12 Conceptualising technology-enhanced embodied pedagogy

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Introduction

Learning and human cognition are holistic embodied activities in which the physical body, interactions with the social and cultural environment, and sensory and motor experiences are intertwined (Frangou & Körkkö, 2020; Sullivan, 2018). Body-mind integration in technology-mediated learning refers to the use of technology to engage both the physical and mental aspects of a learner, promoting a holistic and immersive learning experience. For example, virtual reality for learning anatomy through exploring 3D models of the human body can incorporate haptic feedback devices such as gloves or vests to stimulate the mind (cognitive understanding) and body (sensory input).

The advancement of digital technologies has significantly impacted our social, political, and cultural domains, increasing the need to integrate technologies into pedagogical practices at all levels of education. Some studies have shown considerable benefits of incorporating embodied perspectives into technology-enhanced learning environments in the contexts of special education, languages, STEM (science, technology, engineering, and mathematics), and STEAM (science, technology, engineering, arts, and mathematics) education in elementary and middle school (Kosmas & Zaphiris, 2023; Lindgren et al., 2016; Xu & Ke, 2020).

In what follows, we first look at the learning experience (LX) design experiment (Georgiou & Ioannou, 2021), which is, so far, the only technology-enabled embodied learning design experiment derived from the 4E embodied cognition framework. We have included it in this chapter specifically because it offers empirical evidence and has a perspective on learning as a cognitive, kinaesthetic, and socio-emotional process. Second, we examine the framework for technology-enabled embodied learning environments (TEELEs) by Xu et al. (2021), in which the concepts of presence, immersion, and agency overlap through physical, sensory, and cognitive features in learning. The TEELE framework was chosen in this chapter for its unique view on embodied immersion and how it embodies technology use by providing valuable practical directions. Third, we look into the model of technology-enhanced

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affective learning (Frangou & Körkkö, 2020), which sees cognition as a socio-emotional process interlaced with cultural, ethical, and cognitive aspects. This model strengthens the theoretical background of this chapter. By merging the three models' common fundamental practice-oriented principles, we offer a new model for technology-enhanced embodied pedagogy as a practical tool for teachers wishing to create holistic, technology-enabled learning experiences.

Learning experience design and technology-enabled embodied learning environment frameworks

In this paper, we build on socio-constructivist and sociocultural perspectives on learning (Lave & Wenger, 1991; Vygotsky, 1978). We understand learning to be constructed upon existing knowledge and connected to all activities inside and outside the learner, hence encompassing sociocultural contexts and artefacts, and taking into account the learner as a whole. Therefore, learning is a situated activity that involves social and cognitive processes, leading learners to participate in their community's sociocultural practices (Lave & Wenger, 1991). This view is in line with the 4E cognition framework, in which embodied learning is defined as encompassing four elements (Lund et al., 2019; Newen et al., 2018):

a Embodied learning (i.e., learning is a cognitive and bodily process)
b Enactive learning (i.e., learning is active and interactive)
c Extended learning (i.e., learning can occur with and through a medium)
d Embedded learning (i.e., learning occurs within physical and sociocultural learning environments)

Learning experience design

The 4E elements (embodied, enactive, extended, and embedded learning) form the basis of the LX design experiment by Georgiou and Ioannou (2021). The study aimed to determine how teachers and students perceived the LX design and how it impacted students' engagement and subsequent conceptual learning gains regarding geometry (angles). The LX design was implemented and evaluated by eight primary school teachers in Cyprus as part of the mathematics curriculum in 13 primary education classrooms in eight schools, with 213 students from the third to fifth grades (ages 8–10).

The experiment included four learning stations: two incorporated technology, while the other two had paper, pencils, and traditional mathematics props. The technology used included the Kinect-based angle-maker (see Figure 12.1) embodied learning application projected onto a screen, and Bee-Bot and Blue-Bot floor robots (see Figure 12.2) coded to make predefined angles in their movements. The angle-maker is a noncommercial application that uses the

Figure 12.1 Kinect-based angle calculations are made by looking at the human body's different angles. Photograph by Satu-Maarit Korte.

Kinect camera—a line-of-motion sensing device—to track students' arm movements and create a visual representation of body movements on the screen (Georgiou & Ioannou, 2021).

Bee-Bot and Blue-Bot (see Figure 12.2) are floor robots that are programmable from the six directional keys on their "backs" to make up to a 40-command code, according to which the robot moves; Bee-Bot is often used for teaching computational thinking to children (Angeli & Valanides, 2020). Blue-Bot has the same function keys, but it is transparent so that its hardware is visible, and it can also be connected to and programmed through a mobile application via Bluetooth.

The LX design learning experiment (Georgiou & Ioannou, 2021) lasted 80 minutes; students were divided into mixed-ability groups of four to five students in the same grade. At the technology-enhanced learning stations (angle-maker and floor robots), the students took turns using technology to learn geometry while the other students provided feedback and support. The study

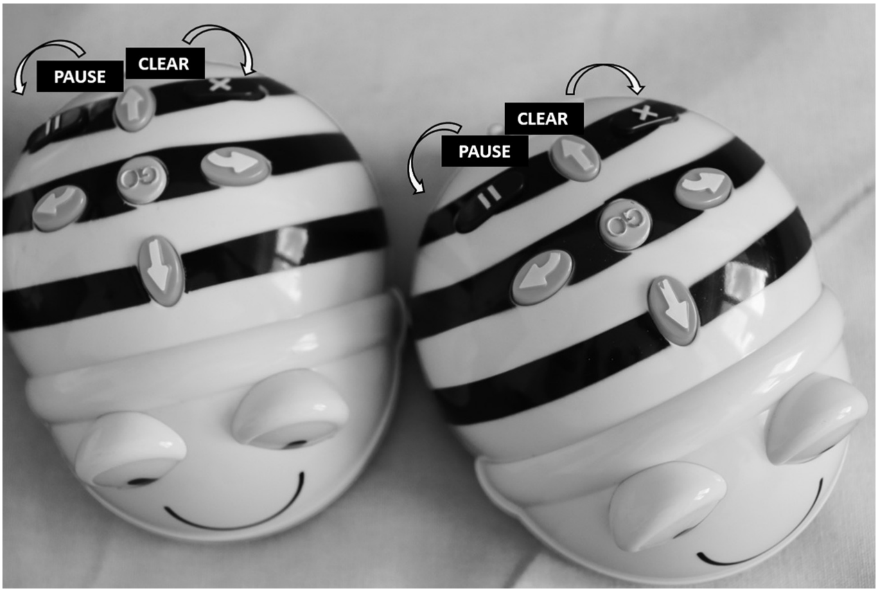

Figure 12.2 Bee-Bot floor robots. Photograph by Satu-Maarit Korte.

data was collected through students' appraisals of the LX design, their pre- and post-conceptual tests consisting of five mathematical tasks involving angles, student engagement surveys (cognitive, emotional, and social engagement), and teachers' interviews after the intervention.

The students especially appreciated the kinaesthetic nature of the angle-maker and, thus, the possibility of integrating moves and gestures into the learning content. When evaluating the LX design, the students made positive statements related to the use of robotics and the game-based approach that guided the design of the learning stations. The students also appreciated working collaboratively and using technology, computers, and tablets to programme the Bee-Bot/Blue-Bot floor robots. The students mentioned positive emotions experienced during the intervention, most commonly enjoyment and excitement. The students felt that the learning experiment had improved their conceptual understanding of angles, as well as their digital skills. The LX design also enhanced the students' positive attitudes towards learning mathematics.

The teachers shared similar thoughts: They found the experiment contributed positively to the students' knowledge acquisition, conceptual understanding, digital skills, engagement and motivation, collaboration, and communication. The teachers related the increase in students' knowledge acquisition to features of the embodied learning application that allowed diverse bodily involvement, the use of multiple senses (sight, touch, and hearing), the visualisation of abstract concepts, and real-time feedback (such as hints). Increases in student engagement and motivation were similarly related to the application, especially its playfulness, the novelty of the learning approach, and the application's immersive and user-friendly interface. Students' collaboration and communication skills improved significantly because of the structure of the LX design, facilitating teamwork and support for each other at learning stations.

This LX design experiment was planned around the 4E elements. Embodied learning is integrated into the LX design through the involvement of the body in the cognitive process with the bodily movements of the limbs, facilitated by the angle-maker application. Enactive learning is manifested through the interactive features of the intervention, as well as the active features of the angle-maker application. Extended learning can be seen in that learning occurs with and through the medium of the angle-maker application. Finally, embedded learning is an integral part of the intervention because learning occurs within both physical and interactive sociocultural learning environments, where angles are understood to exist everywhere.

Embodied immersion framework

TEELEs, and their salient potential for embodied features in learning designs, were investigated by Xu et al. (2021). Their review article on 28 empirical studies of TEELEs formed the foundation for the development of an embodied immersion framework. Most of the studies involved science and language learning, and they were conducted at all levels of education. The framework seeks to understand the features of embodiment and conceptualise how to embody technology use by providing valuable practical directions. The embodied immersion framework stems from the sometimes overlapping concepts of presence, immersion and agency, and has three major dimensions: physical, sensory, and cognitive immersion (Xu et al., 2021). Presence can be seen as the psychological sense of consciousness and response to the technology-enhanced learning environment, whereas immersion or engagement can be considered the illusion of reality projected by the affective properties of the technological hardware (Calleja, 2014). Agency is essential because it gives the technology user (i.e., the learner) a role in shaping the learning experience (Calleja, 2014). The three dimensions of the framework with their eight additional subdimensions are as follows (Xu et al., 2021):

1 Physical immersion: the means of embodiment and the number of motoric movements

   The physical immersion dimension (Xu et al., 2021) first entails the means or medium of technology-enabled embodiment. Furthermore, in an embodied technology-enabled interactive scenario, the user can be either a passive observer or an active agent, interacting with the learning material and moving their body in the process. One can also view and evaluate the number of bodily or motoric movements to define the intensity of the embodied interactions, from mouse clicks to full-body movements. In this dimension, all of the 4E framework's elements are recognisable. Embodied learning includes motoric body movements, whereas enactive learning involves activity, interactivity, and observing activity, which is passive embodiment. Extended learning occurs in TEELEs with and through a technological medium. Learning is embedded because it takes place in a certain physical environment.

2 Sensory immersion: point of view, media effects, and haptic effects

The sensory immersion dimension is subjective and, hence, more difficult to define. It is important to understand the user's point of view and perspective within the technology-enhanced learning environment. Immersive experiences offered by a learning environment that is perceived from the point of view of the first or third person can be very different. Moreover, media effects—namely, audio (music, voice, and sound effects) and video (animated or static images, videos, and texts) qualities—are significant affordances within the immersive learning environment that may enhance the sense of immersion. The haptic effect refers to the learner's ability to sense or feel their learning surroundings and receive haptic sensations, which contribute to the learner's cognitive processes as they become more involved in the activity and gain a multidimensional understanding of the learning subject. All the elements of the 4E framework are also recognisable in this dimension. Embodied learning occurs through bodily sensations; this requires that a person is actively present in the embedded learning environment in which the learning is organised with and through a technological medium.

3 Cognitive immersion: operational congruence, learning congruence, and personalisation

According to Xu et al. (2021), cognitive immersion is the bridge between the learning process and a technology-enhanced or technology-enabled immersive experience. Within cognitive immersion, motoric activities may serve operational purposes; however, in some experiments, operational congruence is higher than in others because embodied interactions are linked to operational purposes. Learning congruence, on the other hand, links embodied interactions and motoric activities with learning objectives. Some emerging learning technologies are adaptive and support personalisation based on the learner's developing abilities. This is still a growing area of research, an area Xu et al. (2021) considered critical for developing personalised learning paths that scaffold learning and enhance learners' engagement. This third dimension of the TEELEs framework is in line with the elements of the 4E framework in that embodied interactions are part of the basis of learning congruence. Learning takes place with and through a technological medium that defines the physical learning environment.

Model of technology-enhanced affective learning

The model of technology-enhanced affective learning (Frangou & Körkkö, 2020) views learning as enhanced through four core elements that are important when designing affective learning experiences: *engagement*, *elaboration*, *encouragement*, and *exploration*. *Engagement* refers to the fact that an increase in learning engagement, in which technology can play a significant role, may improve learning achievements. This can simultaneously develop the learners' agency, and positive and negative learning experiences can influence the learner's future disposition and motivation for learning.

Offering opportunities to *elaborate* on and expand positive learning experiences ensures that learners are eager to return to class. Sharing, reflecting, and *elaborating* on positive experiences are significant for promoting learning motivation.

Encouragement builds learners' self-perceptions and supports their agency, as well as the general development of the learning atmosphere. The learner's emotions and understanding of their abilities and competencies can inhibit or increase their motivation to take part in the learning activities. Sensitising learners to diverse technologies and *encouraging* them to try new ones later is good for their self-confidence and self-perception while also promoting lifelong learning.

Exploring group members' different perspectives and social and cultural backgrounds enhances learners' reflective practices and, consequently, their sensitivity to situational awareness. To support these elements, the maintenance and improvement of a positive and dialogical social learning environment is continuously facilitated. *Exploring* diversity can connect the learner not only to the learning experiment but also to fellow learners, creating a positive learning environment.

The element of engagement correlates with the dimensions of the 4E framework by involving cognitive and bodily processes in an active and interactive learning environment. The physical and sociocultural learning environment is designed to take advantage of technological mediums, possibly embodied, that have the potential to enhance engagement and motivation. At the same time, the element of elaboration is an active and interactive process that can be seen in the 4E framework as an activity in which learners can be both alone and with others. Elaboration can also be done with and through technological mediums in diverse physical and sociocultural learning environments. The element of encouragement can be seen in learning as both enactive and extended, as per the 4E framework: learning is active and interactive, and it can occur with and through a medium. The element of exploration is recognisable in the 4E framework, particularly in enactive and embedded learning. This involves active and interactive learning, which occurs within physical and sociocultural learning environments.

In what follows, by merging the aforementioned three frameworks' common and fundamental practice-oriented principles, we offer a new model for technology-enhanced embodied pedagogy as a practical tool for teachers wishing to create holistic, technology-enabled learning experiences.

Technology-enhanced embodied pedagogy

Given the diversity of the models discussed earlier (Frangou & Körkkö, 2020; Georgiou & Ioannou, 2021; Xu et al., 2021), it is essential to focus on their common features. The LX design experiment (Georgiou & Ioannou, 2021) highlights selecting embodied applications that enable the integration of the physical body, motion and cognition, and a learning approach based on student collaboration. Conceptual understanding is promoted by guiding students to work through conceptually connected learning stations or other modules. It is assumed that immediate feedback and peer feedback may play a role in motivation and learning outcomes (Georgiou & Ioannou, 2021). The TEELEs (Xu et al., 2021) framework has three dimensions of immersion—physical, sensory, and cognitive—which are all essential when promoting immersiveness together with all eight subdimensions of immersion. The model of technology-enhanced affective learning (Frangou & Körkkö, 2020) illustrates the core elements that are important when designing affective learning experiences: engagement, elaboration, encouragement, and exploration.

Figure 12.3 shows the essential elements of technology-enhanced pedagogy based on the principles that summarise the key features of the three

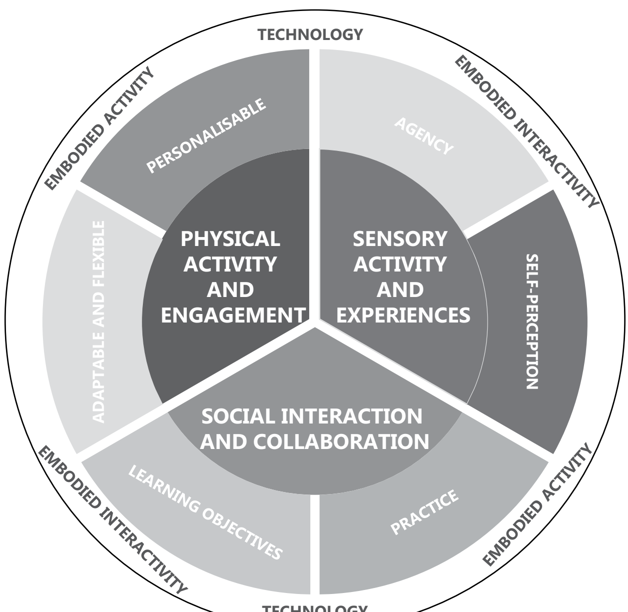

Figure 12.3 Technology-enhanced embodied pedagogy.

discussed models. First, as the figure's fundamental principle (background circle of Figure 12.3), learning involves diverse *technologies* and exposure to technologies (e.g., angles are investigated with the help of a Kinect-based angle-maker application, and computational thinking and coding can be taught through Microsoft Minecraft Education Edition and LEGO robot building and programming). As a result, technology and media are integrated into the learning environment and/or context. Therefore, the learning environment promotes *embodied activity and interactivity* (e.g., the use of an angle-maker application as a group activity and the use of makerspaces, such as arts and crafts rooms).

Second, both the LX design (Georgiou & Ioannou, 2021) and the TEELEs (Xu et al., 2021) framework emphasise physical features (inner circle of Figure 12.3). Hence, learning involves *physical activity and engagement* (e.g., the Kinect-based PanBoy application for language learning or the Kinems learning games). It would be optimal if the learning were *personalisable*, *adaptable*, and *flexible* (outer circle of Figure 12.3) (Xu et al., 2021) to support the *elaboration* (Frangou & Körkkö, 2020) on and expansion of positive learning experiences.

Third, learning involves *social interaction and collaboration* (inner circle of Figure 12.3) (e.g., collaborative Bee-Bot game-making or QR code navigation exercises in small groups) as per the LX design experiment (Georgiou & Ioannou, 2021) and the model of technology-enhanced affective learning (Frangou & Körkkö, 2020). Learning is linked to *learning objectives* and *practice* (outer circle of Figure 12.3) (e.g., Bee-Bot game-testing in groups, Kinems learning games, or visiting each other's Minecraft worlds) (Xu et al., 2021) while at the same time supporting the *exploring* (Frangou & Körkkö, 2020) of different perspectives.

Fourth, learning involves *sensory activity and experiences* (inner circle of Figure 12.3) (Xu et al., 2021) and *elaborates positive experiences* and *emotions* (e.g., Kinect-based applications, using a drawing application on a tablet computer or Kinems learning games) (Frangou & Körkkö, 2020; Georgiou & Ioannou, 2021). Learning promotes and *encourages agency* and *self-perception* (outer circle of Figure 12.3) (e.g., personalisable applications for learning in which the exercises become gradually more demanding) (Frangou & Körkkö, 2020; Xu et al., 2021).

The elements of the 4E framework are integrated and present in each of the model's principles, depending on the context and situation.

Embodied learning relies on the premise that knowledge is constructed by intertwining experiences, perceptions, bodily activity, and the body's sensorimotor capacities (Nathan, 2021). The principles of technology-enhanced embodied pedagogy are derived from the idea that the learning process is a holistic and multimodal activity (Frangou & Körkkö, 2020); however, to create technology-enhanced embodied learning activities, not all principles are always—or can be—present. In this chapter, we have looked into three frameworks that embrace embodied learning experiences and give some guidelines for the introduction of technology-enhanced embodied learning (Georgiou & Ioannou, 2021). In all three, we have focused on the common embodied learning features and subsequently brought them together to develop the practical pedagogical principles that teachers can apply in diverse teaching.

Technology-enhanced embodied pedagogy is an educational approach that combines technology with embodied learning experiences to enhance the learning process. The strengths of the model include its generalisability; it can be applied at all educational levels. Furthermore, it can make learning more engaging and interactive. It can capture learners' attention and motivate them to participate actively in the learning process. It provides opportunities for experiential learning and multisensory learning, which can enhance the retention and understanding of complex topics. Technology allows for the customisation of learning experiences, catering to individual learning styles and pacing. Technology can also provide immediate feedback, allowing learners to correct mistakes and reinforce their understanding in real time.

However, the model has some weaknesses. Implementing technology-enhanced embodied pedagogy can be expensive. The cost of hardware, software, and training can be a significant barrier, particularly for resource-constrained educational institutions. Furthermore, technical problems—such as software glitches or hardware malfunctions—can disrupt the learning process and frustrate both educators and learners, particularly those who are not tech-savvy. Also, not all students have equal access to technology, creating a digital divide. Those without access to the necessary devices or reliable internet connection may be left at a disadvantage. Additionally, using technology often involves collecting and analysing data, which raises privacy and ethical concerns about how that data is used and protected.

Implications for education

This chapter has provided instructional strategies within technology-enhanced embodied learning design by offering examples of technology-mediated activity-based interventions that are adaptable and usable in any classroom. Technology-enhanced embodied pedagogy is important as it offers a unique approach to education that leverages technology to enhance the learning process through embodied experiences. Furthermore, it can enhance engagement, improve learning outcomes, promote inclusivity, prepare students for the digital world, and encourage innovation in education. This chapter provides a reference for practitioners who seek to design technology-mediated learning experiences that link movement and learning objectives. However, we acknowledge that, in many cases, educational technology or tools are neither necessary nor accessible. The teacher can still take advantage of the embodied learning approach with non-digital media or even without any media at all. In conclusion, technology-enhanced embodied pedagogy offers a dynamic and effective approach to teaching and learning that aligns with the evolving needs of learners and the demands of the 21st century.

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