# Inclusive and AI Design: Reflections and Challenges for Enaction Design

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**> Abstract** • We focus on the enactivist principles of inclusive design and AI from the perspective of relational engineering. Additionally, we outline critical challenges and reflections on the potential of enaction design in response to the growing sensorimotor debilities in digital cultures.

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« 1 » In their target article, Olivier Gapenne, François Marès, Claire Littaye, Cléo Collomb and Bruno Bachimont present a motivating theoretical and ethical study, exemplary of their vision of enaction design. The authors suggest four necessary and sufficient relations for designing with digital technologies: supplementing, substituting, instructing, and assisting. These four relations are conceived within the framework of relational engineering derived from enactive design.

« 2 » Conventional UX (User Experience) and UI (User Interface) designs create a prototypical experience profile for interacting with various technological devices, based on user needs and the architecture of hardware and software. In contrast, enaction design prioritizes the creation of four human–computer relationships based on phenotechnical use regimes, inspired by the constitution of human experience and the types of couplings between a subject and their environment through technological devices.

« 3 » In this article, we highlight two fundamental aspects that could expand and enrich the discussion on supplementation, substitution, and instruction relationships within the framework of relational engineering in enaction design: (a) Inclusive design and enactivist variations (b) Sensorimotor debilities in digital cultures. More concretely, we discuss the supplementation relationship for generating technological devices for people with sensory diversity, such as in the case of learning for blind individuals. Additionally, we explore the role of substitution in the design of devices based on AI systems, like the autopilot in Tesla cars. We reflect on the role of uncertainty in technological design with AI and the extent to which these systems emulate expert driving in hostile environments. Finally, we discuss the instruction relationship concerning sensorimotor debilities in the design of immersive technology, based on professional training for individuals with qualified experience. We outline a critique based on the devaluation of the body and agency in immersive educational contexts of virtual and mixed reality.

## Inclusive design and enactivist variations

« 4 » In §5 of their target article, the authors argue that the four relations (supplementing, substituting, instructing, and assisting) –

> “can be viewed from the perspective of the designer, that is to say externally, as instrumented human-environment couplings, or, alternatively, from the perspective of what is experienced by the humans who are party to them.”

Furthermore, they argue that both perspectives must be consistent with each other. We consider this crucial point to emphasize the roots of enactivism and two of its current variations, i.e., radical and sensorimotor enactivism, in the light of design with technologies. For an observer to establish the coherence between people’s behavior and the description from their unique perspective requires a fundamental principle to avoid the characteristic objectivity of the validation of explanations/descriptions: “Both, the phenomenon to be explained and the proposed generative mechanism, are proposed by the observer in the flow of their praxis of living” (Maturana 1997: 37, our translation). Reconciling the descriptions of the observer with the perspectives of the observed requires directing attention to the action domains that make “phenotechnical” relationships possible: the joint history of couplings and the changing context.

« 5 » Based on the above, we consider it important to establish a model integrating orthogonal aspects: on the one hand, what the observer discerns from their technical and experimental knowledge, and on the other, the multiple possible domains of user action. Therefore, the orthogonal model should incorporate a continuous iterative process with potential users, integrating different contexts and uses. The result of the orthogonal model should capture the ecological dynamics of relationships between users and devices, in contrast to conventional models typically tested in laboratories. An example of an orthogonal model is *inclusive design*, which takes into account the multiple uses by sensory-diverse[1] individuals.

« 6 » To exemplify the above and to discuss the criticism of the neutrality of technology that we share with the authors (§3), we will use a reflection based on our technological design practice that we are preparing in our Laboratorio de Innovación STEAM[2] and that we can compare with the relational engineering proposed by the authors. Challenged by the Quad[3] technological device co-constructed by the Berkeley University of California, the University of Colorado Boulder and the University of St. Louis in Missouri to teach geometry to blind people, we set out to recreate a low-cost version based on the experience of blind students participating in formal education.[4] In our longitudinal (but so far unpublished) research, we combined ethnographic observations, vid-

1| Sensory diversity refers to the congenital or acquired characteristics of individuals that affect how they process, integrate, and utilize their various senses (Bundy & Lane 2020).

2| https://www.instagram.com/innovasteam_lab

3| https://edrl.berkeley.edu/design/quad

4| https://www.cienciaenchile.cl/a-un-bajo-costo-dispositivo-tecnologico-permitira-el-aprendizaje-de-geometria-a-personas-ciegas-hispanohablantes



https://constructivist.info/20/1/033.gapenne

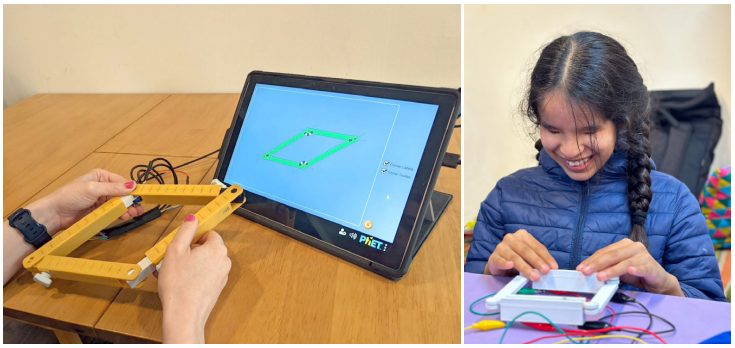

**Figure 1** • Left: the original Quad device. Right: the recreated device designed for inclusive educational contexts that use the Braille language system.

eos, photos and interviews with students between 10 and 17 years, and teachers who use the Braille system to teach with the Quad prototype. In the original Quad device (Figure 1 left), students manipulate tangible figures according to their interests, obtaining as a result a sound according to the simulated figure with the hands, which in turn is reflected on a computer or tablet screen. Unlike the original Quad Prototype, which focuses on grasping as the fundamental action to shape figures and thus concepts by moving the sides of the device, our design-based research in formal Braille-education contexts (Figure 1 right) revealed that blind students follow different explorative routes. These alternative routes highlighted the stealthy and positional movement of fingers on the upper surface of the device, rather than the gripping action suggested by the original prototype. Through strategically positioning their fingers, blind students gradually refined their more generic movements into more specialized actions to shape geometric figures. These actions challenged the original model, leading our team to restructure the design based on modifications to the device. We began to see this in different contexts, in individuals and in groups, as well as in students of different ages who learn diverse material in technological environments. When inquiring with teachers who teach blind people, we found that the Braille system, as a semiotic structure based on the exploration using the fingers, conditioned the course of action provided by the original design.

« 7 » A key aspect of inclusive design with technologies from an orthogonal model is the continuous incorporation of contextual dynamics and experiential variability to enhance learning opportunities for sensory-diverse individuals. This goal is relevant to other design challenges with technologies, particularly in the field of artificial intelligence. A characteristic example is the programmers at Tesla's AI Lab, who strive to create increasingly reliable models of natural environments but often overlook risk paths and reckless drivers. Andrej Karpathy, the former AI director at Tesla and co-founder of OpenAI, noted, "Everything might be syntactically correct, but not everything is organized correctly, and it's really hard to know in such a complex and unpredictable world." [5] According to him, training artificial neural networks must also involve a kind of "leaky abstraction," i.e., an abstraction that does not intend to cover all possible situations. Based on these reflections on inclusive design and the current limitations of artificial intelligence in dealing with human and contextual uncertainty, we draw attention to the perspective of programmers and designers, particularly their design heuristics that could take into account the dynamics of context and the sensory diversity of users. Therefore, we ask from an enaction-design perspective: What role does relational engineering play in the context of inclusive design and artificial intelligence? Q1

5 | https://karpathy.github.io/2019/04/25/recipe

« 8 » The enactivist approach, from which Gapenne et al.'s proposal is derived, comes in a variety of versions, each of which can have different implications for technological design. The most notable variations include radical enactivism (Hutto & Myin 2012), extensive enactivism (Hutto, Kirchhoff & Myin 2014), and sensorimotor enactivism (Di Paolo et al. 2014). In their proposal, Gapenne et al. adhere to yet another version, called autopoietic enactivism (Varela, Thompson & Rosch 1991), when they write, "Enaction design derives from an approach where the problem of embodiedness is paramount, in regard to a living entity that has an autonomous, autopoietic organization" (§10). Although all these variations share the thesis that cognition is anti-representational, embodied, and situated, they have different nuances that the authors did not explore in depth, in their proposal. These nuances can vary in terms of the role of intentionality, agency, and the dynamics of sensorimotor contingencies. To highlight these nuances, we would like to draw Gapenne et al.'s attention to the concept of substitution relationships.

« 9 » The substitution relationship occurs when the organism partially or completely delegates its participation. This implies that the organism does not influence the course of actions necessary to achieve a goal, such as traveling in a vehicle from home to work. If we consider the autopilot function in Tesla cars, the decision-making of the organism is replaced by an artificial-intelligence system that learns from data captured by a set of cameras and processed by complex chains of algorithms that predict subsequent movement. This process of intelligent automation depends on the efficiency of supervised training of artificial neural networks, which are independent of the driver's history as an autopoietic system structurally coupled with their environment. Arguably, the foundations of the autopoietic enactivist approach are more restrictive in explaining the substitution relationship, where the organism's agency is fully delegated. So, we wonder: Can enaction design, framed within autopoietic enactivism as opposed to other enactivist variations, justify a substitution relationship, such as the autopilot function in Tesla vehicles? Q2

## Sensorimotor debilities in digital cultures

« 10 » In §13 of their target article, the authors argue that "[a] substitute technology can […] serve as both a supplement and a substitution." This is justified by the idea that "[d]eploying a substituting relation can […] give a person another way of accessing the effects of their actions, even when those actions are neither exclusive nor direct" (ibid). Gapenne et al. assert that using a robotic arm can help us supplement our abilities, such as lifting a set of heavy objects and fitting them into different places with considerable precision. After several hours and days of practice, our awareness of our actions with the robotic arm may fade, and thus, our supplementary relationship will transform into a substitution relationship. This seems fundamental to understanding the potential of relational engineering in the use of machines in sociotechnical contexts. However, our concern in this section is based on the latent loss of agency and embodiment in substitution processes. So, it seems desirable that enactive design should offer a way to safeguard against the dissolution of the body in the contemporary digital culture absorbed by artificial intelligence. After all, logic-based operations rooted in symbolic processing cannot replicate the kind of practical knowledge required by organisms and robots to operate effectively in their environments (Dreyfus 1972).

« 11 » Gapenne et al. do not address, in their theoretical proposal on enaction design, how to safeguard against the evaporation of the body in technological design. While the relationships of supplementing, substitution, instruction, and assisting provide a framework that considers the expansion and sophistication of skills when using various technological devices, it is unclear whether substitution relationships might lead, through continuous automation, to a loss of the body. One of us has previously expressed deep concern about the devaluation of bodily practices in digital culture (Penny 2022). This could have harmful effects on human life, such as the devaluation of DIY (bricolage) craftsmanship in art, which is essential for highlighting the aesthetic sense of art based on movement, agency, and proprioception. This raises the question: how can enaction design prevent the sensorimotor debilities inherent in substitution relationships? Q3

« 12 » Finally, considering the rise of metaverse design in various fields of development, we would like to reflect on the relationship of instruction based on qualified or expert experience. Industries such as medicine, mining, and education have begun incorporating training processes for workers using immersive technologies such as augmented, virtual, and mixed reality to offer more cost-effective and digital opportunities for professional development. In some cases, laparoscopic surgeries have been performed using mixed reality with very positive outcomes for patients.

« 13 » Regarding immersive environments, one of our virtual-reality programmers was deeply frustrated by his inability to "virtually recreate" the welding process perfectly (for example, the electrode getting stuck and the vibration of the tool). Several people with no welding experience found the result very convincing, but he was never satisfied because, during his training in high school he had had multisensory welding experiences for hours during iron- and metal-casting processes. While designing a vocational education project based on the virtual experience of welding, the sound, smell, and history of the manual coordination used became less and dimished in his bodily memory.

« 14 » One of the critical aspects we see from enaction design for the development of immersive applications for experts in a field is the oculocentric emphasis of virtual reality. The idea that the body acts solely in reference to a visual organ creates proprioceptive ambiguities that limit skilled experience. For example, in the instructional relationship, we observe a multisensory framework that is limited in its ability to operate in skilled developmental fields. While flight simulators are becoming increasingly naturalistic, we still see aerospace-engineering students feel as though they crash without injury. Based on our experience in virtual-reality design, we conclude that the performance of the code depends on the fidelity of the experience. From this perspective, how does the instructing relationship in enaction design address the multisensory ecology in professional education with immersive technologies? Q4

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