

Future Embodied Learning Technologies

Proposal
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The challenge

We evolve in a fast-paced world, transformed through technological revolutions. As a society, we need to prepare our learners and workers to be adaptive, meaning that they can adjust to new contexts, challenges, and required skill sets quickly; but also to be tech savvy, so that they can best leverage the novel technological possibilities and rise to new professional requirements.

This is a crucial societal pivot point for several reasons.

First, by failing to support this transition, we are at risk of widening the gap between those who can adapt, and those who cannot, typically low progress learners. We need to design educational interventions that work for all learners, with various backgrounds, technological competencies, as well as physical and cognitive abilities. We need to adopt a core focus on **diversity**.

Second, one of Singapore's education core values is to promote a healthy lifestyle, and support the physical and mental health of learners and workers, throughout their entire lifespan. With the rapid expansion of technology, we are at risk of creating socially alienating, emotions agnostic, and stationary learning settings, resulting in a loss of motivation, poorer learning outcomes, worse physical and mental health, and low socio-emotional skills in general. We need to design learning settings that account for **well-being**.

Third, while other programmes have been looking at this challenge in the past, most of them focus on observational studies, rather than interventions. Moreover, the rare promising educational interventions are often costly to implement as they require significant involvement from learning designers and teachers, and thus only benefit a selected few: those who have access to these resources. We need to start focusing on interventions that can be rolled out **at scale**.

We need **scalable** educational **interventions**, accounting for **diversity** and **well-being**, and promoting **adaptivity** and **technological competencies**.

Embodied learning

Manipulating a proxy of a digital object helps learners improve their spatial cognition.
(Tran 2017)



The question of adaptivity is a central one in the Learning Sciences. To build adaptivity, learning interventions need to support deep understanding, and transfer. Through deep understanding, learners grasp new concepts beyond their superficial details; through transfer they are able to identify and apply them in new contexts.

Decades of research show that achieving deep understanding and transfer is hard (Singley 1989, Engle 2012). Novel approaches moving away from passive learning, towards active learning, are promising. A central example is “Productive Failure”, a pedagogical pattern of “learning through failure” leveraging students’ creativity, as they come up with their own solutions to carefully designed open problems (Kapur 2008).

However, these approaches rely mostly on cognitive resources. In contrast, sensorimotor resources remain critically underexplored (Nathan & Alibali 2021). We argue that, to address our challenge, **we must focus on embodied learning, a multi-modal active approach to learning, leveraging both cognitive and sensorimotor resources.**

What is embodied learning? When one learns a sport, be it soccer, dance, skating, it is obvious that their body plays a crucial role. But it is also clear that learning this sport is not just about the body, the mind is also highly engaged: we easily understand that both body and mind need to be involved. What about learning other topics, like physics, engineering or even mathematics? Here, we understand that the mind is crucial. But we forget about the body. The embodied learning perspective stipulates that, rather than solely our minds, our bodies and physical environments are also central to our learning process. **Learning is not just thinking in new ways, it is also moving in new ways.**



By exploring a secret relationship between the position of their hands, learners can understand the difficult concept of proportions.
(Howinson 2011)

Embodied learning activities can also include haptic feedback so learners can feel what they are manipulating, for example they can feel the energy of chemical reactions. (Müller 2024)



Generally, embodied learning is a strong and promising avenue of research to address the several facets of our challenge (Kosmas 2023).

Embodied learning is active. Learners need to explore, manipulate, and engage with the content, not only in thinking, but also in doing. Such active involvement, when restricted to the mind, already supports deep understanding (Kapur 2008), a necessary stepping stone toward adaptivity. Expanding to sensorimotor resources can strengthen this effect.

Embodied learning is multi-modal. Enabling several modalities during the learning process is necessary as learners heavily rely on their bodies and environments for cognitive offloading to avoid saturating their working memory (Wilson 2002), for example using their fingers to keep track of complex operations. This is particularly important for learners with diverse needs, for example math anxious and highly body aware students (Chatain 2024).

Embodied learning is situated. Integrating learners' bodies and environments in the learning process resembles closely how they learn in the real world, through complex and diverse stimuli. As such, learners can reconnect the content to their prior experiences, and are better prepared to learn abstract concepts (Chatain 2023b). Moreover, these situated experiences are also closer to the application context, where learners will ultimately have to apply their knowledge, and thus support transfer (Nathan & Alibali 2021), the remaining stepping stone toward adaptivity.



Explicitly teaching gestures to represent geometry concepts helps learners perform better mathematical proofs. (Walkington 2022)

Manipulating derivatives supports learners with math anxiety or high body awareness. (Chatain 2024, Chatain 2022)



Embodied learning is centered on movement. Learners move more (Kosmas 2023, Chatain 2022), and build a strong connection to their bodies and bodily sensations (Mueller 2018, Höök 2016), thus improving their physical health. Through movement, learners build a deeper understanding of the interconnectedness of their bodies, thoughts, emotions, behaviors, and contexts, and improve their mental health (Fugate 2024). Tailored activities can also support sensorimotor regulation needs, especially for younger learners (Tancredi 2022), and improve their well-being.

Embodied learning leverages technology. A promising avenue for embodied learning is spatial computing, namely Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR), through the integration of the learners bodies and contexts both in interaction and learning (Johnson-Glenberg 2019, Chatain 2023a). But beyond this, leveraging sensing technologies and AI tremendously expands the impact of these activities through the generation of scalable interventions tailored to learners' contexts and needs.

In conclusion, embodied learning fosters adaptivity through deep learning and transfer. By accounting for learners' context, reality and sensations, and by integrating movements, embodied learning supports diversity and well-being. By leveraging technology, embodied learning offers scalable interventions that encourage building of technological competencies.



Experiencing concrete embodied experiences makes learners feel more confident and interested, and prepares them better to learn the underlying abstract concepts. (Chatain 2023b)

Our strategy

To address the challenge, we devise our mission statement as follows:

We explore **embodied learning** interventions **at scale** to support **all learners** in developing the core skills necessary to **adapt and thrive** in this fast-paced world.

We articulate our proposition along three directions, guiding our research agenda.

Interdisciplinary learning design

In nature, our work is interdisciplinary. The design of successful embodied learning interventions takes root in the Learning Sciences, but not only. Other domains, such as interaction design, motivation design, avatar design, are crucial, but often ignored (Chatain 2023a).

We need an integrated design framework for Future Embodied Learning Technologies.

Technology-powered implementation

Often, the technological implementation of educational technologies starts from the technology, rather than from realistic use cases. This kind of work focuses on proving that "it is possible", but ignores the "how?" It is striking that most work in this field stops right after the prototyping stage (Eriksson 2022). Facing the urgency of the education crisis, we need to go beyond theory.

We need technological solutions for embodied learning implementable in practice.

Rigorous assessment

New ways of learning call for new ways of assessing learning. Currently, learners are asked to sit quietly, and solve exercises on paper. Not only is this restricting their cognitive processes, but it is also failing to capture evidence of preliminary learning, which is always embodied (Roth 2001, Chatain 2023c). Moreover, current assessments happen after the learning process, when it is too late to course-correct.

We need robust, scalable, real-time assessment of learning in all its forms.

Our directions are centered around advancing and achieving embodied learning. To complement these and ensure the applicability and impact of our research, we define three lenses, informed by real use cases, central to the Singaporean educational context.

Diversity

All learners have different needs and circumstances, be it from their personality, identity, skills, abilities, or immediate context. Leveraging sensing technologies, we can evaluate the state of the learner. Leveraging AI, we can personalize the content accordingly.

Our solutions acknowledge individual differences and support all learners.

Well-being

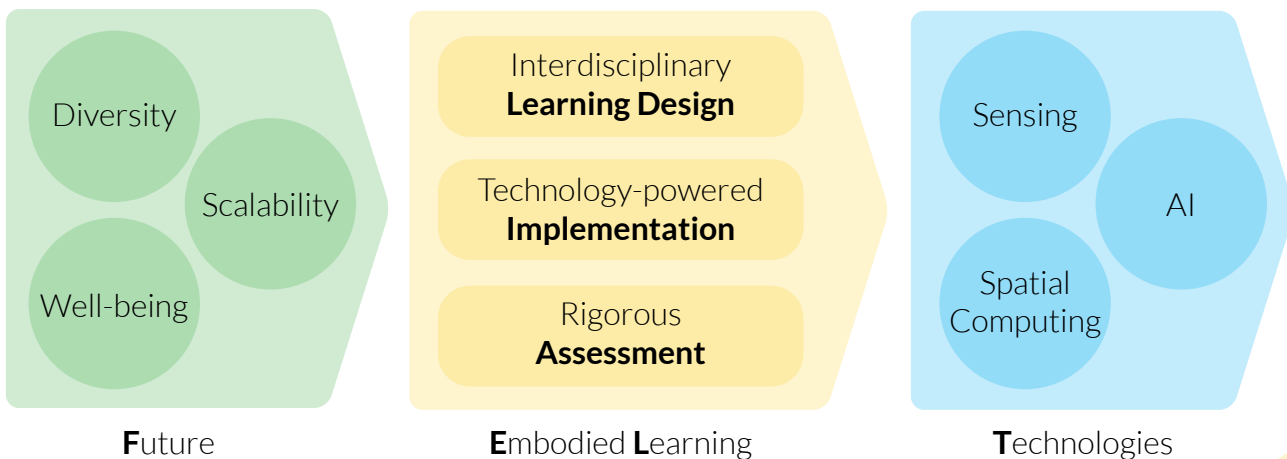
The Singaporean education system aims to foster a “love for learning that stays for life”. Not only is this important for learning, but explicitly focusing on well-being helps learners build self-awareness, self-management, and general socio-emotional skills.

Our solutions support learners’ mental and physical well-being over their entire lifespan.

Scalability

As part of their master plan, the MOE aims to “strengthen a culture of sharing and adapting tech-enhanced lectures, resources, and good practices”. This is crucial to ensure that all students benefit from these interventions, across the country and beyond.

Our solutions can be rolled out at scale with limited extra effort from lecturers.



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