

# Experience as an Object to Think with: from Sensing-in-action to Making-Sense of action in Full-Body Interaction Learning Environments

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## ABSTRACT

We present a qualitative, idiographic study aimed at exploring how children create bridges between embodied experience and meaning construction while interacting with a Full-Body Interaction Learning Environment. Starting from the analysis of four case studies, we illustrate different possible paths through which children can transform embodied experience into an ‘object-to-think-with’ and delineate the different resources for meaning making that they employed. These outcomes contribute to expand the current understanding around embodied learning with interactive technologies, as well as suggest a set of qualities to think about interaction design and future research.

## Author Keywords

Embodied Learning; Full-Body Interaction; Concrete Experience; Embodied Cognition; Case Study

## ACM Classification Keywords

H.5.1. Multimedia Information Systems: Artificial, augmented, and virtual realities; Evaluation / Methodology

## INTRODUCTION

Over the past years, several Learning Environments based on novel interaction modalities have been developed. Grounded in the embodied cognition paradigm, these approaches have shed new light on previously neglected design aspects by moving away from the conception of the user as ‘fingers and eyes’ and by incorporating the body and space in the interactive experience. In the context of learning technologies, embodied interaction has revitalized the notion from constructivists that ‘acting-in-the-world’ is key to knowledge construction [1] and has incorporated this concept in the HCI agenda. Moreover, research on the evaluation of embodied interaction has shown benefits in fostering collaboration, exploration and meaning-making in human learning and knowledge construction [17].

Nonetheless, despite these promising initial findings, further research is still needed to understand how to properly tap and bring to fruition the potential of embodied forms of learning. As Antle suggests [2] many learning environments based on embodied interaction are still designed from a technology-driven approach that poorly understands the embodied cognition framework [4,27]. Most commonly found shortcomings derive from a naive and literal interpretation of embodied learning which, in

turn, leads to approaches oblivious to the notions that learning emerges from a network of meanings and that embodied experiences need to be transformed in order to become available for use in thinking about abstract concepts [1,14,20].

To address these shortcomings, our study aims at providing an initial exploration on how embodied experiences may be transformed into ‘objects-to-think-with’—in other words, how users’ sensing-in-action can lead them to make sense of action, taking *action* itself as an entity to operate upon. For this purpose, we present a qualitative, idiographic study aimed at exploring how children create bridges between embodied experience and construction of meaning. Specifically, we will present four case studies of children playing with a Full-Body Interaction Learning Environment. The analysis of these cases highlights how creating bridges between embodied experience and understandings can assume a variety of paths, which are situated in the network of meanings that the system affords. To conclude, we derive a set of qualities to think about design and future research.

## ONLINE AND OFFLINE EMBODIED COGNITION: IMPLICATIONS FOR DESIGN

In recent years, the notion of Embodied Cognition has engendered a significant paradigm shift across several disciplines, including cognitive science [27], social psychology [3] and learning theories [9]. This idea has its philosophical roots in phenomenology, and in particular Merleau-Ponty who re-introduced the crucial role of the body in knowledge construction.. According to this framework, cognition cannot be restricted only to the mind but arises in the relation between the mind, the body and the world [27].

This claim is supported by empirical research, which has shown that thoughts, concepts, emotions, attitudes and social competences are influenced by the role of physical states, bodily structures and experiential opportunities [4]. These findings suggest that, not only do cognitive processes involved in mastering sensorimotor contingencies meet their origin in embodied experiences, but "*also higher-level cognitive skills - as mental imagery, working memory, implicit memory, reasoning and problem solving, may arise from sensorimotor functions.*" [27].

In short, this framework postulates that, embodied cognition works both at an *'online'* and an *'offline'* level. *Online* embodied cognition constitutes one of the mechanisms upon which knowledge is constructed, and refers to meanings that people generate during a specific concrete experience. According to this hypothesis, the most pregnant perceptual, motor and introspective states lived during an experience in the world, tend to gain weight and become engrained as lasting impressions and multimodal representations that are then re-enacted in situations perceived as calling for a similar handling [4]. On the other hand, *offline* embodied cognition refers to the uses of previously acquired embodied knowledge in tasks that do not involve a specific physical experience [27]. It, thus suggests that, for instance, the understanding of certain abstract concepts may use mental structures that originally evolved from sensorimotor experiences [27]. This idea has been eloquently fleshed out by Lakoff and Johnson, who proposed the notion of “embodied schemas”, according to which the understanding of certain metaphorical concepts may be grounded in embodied experiences [12]. Examples of these can be found in the uses of spatial and directional metaphors or in concepts such as ‘balance’ or ‘container’.

From an interaction design perspective, the distinction between *online* and *offline* embodied cognition indicates two different forms in which embodied cognition can be applied to design. A first approach is through the design of concrete and embodied experiences to facilitate meaning construction. Examples of this can be found in the development of interactive systems such as Tangible User Interfaces and Full-Body Interaction. A second approach instead, relies on designing systems that use previously acquired embodied knowledge to convey abstract concepts (e.g. mathematical concepts, see [5]).

At the same time, the distinction between *on-* and *offline* embodied cognition, also indicates the necessity of paying attention to an aspect that is often neglected in the design practice, namely, the ways in which concrete and embodied experiences may or may not be transformed into explicit knowledge. In other words, how and whether people use experiences to think about abstract concepts or derive implications for action.

### **FULL-BODY INTERACTION AND LEARNING**

Grounded in the embodied cognition framework, several Learning Environments based on novel interaction modalities have been developed over the past years. For the purpose of this paper, we focus on Learning Environments aimed at supporting forms of *online* embodied cognition. In other words, we design experiences that take advantage of the benefits of physicality to enhance user experience, and facilitate learning. In this context, promising possibilities can be found in Full-body Interaction, understood as *using the movements and actions performed in physical space by the user to interact with digital technology, as well as with other users.*

Full-Body Interaction Learning Environments (FUBILEs) have been mainly designed to address the “online” aspect of embodiment and offer rich experiences, where children can interact through their bodies and senses. These multimodal experiences hold the potential to facilitate meaning-making by providing users with multiple entry paths and allowing them to construct multimodal representations [4]. In this context, a number of FUBILEs have been proposed using physical activity to support the learning of a wide range of concepts, e.g. physics [8], language [7] or mathematics [6].

Even if, from a theoretical perspective, Full-Body Interaction provides a promising venue to support learning [23], research related to its evaluation has offered a scattered panorama from which robust conclusions cannot be derived [17]. Other potential shortcomings have been identified in the lack of appropriate and consistent design and assessment methods [17]. Lastly, we suggest that additional weaknesses may be related to a poor understanding of the embodied cognition theoretical framework itself.

Taking embodied cognition seriously requires that we move beyond reductionist and positivist epistemologies and shift our attention towards relational and situated approaches [10,19]. In other words, we need to consider meaning-making as a complex process, emerging from the iterative connection between features of the socio-cultural and physical context, the affordances of an artifact, and people’s previous knowledge, interests, moods, and mindsets. [11].

In designing for FUBILEs, we can say, in retrospect, that some projects were still grounded in the premise of a *direct and unmediated one-to-one* relation between embodied experience and the construction of abstract concepts. This alleged isomorphism can take different forms. For example, we find cases based on unquestioned adult projections, such as: “if user does X then she should understand Y”. These approaches do not take into account that meaning-making is a creative act emerging from a network of personal and contextual resources and that situated experience needs to be transformed in order to become an *'object-to-think-with'*.

This tendency is reflected both in the claims of designers about their intentions, as well as the choices of specific design and evaluation strategies. A clear example is the widespread use of pre and posttest assessment methods such as multiple-choice questionnaires [17], which carries implications about the specific kind of knowledge that users should construct and is often in conflict with constructivist learning approaches.

This notion of “*you do, therefore you know*” amounts to little more, in its naïve form, than a new Cartesian dualism applied to experience design. Such reductionism calls for further examination of how experience can be transformed into knowledge (to properly inform design).

### **EXPERIENCE AS AN OBJECT TO THINK WITH**

Research in developmental psychology and studies on gestures pointed out that concrete experience needs to be transformed in order to become available and put to good uses in thinking about abstract concepts. In this context, Karminoff-Smith [13] suggested that procedural knowledge is gradually redescribed and transformed before becoming explicit, accessible and available for use. This model is consistent with studies on the relation between gestures and learning [21], which suggest that often gestures can reveal knowledge that is not yet accessible to children's awareness and verbal report [9], hence constituting an index of transition between concrete experience and abstraction.

From an applied perspective, these studies suggest that we cannot neglect the fact that learners' embodied experience needs to be elaborated and transformed in order to be able to carry abstract concepts. This idea has been powerfully expressed by Papert [20] through the notion of 'objects-to-think-with', best understood as user-appropriated cognitive tools, or artifacts that provide a tangible and shareable mid-ground between sensori-motor and abstract knowledge. The author, taking as an example his own story, describes how he transformed his concrete experience of playing with gears into a lasting "privileged model" that allowed him to understand many abstract concepts, in many realms, such as in mathematics, physics, or music. Papert, thus points out the importance of creating bridges between concrete experience and abstract concepts and the role of personal investment and interests in this transformative process.

On the other hand, Kolb's theory of experiential learning [14] points out the fundamental role of reflection and observation in the formation of abstract concepts, from which new implications for actions can be derived. This idea is further extended by Ackermann [1], who suggests that, as they seek to reach new insights or understanding, even very young learners seem to "know" how to frame and reframe a task at hand by iteratively: (1) immersing themselves (dwell in); (2) stepping back and looking at things from afar (bird-eye view) or obliquely (through unusual angles or lenses); and (3) putting themselves in other people's shoes (adopting different stances, including other "voices").

The overview of this theoretical framework suggests that in the process of knowledge construction, concrete experience needs to be transformed in order to create bridges with abstract concepts and explicit forms of knowledge. Furthermore, they point out how, in this transformative process, concrete experience interacts with the network of meanings, resources, previous knowledge and interests that are specific of each learner and their contexts.

### **Design for learning: unpacking 'experience as an object to think with'**

Designing for FUBILEs implies defining situated embodied experiences susceptible of being transformed into "objects-to-think-with". To facilitate this process, different possible strategies may be adopted.

From a trans-disciplinary perspective, *framing* and *reflecting* are generally foregrounded as key drivers in the transformation of personal experience into an 'object-to-think-with'. Both designers and users (each in their own ways) resort to intentional framing and reflecting. And the techniques used come in many different forms. Examples of *framing* for design may include museum labels, or suggested paths, to help visitors focus on aspects of an exhibit deemed important. Here, by providing an interpretative context or additional information, museum curators seek to guide people into understanding their experience. Examples of *reflection*, on the other hand, can be found in the mediation of group discussion or echoed in embodied practices such as psychodrama, art therapy and Forum Theatre. Both *framing* and *reflective* techniques represent effective strategies to enhance the impact of a FUBILE, even if, quite surprisingly only a reduced number of projects employ them.

Nonetheless, we suggest that, in the context of FUBILEs, the designers' effort to help learners leverage their "lived" experience should not be limited to providing extra information, or even reflection time, just before or after the experience. In other words, designers should avoid the dualistic trap of "*this is the moment for doing; this is the moment for thinking*". Instead, they must address how experience can be reflected and externalized during action, i.e. during the situated interaction with a FUBILE [24]. In order to address this need we propose a case study related to the analysis of children's genres of engagement during the interaction with a FUBILE.

### **THE STUDY**

In this study we report observations proceeding from the analysis of children's interaction with a Full-Body Interaction Learning Environment, named "Archimedes" and based on the Interactive Slide platform [25]. The goals of this study are: 1) to illustrate different possible paths through which children create bridges between embodied experience and the construction of meaning; 2) to delineate how different resources for meaning making are employed; 3) to define a set of qualities to think about the design of FUBILEs capable of offering conditions to support the transformation of embodied experience into an "object-to-think-with".

#### **The Full-body Interaction Learning Environment**

The Interactive Slide is an exergame platform based on a large inflatable slide augmented with digital technology. Four main parts compose the interface: a sliding surface where the digital content is projected, an upper part where the children can stand before sliding down, a bottom part where children land after sliding, and the lateral stairs. The Interactive Slide allows a natural and playful interaction as children interact with the digital content by moving through and across the sliding surface, where the interactive content is projected.

For this study, we evaluated the use of the Archimedes game for the Interactive Slide (Figure 1). Archimedes was originally designed to support children's hands-on learning on the notion of buoyancy and Archimedes principle [16]. The goals of the game are: 1) allow the cat to cross a pool of water by building a bridge; 2) raise the level of water in the right pool to allow the green fish to jump to the left pool and meet its pink fish friend. To accomplish these goals, the children have to employ a set of objects that scroll horizontally along the upper part of the game. Children have to understand the physical properties of the objects and make a strategic use of them, since their amount is limited. To interact with the game, children have to slide over one of the objects and drag it down into one of the pools.



Figure 1. Archimedes game on the Interactive Slide

### Procedure

The present exploration is part of a larger study aimed at evaluating user experience in Full-Body Interaction interfaces. The purpose of the current analysis is to describe four case studies to illustrate the different paths that children may undertake to create bridges between embodied experience and the construction of meaning.

For the study, participants were recruited from a local school and a total of 48 children participated (mean age: 11). A week before the study, we administered a short open-ended questionnaire at the school premises to evaluate children's previous knowledge on Archimedes principle and buoyancy. The study itself was carried out at our university during two mornings. Upon their arrival, the children were divided into groups of four. Thus, a total of 12 groups of 4 children played with the game. Then, one group at a time was taken to the room where the Interactive Slide was set-up. Children were introduced to the game by a short video tutorial that explained the main goals and rules of the game. After that, children were invited to play with the game over the course of a six minutes session. Subsequently, children were asked to fill a short questionnaire about user experience and then they were individually interviewed by a researcher according to a semi-structured format. Questions were related to their understanding of the game and to the physical properties of the objects of the game.

## THE CASE STUDIES

### Data collection and analysis

Children activity during the game and interviews were video-recorded. A researcher reviewed the overall video materials of children playing and performed a narrative transcription of the 12 videos by focusing on the overall group behavior. After that, results were discussed between two researchers and four case studies were identified. Each case study has been selected as being representative of one of the observed paths that children used to create bridges between embodied experience and meaning construction. One of the researchers then performed an in-depth multimodal transcription by focusing on the behavior of each child, during the game and during the interview. These transcriptions were performed by annotating both data proceeding from verbal interaction, as well as from embodied resources (the child's position and sensorimotor exploration). Finally, results were further discussed and elaborated by the two researchers. In the following sections we report a summary of the four case studies. Furthermore, the case studies were labeled according to their specific features in order to facilitate the discussion.

#### Child 1: The observer

L. is an extroverted 11 years old girl. She started by experimenting with different forms of sliding down, first doing a somersault and then trying to roll down horizontally. In her sensorimotor exploration, she did not pay attention to the scrolling objects nor did she try to drag them down. After this initial exploration, she suddenly moved to one side of the bottom of the slide and observed the game and the other three players from there. She then climbed up the stairs again, experimented with a new form of sliding down and went back to her "observation tower" (the lateral position). From this location, she started to give suggestions to other players. She told them that they needed to raise the water level by throwing objects and gave them instructions on where to slide down. Finally she climbed back up again and rolled down without trying to drag any objects.

During the interview she gave detailed explanations to the researcher about the game's goals and the strategies that the children used, explaining how they moved between different strategies: *"For moving the fish at the beginning we were throwing only balls because we didn't know what to do, but then we thought that we needed to raise the water level so we started to throw stones"*.

In her own uses of the "exergame" she seemed perfectly at ease separating the nature of the sensorimotor exploration (using the slides' built-in affordance to explore sliding) from her understanding of the "additional required" game that had to be played. When she was physically immersed, she did not care about performing any strategic actions, focusing instead on exploring the opportunity of different types of movements. Yet, she was equally able to focus on the "other" game goals; and to do so, she chose to step aside and watch the game as an observer. From this perspective, and by looking at her peers playing, she built a

clear understanding of the goals and properties of the objects.

### **Child 2: The sensorimotor explorer**

V. is a shy 11 years old girl who did not speak to the other children playing, during the entire session. At the beginning of the game, she quickly climbed up the stairs and slid down without paying attention to the scrolling objects projected at the top. On reaching the bottom, she immediately climbed back up again without looking at the projection on the slide's surface. When she arrived to the top she slid down from the position closest to the stairs. She repeated this sequence five times, exploring small variations in the way she slid down. At a certain point, one of the other children dragged a virtual rock which fell on the cat and the cat made a noise of complaint. V. then moved closer to the cat area and slid over it. After that, she went back to her previous game.

During the interview, when asked about the goal of the game, she explained that it was about a cartoonish cat and the goal was to slide down without hitting the cat.

In her exploration V. mainly focused on exploring the sensorimotor aspects of the experience (i.e. enjoying the sliding). She did not seem interested in the structured game and her attention was driven to it only when the audio of the cat was triggered. While eagerly pursuing the thrills of sliding down, she integrated the incident of the cat to fit her own rules and make up for a narrative to enhance the game she wanted to play.

### **Child 3: The action-perception looper**

N. is an 11 years old girl. She started the game by sliding over random virtual objects. Nonetheless, every time, after reaching the bottom of the slide, she turned around toward the projection to watch the effect of her actions. After three initial trials, she began to have a strategic approach toward the game, showing a clear understanding of the properties of the different objects. Her game mainly unfolded as follows: she stood on the upper part of the slide waiting for the appropriate virtual object to pass below her; she then slid down dragging the object with her; and finally, reached the bottom and turned around to check the result. Toward the end of the game she, too, started to give suggestions to the other players. She told them that they should only throw rocks in the pond of the green fish to make a pile of rocks which would force the water level up and hence allow the fish to jump to the other pond.

During the interview she showed a clear understanding of the game and described how they (she and other children) modified their strategies during the unfolding of the experience. Furthermore, she explained that she enjoyed the game because it was not only about sliding down but "*you have to wait for the correct moment*".

N. showed a strong goal-oriented behavior. Her game was continuously modulated by the loop between action-observation and reflection. She was not specifically

exploring variations in the sensorimotor experience but she used her actions to systematically test out cause-and-effect relations, until she understood the correct strategy and communicated it to the others.

### **Child 4: The framer**

D. is an extrovert 11 years old boy. He started the game by dragging different virtual objects in his sliding actions. On reaching the bottom of the slide, he did not look back at the projection and climbed back up again. He suggested to the others that they should hit the fish so as to make it jump. After trying three times and complaining that it would not work, he took a short pause and stood on the stairs observing the play area. Suddenly, he asked the other children: "*Do you remember some questions they asked us in school? About sinking objects? We have to think.*" He then climbed back up again and dragged a log into the pond of the green fish. He looked back at the projection and stated: "*this way we will never achieve it...we need to think something to help the fish!*" Unfortunately the game ended at that point.

During the interview he explained that the game was quite complex since "*you have to think about it.*" He correctly described how, in the end, they managed to build a bridge for the cat and that they did not manage to make the fish jump: "*you have to put something...but I'm not sure what*".

D. started the game mainly exploring the sensorimotor aspects of the experience. Yet, he soon changed his perspective and connected what he saw in the game with previous knowledge. This shift allowed him to start with a more experimental approach, oriented toward figuring out the correct strategy.

## **DISCUSSION**

These vignettes illustrate how four children focused on different aspects of the game and adopted different paths to build insights and understandings from their concrete and embodied experience. Their strategies were in part informed by the setting's own ambivalent status as an exergame.

The first girl (*the observer*), for instance, showed a certain spatial and temporal separation between her sensorimotor experience and the way she constructs meaning. Her activity on the Interactive Slide mainly focused on exploring variations in "sliding down". She knew there was more to the game than sliding and chose to take an "observer" standpoint. She physically changed her position to one side of the playing area to build her understanding of the task. In her case, she used the relation between the actions of her peers and their effects in the game to mediate her sensorimotor exploration and the construction of her understanding. In this process, she used both the *social construction of meaning* through the actions of others as well as a *shift in her role* to transform embodied experience into an 'object-to-think-with'.

On the other hand, the third (*the action-perception looper*) and fourth children (*the framer*) construct their meanings by creating a close loop between action and observation, even when using different temporalities. This strategy is consistent with Kolb's theory of experiential learning which proposes a cycle where concrete experience subsequently leads to reflective observation, abstract conceptualization and active experimentation [14]. At the same time, interestingly, in both cases, their understanding starts to emerge when they change their movement patterns. While, at the beginning both mostly focus on the action of sliding down, when they start to turn around and take time to observe the effects of their actions on the sliding surface, they both engage in a more strategic approach to the "learning aspect" of the game. Nonetheless, while the third girl assumes a systematic trial and error approach, the fourth boy all of a sudden fathoms specific insight on the game by recalling previous knowledge. Both cases point out the role of the action-perception loop in mediating between embodied experiences and meaning making. Nonetheless, in this relation, different strategies may be employed suggesting the importance of self-regulating the pace of the experience to build one's own understanding.

Furthermore, in the three previous cases, it is relevant to notice how children's physical change in their standpoint, offers an embodied instantiation of Ackermann's [1] model of framing and reframing experience. This suggests the crucial role of adopting different points of view to build understanding (dwell-in, bird-eye view, other people's shoes).

On the other hand, the second girl (*the sensorimotor explorer*), presented completely different patterns from the other cases. She mainly focused on the sensorimotor aspects and built an interpretation that fits with her interests. In this case, it could well be that the act of sliding down was already sufficiently interesting for her and hence chose not to pay attention to the layer of interactive content. This latter case points out how designers should not consider the mapping between concrete experience and meaning construction as a process which is "given" by default or as an univocal interpretative path.

To sum up, the four cases point out how transforming embodied experience into 'an-object-to-think-with' vary and may (or may not) be aligned with the designer's intents. In addition to describing the children's use —and appropriations— of the proposed game, this analysis suggests two important dimensions to take into account when designing for embodied learning.

Firstly, the study highlights how embodied experience may become an 'object-to-think-with' by using different paths, which are situated in the network of meanings that the system can afford. In this study we found examples of instances such as: *the social construction of meaning, the action-perception loop, the adoption of different perspectives, and the use of previous knowledge*. Secondly,

the study points to the importance of *reflection-in-action* [24]. These reflective moments are embedded in the experiential flow and their embodied nature is displayed in users' bodily actions, pace and use of the space (e.g. adopt an "observer position", turn around to see the screen, etc.), and selective engagement (e.g. chose to use the exergame for exercise!)

Framing this outcome within Kolb's theory of experiential learning [14], helps understand how children may display (or not) reflective moments during the interaction by using different resources. These embodied and situated reflective moments fulfill a fundamental epistemic function, since they allow children to transform concrete experience into an 'object-to-think-with'. Furthermore, from a designer's and researcher's perspective, the surprising variety of uses calls for a closer look into the implications of environmental affordances for the design and the evaluation of FUBILEs.

#### **Implications for the design and evaluation of FUBILEs**

In the context of FUBILEs, it is necessary to ask ourselves how we can design conditions to facilitate reflective practice capable of transforming embodied experience into 'an-object-to-think-with'. In order to guide this research, the current study can provide an initial set of qualities to guide design and research.

Using an idiographic, qualitative and multimodal approach has allowed us to spot out a great deal of thought-provoking "anecdotal evidence" that wouldn't have come to the fore just using traditional methodological approaches. In the context of FUBILEs there is a tendency toward adopting mainly quantitative methods to measure eventual learning gains. In this case, however, the choice of digging deeper into understanding a few selected children's uses of a specific environment, seemed necessary and beneficial to shedding new light into the nature and function of embodied learning. It is our belief that relevant opportunities can be found in combining methods aimed at considering the embodied nature of meaning construction, such as multimodal analysis [22], with approaches aimed at eliciting information from children (e.g. interviews, or participatory design).

This complementary – and very targeted case study- has allowed us to address some relevant questions such as: *When, how and in which conditions do children display moments of reflection? Which resources do they use in this process? How do they embody or enact the transformation of the concrete experience into 'an-object-to-think-with'? How do they use the space and their body in this process?*

Addressing these questions does not only deepen our understanding of embodied learning. Instead, it can also inform iterative processes for the design of FUBILEs by guiding relevant improvements and helping designers identify resources that children employ to construct meaning. At the same time, from a broader perspective, this analysis allows us to identify environmental affordances

that may better support the transformation of embodied experience into ‘an-object-to-think-with’. Specifically, in this study, we have identified the following qualities: 1) Spatial and temporal qualities; 2) Social qualities; 3) Mindful qualities.

#### *Spatial and temporal qualities*

The first, third and fourth children show how the physical use of space as a place that enables multiple points of view, perspectives and roles (e.g. observer, performer, etc.) may facilitate instances and conditions for reflexivity. At the same time, the difference between the third and the fourth children points out the importance of the pace of the experience to facilitate reflection. From a design perspective, these findings suggest that certain spatial and temporal configurations may be more useful to facilitate conditions for reflexivity.

From the point of view of designing spaces, relevant opportunities can be found in design solutions that allow users to embody or inhabit different perspectives and standpoints during the experience, since this shift in their role may afford moments for reflection. An example of this can be found in a project by Nemirosky et al. [18], where children can switch between using their bodies and controlling a remote device, to explore graphs of motion. At an applied level, a relevant guideline is therefore related to considering the physical space of the interactive system as a “third teacher” [26], which could offer affordances to navigate into different action-reflection paths. Such aspect is particularly important in FUBILEs where, despite the claim for spatially meaningful experiences, the final design tends to be mainly shaped around technological constraints (e.g. most FUBILEs use mainly vertical screen or floor projections [17]).

Further considerations should address the definition and calibration of the pace of the activity. This implies we must design the temporality of experiences in such a way that it may support the self-regulation of different moments, such as experimentation and reflection, “dive in” and “step out”. From this perspective, when designing a FUBILE, it becomes necessary to analyze how the experience, physical activity and reflexivity can be aligned to support different phases in the process of moving between sensing-in-action to making sense of action, using different resources. Nonetheless, this does not necessarily mean we need to create pre-established “place/time for reflection” and “place/time for action”. Instead, it implies that we think about spatial and temporal configurations to enable different types of “journeys” and ways of engaging during the experience; from taking the highway to indulging in the scenic route.

#### *Social qualities*

The present study showed how the social affordances of the system have enabled instances for transforming experience, either through the observation of peers’ actions or through the externalization of their own reflections (or that from

other children). From the perspective of designing FUBILEs, this suggests a need for further research on how the system may afford both the identification with other people’s actions as well as instances for co-constructing meaning. In this context, relevant design opportunities can be found in combining knowledge proceeding from computer-supported collaborative learning with the use of embodied resources for social understanding (e.g. gaze, mutual orientation, joint attention).

#### *Mindful qualities*

The case of the second girl (the sensorimotor explorer) showed a disconnect between the child’s interpretation and the designer’s intentions (i.e. understand the physical properties of the digital objects and use them strategically). This shortcoming points out the need for research efforts aimed at facilitating a mindful experience, understood as enabling conditions for children to focus on what matters and being sensitive to relevant changes [15]. Furthermore, it points out the need to avoid situations where either the sensorimotor experience or other interactive features act as distracters (i.e. in our study, the sliding experience was already sufficiently interesting on its own for the second girl, thus inhibiting her interest in the superimposed game). Possible strategies to tackle these risks may be found in rethinking the relations between sensorimotor experience and content and in providing hints to frame children interpretations toward the educational goals.

### **CONCLUSION**

We have presented a qualitative, idiographic study aimed at exploring how a selected group of children build bridges between embodied experience and construction of meaning. Through the presentation of four case studies we have highlighted different paths that children may employ to transform experience into ‘an-object-to-think-with’. This analysis allows us to expand the understanding of learning in Full-Body Learning Environments. At the same time, by pointing out the differences in children’s behavior, it highlights the importance of designing for diversity by providing affordances that enable the exploration and enactment of different paths to transform experience.

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