (cutting an apple or play dough); ③ a step-by-step drawing guide accompanied by a short teacher-recorded audio explanation that can be replayed. Students choose which version(s) to use. This design embodies the neurodiversity principle of “multiple means of representation”, allowing students with different cognitive strengths to find the input pathway that works best for them.

In the practice and expression phase, instead of requiring all students to complete the same written worksheet (write the fraction, colour the shape), the inclusive design offers students a choice of ways to demonstrate their understanding of $\frac{1}{4}$: ① fold a square paper to show $\frac{1}{4}$ and take a photo or show the result to a partner; ② draw a square on a whiteboard and colour $\frac{1}{4}$; ③ use magnetic fraction tiles to build $\frac{1}{4}$ and explain orally to a partner. Meanwhile, a step-by-step checklist remains visibly accessible: “Step 1 – divide fairly; Step 2 – count the total number of parts; Step 3 – decide how many parts are taken.” This practice reflects both “multiple means of expression” (neurodiversity) and cognitive offloading through an external checklist (distributed cognition).

In the reflection and metacognition phase, traditional lessons often omit this step or relegate it to homework. In the inclusive design, during the last two minutes of the lesson, students answer two questions on a sticky note or orally: “What helped me understand fractions today? (e.g., folding, listening to audio, watching the video, asking a friend...)” and “What is still confusing?” The teacher collects these responses to adjust the next lesson. Although not a core component of the three main theories, this brief reflective practice serves as a simple metacognitive scaffold that further supports self-regulation.

It is important to emphasise that this 40-minute lesson does not lower mathematical standards – every student must understand equal sharing and the meaning of one-half and one-quarter. The only difference lies in the pathway to understanding: some students learn through hands-on folding (embodied), some through watching an animation (visual + auditory), and some through repeated audio listening. External supports (key term cards, checklist) remain visible at all times, so students do not need to hold instructions in working memory. Moreover, allowing students to choose their response format respects neurodiversity and reduces assessment bias caused by writing or language difficulties.

5. Critical Discussion: Challenges and Limitations

Several caveats must be acknowledged. First, the three frameworks are not universal solutions. An external support that helps one student may distract another; an embodied activity that increases engagement for some students may be uncomfortable or overwhelming for students with sensory sensitivities, anxiety, or motor difficulties. This means that inclusive teaching cannot be reduced to a fixed checklist of strategies. The same visual timer, gesture, manipulative, or assessment choice may function differently depending on the learner, the task, and the classroom context. Teachers therefore need to treat these strategies as hypotheses to be tested through formative assessment and student feedback, not as guaranteed interventions.

Second, distributed cognition creates a productive but delicate tension between support and dependency. If checklists, calculators, graphic organisers, or peer roles are used only to help students complete tasks, they may unintentionally prevent students from developing internal strategies and metacognitive control. However, removing supports too quickly can also recreate the very barriers that inclusive design seeks to reduce. The central question is therefore not whether external supports are good or bad, but how they are faded, combined, and discussed. A strong inclusive lesson should make students aware of why a support helps them, when it is useful, and how they might adapt it independently in future learning situations. In this sense, distributed cognition should expand student agency, not replace it.

Third, the evidence base for Universal Design for Learning and related inclusive frameworks requires careful interpretation. CAST [13] offers a powerful design language through multiple means of engagement, representation, and expression, but a design principle is not the same as proof that every version of the principle works equally well in every classroom. At scale, UDL can become a broad slogan rather than a carefully implemented pedagogy: teachers may offer superficial choices without changing the cognitive demands of the task, or schools may adopt inclusive language while leaving assessment structures unchanged. The empirical studies on gesture, manipulatives, and extra time are valuable because they give more concrete evidence for particular mechanisms, yet they also show that effectiveness depends on task design, student profile, and implementation quality [7, 8, 14].

Fourth, neurodiversity is ethically important but can become rhetorical if it is not accompanied by structural change. Celebrating dyslexic, autistic, or ADHD strengths may challenge deficit thinking, but celebration alone does not change large classes, timed examinations, narrow curricula, or inaccessible written materials. There is also a risk of romanticising learning differences by overemphasising strengths while underplaying real difficulties such as fatigue, anxiety, slow processing, or executive-function challenges. A more rigorous neurodiversity approach must hold both truths together: cognitive differences can be valuable forms of human variation, and students may still need targeted, evidence-informed support. Inclusion therefore requires both cultural recognition and practical redesign.

Fifth, the three frameworks sometimes pull teaching design in different directions. Distributed cognition may prioritise external tools and environmental organisation; embodied cognition may prioritise movement, manipulation, and situated activity; neurodiversity may prioritise choice and student self-advocacy. These priorities are complementary in principle, but they can conflict in practice. For example, a highly structured checklist may reduce executive load, but too much structure may limit the flexible choice valued by neurodiversity. A movement-based activity may deepen understanding for many learners, but it may also increase noise and sensory demands for others. Inclusive design therefore requires professional judgement rather than automatic application. Teachers must balance access, challenge, student dignity, and curriculum goals.

Finally, resource and institutional constraints cannot be ignored. Teachers may support inclusion in principle but work within systems shaped by limited planning time, insufficient training, standardised testing pressures, and uneven access to technology or classroom assistants. This is why low-cost strategies—such as consistent gestures, visible step cards, flexible response formats, and student reflection prompts—are important. Nevertheless, individual teacher creativity cannot compensate for all structural barriers. For cognitive science to inform inclusive education seriously,

schools must invest in professional development, accessible assessment policies, and classroom designs that make flexible support normal rather than exceptional. The value of these frameworks lies not in promising perfect inclusion, but in shifting responsibility from the supposedly deficient learner to the design of the learning system.

6. Conclusion

Cognitive science does not merely explain why some students struggle; it provides proactive design principles for inclusion. Distributed cognition shows that tools, peers, and classroom environments can reduce unnecessary cognitive load. Embodied cognition shows that movement, gesture, and manipulation can form part of conceptual understanding rather than simply decorate instruction. Neurodiversity gives these strategies an ethical direction by reframing learning differences as natural variation and by challenging deficit-based assumptions. Taken together, however, these frameworks also warn against simple solutions. Supports must be responsive rather than standardised, embodied activities must remain optional rather than compulsory, and neurodiversity must be translated into structural changes rather than celebratory language alone. The most inclusive classroom is therefore not one that lowers expectations, but one that provides multiple well-designed routes toward the same demanding learning goals. Teachers can begin with small changes—adding a step card, using a consistent gesture, offering a choice of assessment formats, or asking students which support helped them—while also advocating for wider institutional change. In this way, cognitive science can help transform classrooms from spaces built around an imagined average learner into learning communities where diverse cognitive styles can participate, develop agency, and succeed.

References

- [1] Hutchins, E. (1995). *Cognition in the wild*. MIT Press.
- [2] Kaptelinin, V. (1996). Distribution of cognition between minds and artifacts: Augmentation of mediation? *AI & Society*, 10, 15–25.
- [3] Salomon, G. (Ed.). (1993). *Distributed cognitions: Psychological and educational considerations*. Cambridge University Press.
- [4] Ye, H. S. (2011). The dilemma of mind-body dualism and the rise of embodied cognition research. *Psychological Science*, 34(4), 999–1005.
- [5] M. Wilson. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4), 625–636. <https://doi.org/10.3758/BF03196322>
- [6] Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, 59, 617–645.
- [7] Seccia, A., & Goldin-Meadow, S. (2024). Gestures can help children learn mathematics: How researchers can work with teachers to make gesture studies applicable to classrooms. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 379(1911), 20230156. <https://doi.org/10.1098/rstb.2023.0156>
- [8] Shvarts, A., Bos, R., Doorman, M., & Drijvers, P. (2024). Reifying actions into artifacts: Process-object duality from an embodied perspective on mathematics learning. *Educational Studies in Mathematics*, 117(2), 193–214.
- [9] Zhang, L. (2013). On the curriculum and teaching implications of embodied cognition theory. *Global Education Outlook*, 42(4), 27–32, 67.
- [10] Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
- [11] Armstrong, T. (2010). *Neurodiversity: Discovering the extraordinary gifts of autism, ADHD, dyslexia, and other brain differences*. Da Capo Press.
- [12] Chapman, R. (2021). Neurodiversity and the social ecology of mental functions. *Perspectives on Psychological Science*, 16(6), 1360–1372.
- [13] CAST. (2018). *Universal design for learning guidelines (Version 2.2)*.

- [14] Ontong, J. M., & Rossouw, M. (2024). The role of extra time in the performance of students with learning disabilities in time-constrained assessment. *Cogent Education*, 11(1), 2334559. <https://doi.org/10.1080/2331186X.2024.2334559>
- [15] Videla, R., Aros, M. B., Parada, F., Kausel, L., Sandoval-Obando, E., Jorquera, D., Ibacache, D., Maluenda, S., Rodriguez-Herrero, P., Cerpa, C., Gonzalez, M. J., Chavez, M., & Ramirez, P. (2025). Neurodiversity: Post-cognitivist foundations of the 3E approach for educational inclusion of autistic students with technology. *Frontiers in Human Neuroscience*, 18, 1493863. <https://doi.org/10.3389/fnhum.2024.1493863>