https://doi.org/10.1093/iwc/iwac016

Narrating by Doing: A Bridging Concept for Understanding and Informing the Design of Tangible Interfaces for Storytelling

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We present and discuss the concept 'narrating by doing' as the process of creating narratives by performing different embodied actions with tangible interfaces for storytelling. We characterize it as a 'bridging concept' that can facilitate exchange between theory and design, informing research and design of TUIs for storytelling targeting young children. The concept builds on theories of cognition, learning and narration, specifically drawing upon the following perspectives: Constructionism, Socio-Constructivism, Embodied Cognition, Narratology and The Narrative Practice Hypothesis. Building upon these theoretical foundations, we identify and discuss four 'design articulations' (i.e. important parameters that express the qualities of the concept), namely *communicative situation, narrative function of the tangible objects, collaborative and embodied actions* and *the narrator's position*. Finally, we add evidence to the concept and discuss its productiveness by presenting a set of considerations to inform the design of tangible interfaces for storytelling.

RESEARCH HIGHLIGHTS

- 'Narrating by doing' refers to the process of creating narratives with TUIs.
- It as a 'bridging concept' that helps the dialogue between theory and practice.
- Important parameters of the concept that potentially creates design opportunities are discussed.
- Empirical evidence is added by exemplifying the concept of 'narrating by doing'.

Keywords: children; storytelling; tangible interfaces; interaction design; bridging concepts

Handling Editor: Dr. Juan Pablo Hourcade

Received 8 July 2021; Revised 1 April 2022; Accepted 1 May 2022

1. INTRODUCTION

This paper presents and discusses the concept 'narrating by doing' as a bridging concept (Dalsgaard and Dindler, 2014) that can facilitate exchange between theory and practice, informing in particular the design of tangible interfaces (TUIs) for storytelling directed to young children. A recent review of thematic areas in Child Computer Interaction (CCI) carried out between 2003 and 2018 identified collaboration, creativity, tangibles, storytelling and interactive surfaces as motor themes in the field of CCI (Giannakos *et al.*, 2020). Another review (Barendregt *et al.*, 2017) that analysed all full papers from the Interaction Design and Children Conference from 2003 to 2016 identified 'collective storytelling', i.e. 'the combination of cooperative technologies with storytelling in order to coordinate several authoring efforts' (Barendregt *et al.*, 2017:12), as a strong concept in CCI. However, most work on tangible interfaces for storytelling still focuses on the technological properties of the systems that are often developed for single case uses (Garzotto, 2014; Harley *et al.*, 2016). Barendregt *et al.* (2017)

and Giannakos *et al.* (2020) concluded that a great part of investigation in CCI has primarily focused on technical development and on 'artefacts-centred evaluations' (Barendregt *et al.*, 2017), failing to develop 'intermediate-level knowledge' (Höök & Löwgren, 2002). 'Intermediate-level knowledge' refers to representations of knowledge that can fill the space in-between general theories and particular artefacts in terms of abstraction and generalizability (Dalsgaard and Dindler, 2014). The need to develop models and guidelines that inform the design of interactive artefacts for children has already been voiced by Read and Markopoulos (2013). Research in Interactive Digital Narratives has also concluded that working prototypes of tangible stories are few, and that there is a need for updated theoretical discussion on newer forms of interactive narrative construction (Echeverri and Wei, 2020).

Relevant theoretical contributions in the field have been made by Marshall (2007), who provided an analytic framework for guiding the development of tangible interfaces for learning composed of six perspectives: possible learning benefits; typical learning domains; exploratory and expressive activity; integration of representations; concreteness and sensory directness; and effects of physicality. Antle and Wise (2013) proposed the Tangible Learning Design Framework, which aims at providing guidance for decisions in TUI design for learning through the lenses of theories of cognition and learning. Hornecker (2005) and Hornecker and Buur (2006) developed the Tangible Interaction Framework, which provides concepts and perspectives for considering the social aspects of tangible interaction and offers design guidelines for collaboration.

Aligned with the need to go beyond 'artefacts-centred evaluations' and to create both empirical and theoretical work that can inspire and inform research in CCI (Barendregt *et al.*, 2017), the major contribution of this paper is to introduce the concept of 'narrating by doing' as a bridging concept by bringing together concepts, practices and design aspects that permeate TUIs for storytelling. We begin with a brief review of the 'bridging concept'; we then develop the 'narrating by doing' concept by discussing its theoretical foundations, 'design articulations' and illustrative exemplars from design practice. Finally, we present a set of practical guidelines derivable from the bridging concept and discuss the productiveness and the importance of the development of concepts that aim to facilitate exchanges between theory and practice in CCI investigation and design with reference to 'narrating by doing'.

2. 'NARRATING BY DOING': A BRIDGING CONCEPT FOR DESIGNING TUIS FOR STORYTELLING

Höök and Löwgren (2002) argued that research on interaction design can develop intermediate-level knowledge, defining it as a kind of 'knowledge that is more abstracted than particular instances, yet does not aspire to the generality of a theory' (Höök & Löwgren, 2002:2). They consider that intermediate-level knowledge concepts are potentially useful constructs, for instance, to operationalize the process of discursive knowledge construction in design-oriented HCI research. Examples of intermediate-level knowledge concepts are 'conceptual constructs', 'strong concepts', 'bridging concepts' and 'annotated portfolios'. These forms of intermediate-level knowledge differ from each other in their primary origin and intent (see Table 1). 'Conceptual constructs' emerge from theory and aim at promoting theoretical advancements; 'strong concepts' and 'annotated portfolios' originate from instances and their primary intent is to inform design practices and to communicate design research, respectively. 'Bridging concepts' originate from theory and instances and aim at facilitating exchange between theory and design practice. Only this form of intermediate-level knowledge aims to facilitate this dialogue.

In this paper we introduce 'narrating by doing' as a bridging concept. According to Dalsgaard and Dindler (2014), bridging concepts are a form 'distinguished by their ability to facilitate exchange both ways between overarching theory and design practice, rather than by being developed from theory or practice or with the specific aim of informing either theory or practice' (Dalsgaard and Dindler, 2014:1637). They consider that by spanning the gap between theory and practice, a bridging concept unveils and articulates untried design opportunities and potential theoretical advancements. The concept comprises three constituents: theoretical grounding, design articulations and exemplars that illustrate critical aspects of the concept (Dalsgaard and Dindler, 2014).

In accordance with Dalsgaard and Dindler's definition, 'narrating by doing' emerged from instances and theories and intends to facilitate an exchange between theory and practice in the design of TUIs for storytelling. Here we discuss its theoretical grounding, the design articulations and a sample of exemplars.

2.1. The concept

'Narrating by doing' refers to the process of creating narratives by performing different embodied actions with digital tangible interfaces for storytelling.

2.2. Theoretical grounding of 'narrating by doing'

Our conception of 'narrating by doing' builds on theories of cognition, learning and narration, specifically drawing upon the following perspectives: Socio-Constructivism, Constructionism, Embodied Cognition, Narratology and the Narrative Practice Hypothesis. Here, we provide a brief outline of these perspectives, focusing on the implications they have for establishing the concept 'narrating by doing'.

TABLE 1. Comparison of different forms of intermediate-level knowledge, adapted from Dalsgaard and Dindler (2014) and Barendregt *et al.* (2017).

	CONCEPTUAL CONSTRUCTS	STRONG CONCEPTS	BRIDGING CONCEPTS	ANNOTATED PORTFOLIOS
PRIMARY ORIGINS	Theory	Instances	Instances and theory	Instances
PRIMARY INTENT	Theoretical advancements	Informing design practice	Facilitating exchange between theory and practice	Communicate design research
INTRODUCED BY	Stolterman and Wiber, 2010	Höök & Löwgren, 2002	Dalsgaard and Dindler, 2014	Gaver and Bowers, 2012

2.2.1. *Socio-constructivism: Learning, collaboration and play*

Socio-Constructivism conceives human cognitive development as the internalization of cultural heritage (Vygotsky, 1978). 'Narrating by doing' builds on two central tenets with which Socio-Constructivism explains such internalization: collaboration and play. Socio-Constructivism emphasizes the social processes involved in the internalization of cultural heritage. It envisages collaboration with others as essential for sharing such knowledge, and verbal language as playing an inescapable pivotal role in establishing interactions and in sharing meanings (Vygotsky, 1978). In Socio-Constructivism, play is fundamental in children's enculturation (Vygotsky, 1978; van Oers, 2012). Being driven by creativity (Vygotsky, 2004), play gives children the opportunity to engage and experiment with the world around them (Veraksa and Veraksa, 2016), thus supporting their appropriation of culture.

2.2.2. *Constructionism: Learning through active manipulation of physical objects*

Constructionism underpins the active 'doing' involved in 'narrating by doing'. Building on Constructivism theories, Constructionism puts a renewed emphasis on the learner in action as well as on the learning contexts. It emphasizes the conception of children as active 'builders' of ideas and the importance of their interactions with tools that are meaningful for them and their surrounding environment (Papert, 1993; Kafai and Resnick, 1996; Ackermann, 2001). As such, Constructionism conceives 'contexts that trigger learning' as situations that are deeply engaging, immersing learners in challenges and interactions with physical artefacts. As identified by Resnick (1998), the use of objects to facilitate the understanding of abstract concepts that is valued in Constructionism can be traced back to Fröbel (Brosterman, 1997) and Maria Montessori (Montessori, 1912).

2.2.3. *Embodied cognition: Active minds in active bodies in the world*

Embodied Cognition is another central assumption sustaining the 'doing' in 'narrating by doing'. The unifying tenet underlying Embodied Cognition is 'the idea that the body or the body's interactions with the environment constitute or contribute to cognition' (Shapiro and Spaulding, 2021). By emphasizing the constitutive role of the body and its experiences in the world in the construction of the human mind, Embodied Cognition firmly rejects the idea that mental processes are restricted to computational processes as performed in the brain alone (Lakoff and Johnson, 1999; Pfeifer and Bongard, 2006). By assuming that the whole of our situated interactive bodies constitutes the system with which we think, know, reason or feel, Embodied + / Extended Cognition endorses the idea that manipulation or exploitation of the external supports (scaffoldings) is part of cognitive processes (Clark and Chalmers, 1998). Accordingly, the interactions of our sensorimotor system—eyes, hands, ears . . . —with other people, multimodal tools, objects and materials as mediated by language are causally involved in the construction of human cognition (Wilson, 1998; Sheets-Johnstone, 1999; Kirsh, 2013; Hollan *et al.*, 2000).

2.2.4. *Narratology and narrative forms of thinking: Storytelling to learn about life*

'Narrating by doing' is finally informed by narratology, which describes the rhetorical act of narrating, as well as by theories about the role of narrative in the development of human cognition. To narrate is to tell a story to an addressee (Bal, 2017). From this perspective, a narrative is a text in which the key elements from which stories are made (events, actors, time and location) have been assembled by a narrator (storyteller). For instance, with the exception of direct speech, it is the narrator who orders events (e.g. in chronological order), attributes traits and motivations to actors (who thus become characters), describes locations and defines the focalization processes (i.e. the position from which the story elements are presented to the addressee). The narrator assumes a prominent role in storytelling, because she/he can choose to assemble these elements in many different ways in order to cause different effects in the audience.

According to (Bruner and Jerome, 1990), storytelling is a human practice that plays a central role in the development of a narrative form of human cognition, and narrative thinking is a universal ability in understanding the world, including one's

own life and the lives of others. In this perspective, it is narrative thinking that compels us to look for significance in whatever events we experience, including the meanings that we make in narrative practices, either the stories that we tell or the meanings that we interpret in the stories that are created by other storytellers. When they are meaningful, narratives are assumed to be indisputable sources of order and coherence about life, and, as such, of human learning (Hutto and Ravenscroft, 2021).

2.3. 'Design articulations' of 'narrating by doing' in tangible interfaces for storytelling

Building upon the theoretical foundations presented above, we have identified four major parameters in the development of the concept 'narrating by doing'. Dalsgaard and Dindler define 'design articulations' as 'parameters that are important in expressing the qualities of the concept [...] and that designers can manipulate to change the interaction and experience of an artefact' (2014:1638).

In the establishment of the design articulations, we started by identifying characteristics that define narratives and TUIs (as detailed in the previous section). Considering that to narrate is to tell a story—about the actions developed by some characters in time and space—to an addressee, three central aspects emerged: the need for a communicative situation, the availability of key story elements with which to construct the story and the telling action of a narrator. Regarding TUIs, a key feature is the body's (collaborative) interactions with physical artefacts. We have simultaneously developed the analysis of exemplars in order to validate the adequacy of our inductions. Outgoing from this process, we have established the following four design articulations: (i) *communicative situation*; (ii) *narrative function of the tangible objects*; (iii) *collaborative and embodied actions*; (iv) *narrator's position*. We assume that the articulation of these parameters, which we discuss in detail in the following subsections, is essential for designing interfaces that can create opportunities for children to have significant cognitive, physical and social experiences with (and during) their storytelling.

2.3.1. *Communicative situation in 'narrating by doing'*

This design articulation establishes that, when designing a TUI for storytelling aimed at children, it is necessary to define the *communicative situation*, that is to think about the *context, purpose, content* and *audience* of the storytelling (Page and Thomas, 2011; Lotherington, 2011) (Fig. 1). Narratology was particularly important in defining this parameter.

In 'narrating by doing', narrating is clearly the aim. As in any other discursive case, narrative purposes and target audiences are determined by communicative situations. In dramatic play, for instance, the purpose is intrinsic to the play itself (Rowe, 1998). Children tell a story to play, e.g. that they are someone else, living in another place or even in another time, this way experimenting with life possibilities, making sense of the

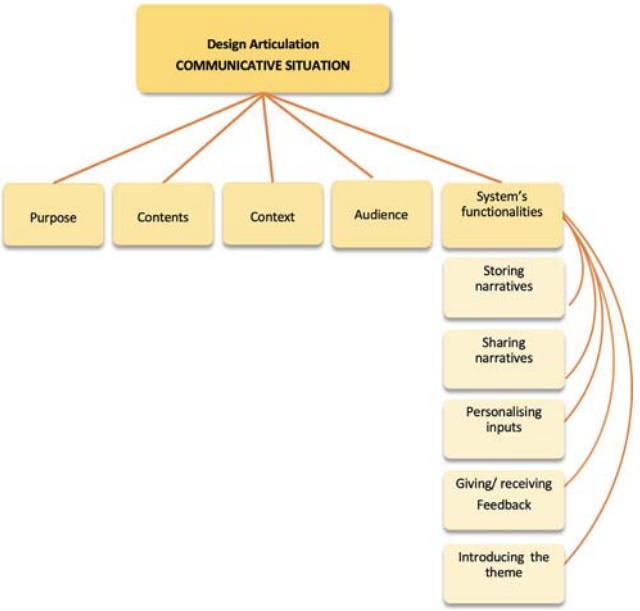

FIGURE 1. Design decisions related to the design articulation *Communicative Situation* in 'narrating by doing'.

life for themselves. When narrating a story children play to experiment with and develop the act of narrating. We therefore argue that it is important that the design of digital tools for storytelling allows the users to set clear *communicative situations* for their 'narrating by doing'. This implies defining the *purpose, content*, *context* and *audience* of the storytelling, as well as defining relevant *functionalities of the system* (Fig. 1) to clearly establish the *communicative situation*. For instance, if the *purpose* is to learn and create stories about ecology (*content*) in the *context* of ecological education and share them with other children (*audience*), the design of the TUI might include system's functionalities that present story elements related to the theme (*introducing it*), enabling the *sharing* of the narratives.

Depending on the definitions of the *purpose, content*, *context* and *audience* of the communicative situation of the storytelling, some possible functionalities can allow for storing the narrative (in different formats, i.e. audio, static and/or moving images; written text, etc.); sharing the narrative with others (asynchronously or synchronously); personalizing the inputs; and giving feedback (e.g. by the system, the peers or the audience).

2.3.2. *Narrative function of the tangible objects in 'narrating by doing'*

This design articulation specifically refers to the tangibility of the tools involved in TUIs for storytelling. The tangible objects have a prominent role in 'narrating by doing' environments as it is through their manipulation that children create their narratives. They enhance children's creativity by specifically scaffolding them into entering the story world. The physical

activity that takes place when manipulating digital information using objects helps to build representational mappings, facilitating the understanding of more symbolically mediated activity (O'Malley and Fraser, 2005). The objects scaffold and guide the users and display the results of their actions. Moreover, the haptic affordances of TUIs and its multimodal nature transform storytelling into a fully embodied experience (Bezemer and Kress, 2014; Mangen, 2016), promoting multimodal meaning-making, i.e. understanding and involvement by doing (Moreno and Mayer, 2007).

In our analyses, we have identified different possible functions that the tangible objects may have (i) building blocks of the narrative, allowing creating or combining story content; (ii) empty containers-to-be-filled with children's creations (often in audio format); (iii) navigators for multiple-track stories. By having different functions, the tangible objects also shape the narrative creation. Tangible objects like (i) support the meaning making across modes (Kress, 2010), since they offer narrative input that may address various senses (e.g. visual, haptic, aural). Tangible objects like (ii) are containers for children's creations and their manipulation may support the sequencing of the narratives, that is, help children to organize the events in their story according to temporal and causal relations. In (iii), objects may help to organize sequences.

Considering TUIs with properties as (i) and (iii) there are two fundamental aspects to define: (a) the *narrative information embedded in the objects* and the (b) *randomness of the interactions.* Regarding (a) the objects scaffold the organization of the narratives created by the children, offering different environments for storytelling, i.e. they may represent story elements from classical children's stories, or represent environments that allow exploring specific themes, e.g. environment, cultural diversity, etc. Regarding (b) as the story environment is predefined, it is important to create a certain degree of surprise to maintain engagement and foster children's creativity, that is, to consider the randomness of the interactions between the story elements when defining interaction rules and behaviours between the different story elements. A possible approach is to use Behaviour Trees (BTs) to model the story world, a concept well known in the field of computer games used to model character behaviour, reactive decision-making and control of virtual characters (Knafla and Champandard, 2012).

Another important aspect when considering TUIs with properties as (i), (ii) and (iii) is the number of the tangible objects. A small number of elements will limit the possibilities of the narrative construction and children may soon lose interest in the activity, whereas too many elements can confuse children and lead to narratives that lack coherence. Regarding TUIs with properties as (ii) the communication between the tangible objects and the storage capacity of the tangible objects are further relevant aspects to consider. Together, the decisions related to this articulation will have implications on user's engagement and on scaffolding the story creation (Fig. 2).

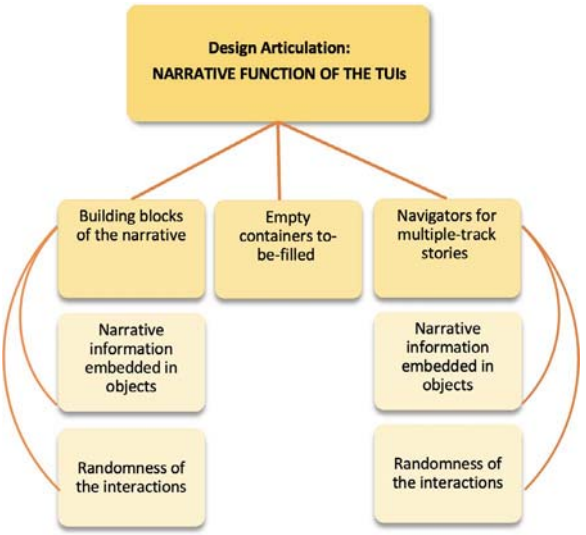

FIGURE 2. Design decisions related to the design articulation *Narrative Function of the Tangible Objects* in 'narrating by doing'.

2.3.3. *Collaborative and embodied actions*

As discussed in the theoretical foundations of 'narrating by doing', physical and social experiences are fundamental in conceptualization and reasoning processes (Lakoff and Johnson, 1999; Pfeifer and Bongard, 2006). In this sense, 'narrating by doing' environments place an emphasis on the learners in action, prompting them to perform different kinds of tasks, which may require different cognitive responses (e.g. visualization, attentive listening, verbalizations, inquiry, discussion, negotiation and story creation) and physical responses (e.g. grasping, sorting, dividing, arranging, crafting the tangible elements). The integration of these affordances into the design of tangible interfaces for storytelling can be explored in different ways e.g. by prompting users to physically act to realize the tasks and/or asking for oral production. Although the tasks can be performed individually, the support and promotion of collaborative actions among users is of special importance (Hornecker, 2005), as collaboration fosters the development of social competences as well as children's creativity, as discussed in the theoretical grounding of 'narrating by doing' (section 2.2).

Two main general affordances of TUIs seem to be essential for this design articulation, namely: the number of '*access points*', which allow more than one user to actively interact and manipulate the story content, and the type of access points (e.g. single, multiple, Bluetooth connection, an electronic platform, an interactive table, etc.).

It also becomes necessary to define how the '*embodied facilitation*' will be promoted, that is, how the users will act or move both in the physical space (e.g. by connecting blocks, ordering tangibles, placing objects on an electronic platform, crafting new objects, etc.) and in the system's space

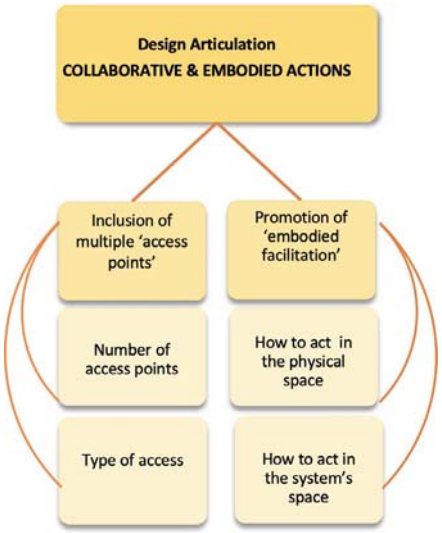

FIGURE 3. Design decisions related to the design articulation *Collaborative and Embodied Actions* in 'narrating by doing'.

FIGURE 4. Design decisions related to the design articulation *Narrator's Position* in 'narrating by doing'.

(e.g. by changing the system's content, reordering presented information, visualizing the system's content, etc.). The design decisions related to '*embodied facilitation*' are closely linked to the previous parameter, determining, for instance, if the users will be able to freely create their own story content; change the course of the action that is programmed by the system, e.g. by being able to stop ongoing actions; or reorder pre-created parts of a story. Together, these different possibilities will lead to different actions that may promote different levels of involvement and collaboration in the storytelling. Thus, depending on the design choices related to these aspects, the 'doing' dimension of 'narrating by doing' can have a more or less prominent role, ultimately determining the user's rich agency (Fig. 3).

2.3.4. Narrator's position

The position of the user-as-narrator in the storytelling is a central aspect in 'narrating by doing'. The definition of this design articulation was strongly inspired by Narratology, and our classification of the narrators' position borrows from Ryan's forms of interactivity, which define the relations between the user and the virtual world (Ryan, 2002). Relevant for 'narrating by doing' are the *exploratory* and the *ontological narrative* positions, which we assume to be two important affordances (Fig. 4).

In the *exploratory position*, users explore the story elements in order to learn more about the story world, whereas in the *ontological position* the users actively create and influence the story (Ryan, 2002). While in the exploratory position users play and explore a 'back-stage' narrating role to construct relevant knowledge about the possibilities that are offered for their narration, it is in the ontological position that they use that knowledge and become the 'directors of the narrating that goes on stage'. When assuming the ontological position, the user-as-narrator can either take an internal position, i.e. identifying with or embodying/performing the role of characters—playing a role, projecting her/himself as part of the story and perceiving the story world from a first-person perspective (Sylla *et al.*, 2014); or an external position, i.e. situating her/himself outside the story world, observing it and therefore acting at a different level from that of the story's characters. A particularly interesting aspect of 'narrating by doing' with TUIs for storytelling is the variety of different roles that the storytellers can assume. This is, children can become authors, directors, performers and spectators of their own stories (Sylla *et al.*, 2014).

Both central positions (*exploratory* vs. *ontological*) are encompassed in 'narrating by doing' scenarios, since there is usually an interplay between them (i.e. the narrator sometimes steps back to explore the story elements to get to know them better and then, takes up the narration). However, we argue that TUIs for storytelling should provide opportunities for the user to assume an ontological position, since this is the position from which users can narrate actively, which is a key aspect of the 'doing' in 'narrating by doing'.

In the case of the *exploratory* position, it is necessary to make the story elements available for children to playfully try and experiment with outside the context of the narration. In this position, the user needs to have opportunity to uncover or learn about the story and its components, including reconstructing or rearranging events (Harley *et al.*, 2016). To foster the *ontological* position, it is important that the user can make decisions that alter the state of the story world, changing and/or customizing the story elements (e.g. creating new content, detailing the

existing story world). Relevant design decisions are as follows: Is the story environment presented or pre-defined? Is there a scenario? Are the characters pre-defined? Is the story world situated in time? Will be possible the customization of the story elements (e.g. changing some characteristics of the characters, including details in the scenario, creating a new background, etc.)? It is also relevant to develop an open and engaging protostory, i.e. establishing potential narrative paths that may allow different walkthroughs in the storytelling. The more the user can act in the story world, the more narrator's positions can he assume.

2.3.5. *Interactions and interdependencies between the four design articulations*

As suggested in the description of each design articulation, there are necessary interactions and interdependencies among these parameters. They are, indeed, facets of the whole and it is their interplay that supports 'narrating by doing'.

For instance, the more access points a TUI offers, the more possibilities for collaborative and embodied actions it will provide. This in turn will also open opportunities for taking different narrator's positions. Even within the same narrative, for instance, some users may take an internal and others an external narrative position. In this case, joint narration could lead to complementary positions or to conflicting results among collaborators, which however may also increase discussion and negotiation among users, promoting the development of social skills.

The number of access points is also strongly related to the function of the tangible objects, depending on, for instance, if the tangibles are representations of story elements or if they are empty containers-to-be-filled with children's own stories. In the latter, a reduced number of tangible objects may be sufficient, whereas the former might need more elements to create a variety of narrative possibilities. Multiple access points will also affect the design of the tangible objects, for example, in a TUIs designed to navigate multiple-track stories a balance may be needed between the number of access points and the navigation possibilities provided by the system.

The suggested design parameters and articulations may be combined in endless ways, resulting in a variety of different developments. Depending on the choice and combination of the design articulations, some dimensions will be more prominent than others and result in different storytelling experiences.

2.4. Exemplars of 'narrating by doing'

In this section, we discuss design exemplars that show the potential and scope of the concept 'narrating by doing' in terms of design practice. To select the TUIs to compose our sample, we departed from Harley *et al.* (2016) list of tangible interfaces for storytelling and, then, selected the TUIs based on the set of inclusion and exclusion criteria presented below:

1. TUIs developed after 2000 were included;
2. TUIs that are directed to adults were excluded;
3. TUIs that are toys were excluded;
4. TUIs that do not allow narrative creation were excluded.

The final sample consisted of five TUIs (TellTale, TeleStory, PuzzleTale, TellTable, TOK). To this list, we added two TUIs developed after Harley *et al.* (2016), namely, Mobeybou and StoryBox, aiming at having TUIs more recently developed. Thus, the resulting sample consists of seven TUIs.

After selecting the final sample, we followed three steps: (i) outlined a general characterization of each of the systems; (ii) mapped their characteristics to the referred design articulations, investigating if the four design articulations that we have identified were present in any of these TUIs; and (iii) analysed in detail three of them, in order to highlight how different design manipulations of the proposed parameters model different experiences of tangible storytelling.

In the foling, we present a brief characterization of each of the systems.

TellTale (Ananny, 2002) has the form of a caterpillar with a head and a body of five pieces. A button on each body piece allows users to record audio into the respective body piece. The pieces can be pulled apart, rearranged and re-connected to each other. By attaching the head piece to the body children can hear the whole recorded sequence.

PuzzleTale (Shen and Mazalek, 2010) uses tangible puzzle pieces with digital characters on the surface of an interactive table. Assembling the puzzle pieces affects the digital characters and creates a flexible story context. Different assembled patterns represent the diverse ways that users explore and compose the story.

TeleStory (Hunter *et al.*, 2010) is composed of small blocks with an LCD that communicate with each other and become active in pairs, triggering animations on a parallel screen. TeleStory presents 22 episodes created around a cat and a dog. Placing a prop cube to the right or left of a character cube will trigger a new episode.

TellTable (Cao *et al.*, 2010) is a multi-touch interactive table that children can use to create story components through photography of real-world objects and drawing with their fingers. These can then be used to record a story which can be played back.

TOK (Sylla *et al.*, 2014) uses tangible blocks on an electronic board that depict characters and other story components. When children place the tangibles on the electronic board, corresponding images and animations are triggered and displayed on the computer.

StoryBox (Wallbaum *et al.*, 2018) enables different generations to remotely share daily stories and moments of their lives, e.g. crafted objects, pictures, written messages and audio samples in an asynchronous manner.

Mobeybou (Sylla *et al.*, 2019) uses physical blocks that represent story elements to manipulate digital content. The blocks

communicate with a computer device via Bluetooth. Connecting the blocks to each other displays the corresponding animations on the screen. Children can record, share and playback their verbalized stories.

Table 2 presents a summary of key dimensions of the four design articulations as found in each of the analysed TUIs.

To better convey the potential and scope of the concept 'narrating by doing' in terms of design practice, we have selected three of the presented TUIs, namely, Mobeybou, StoryBox and TellTale, and detail its analyses in the following section. By doing so, our aim is to demonstrate how (different realizations of) the design articulations presented above shape the qualities of tangible interfaces for storytelling in different ways, as well as to support designers and researchers identify relevant elements in TUIs for storytelling targeting young children.

2.4.1. Mobeybou (MBB)

Mobeybou uses a set of 60 physical blocks to communicate with a computer device and manipulate digital content for storytelling.

Communicative Situation: Mobeybou aims at promoting social (role) play (with others), developing narrative competences and intercultural awareness (*purpose)*. Its *contents* are story elements (protagonists, antagonists, animals, objects, musical instruments, landscapes) from different cultures, thus *contextualizing* the storytelling in an intercultural environment. The target *audience* is the narrator himself and his peers, even though the story can be shared with whoever the narrator wants. To promote this communicative situation, the design decisions regarding the functionalities of the MBB system include an option of storing the narrative in audio format, by clicking on a digital microphone icon and activating the recording feature (the recorded files are stored in the computer). As such, the visual representation of the recording function (microphone icon) and the possibility to record themselves act as an invitation to children's storytelling. Children can also share the recorded narrative asynchronously to an extended audience (by sending the audio file). The purpose of developing intercultural awareness entails the inclusion of information and story elements related to interculturality through the content embedded in the tangibles of MBB, in a way that the children clearly understand the context for their narration and get information related to the general theme of the narration.

Narrative function of the tangible objects: In Mobeybou, the tangible objects are building blocks of the narrative, representing story elements, and manipulators-of-what-is-represented. Each block represents a story element and is a multimodal container that stores an animated image, ambient sounds and/or music. Together the blocks contain all the codified narrative information that defines the interactions between the narrative elements (i.e. landscapes, antagonists, protagonists, magical objects and instruments), which are modelled based on Propps' structure of traditional narratives (Propp, 1968). As the story world is modelled using BTs, different combinations of blocks result in the creation of a myriad of original narratives.

Collaborative and embodied actions: Mobeybou provides multiple 'access points'. In fact, each of the 60 blocks that are connected to the computer via Bluetooth provides access to the system. The large number of access points foster collaborative actions, since various users can interact with the system simultaneously. This leads users to take turns, get mutual inspiration, negotiate ideas, plan and construct the story. The users act in the physical space by grasping, connecting and disconnecting the tangibles, as well as holding, sharing and ordering them. These physical movements have implications in the system's space, given that the displayed animations, interactions and sounds change according to the physical connections of the blocks, that is, users can change the course of the actions by selecting different combinations of the story elements at stage, thereby having a considerable degree of agency. Users can also watch the animations and listen to the aural stimuli, and, finally, narrate and record their stories.

Narrator's position: In Mobeybou, the users can assume both exploratory and ontological positions, being internal or external in the later. The story world is very detailed, with scenarios, characters and objects presented by static and moving images and sounds, grouped in different cultural sets (aligned to the thematic context of the storytelling), which can be playfully explored by the users to learn about the story components (*exploratory* position). Users cannot customize the story elements. However, they are free to choose which of them to integrate the narrative. There is a protostory (possibilities structured by the system that allow the creation of multiple stories) in MBB, which contains the space of possible stories embedded in the content of the narrative elements, the narrative preconditions and definitions of the interactions (provided through the BTs of the story elements) and makes possible to the users actively interact with, explore and mix elements from different cultures, making decisions about the story world (*ontological* position). These are provided by the programming code and the interactive interface (Sylla and Gil, 2020). Through the interplay of purpose, actions, objects and narrative position, children are invited to become story authors, directors, performers and spectators of the stories that they actively create (Sylla *et al.*, 2014) (Fig. 5).

2.4.2. StoryBox (SB)

StoryBox promotes the creation and sharing of visual and audio stories with family members and friends. Users can craft objects, drawings or written messages that they place on the StoryBox.

Communicative Situation: Storybox aims at supporting intergenerational communication and social connectedness through experiential storytelling (*purpose)*. Thus, the *content* of the storytelling are daily situations experienced by the story authors' *context* that are shared between the family members (*audience).* The design decisions related to the functionalities

TABLE 2. Design articulations of 'narrating by doing' in each system.

TUI	*Communicative situation*	*Narrative function of the tangible objects*	*Collaborative and embodied actions*	*Narrator's position*
Telltale (2002)	***Purpose****:* promoting social play and development of narrative competences ***Content***: *not predefined* ***Context****: not predefined* ***Audience****:* the narrator himself + peers	Empty containers-to-be- filled with children's creations	Grasp, hold, connect and disconnect the pieces, listen to the narratives, narrate	Exploratory + ontological, internal or external
PuzzleTale (2010)	***Purpose****:* promoting decision-making processes ***Content***: a dog that needs to find his way home ***Context****:* problem-solving situation ***Audience****:* the narrator himself	Navigators for multiple-track stories	Arrange puzzle pieces, manipulate the digital characters, narrate	Exploratory + ontological, external
TellTable (2010)	***Purpose****:* promoting creativity and self-expression ***Content***: *not predefined* ***Context****: not predefined* ***Audience****:* the narrator himself + peers	Empty containers to-be-filled with children's creations	Interact around the table, take turns, draw with fingers, create story elements, get mutual inspiration, plan the story, negotiate, narrate	Exploratory + ontological, internal or external
TeleStory (2010)	***Purpose****:* development of narrative competences ***Content***: cat and dog's interactions ***Context****: not predefined* ***Audience****:* the narrator himself + peers	Building blocks of the narrative to combine content	Hold and sort blocks, watch the interactions, listen to the aural stimuli, narrate	Exploratory + ontological, external
TOK (2014)	***Purpose****:* development of narrative competences ***Content***: fairy tales' story elements ***Context****:* fantasy ***Audience****:* the narrator himself + peers	Building blocks of the narrative to combine content/story elements	Grasp, hold, share, order, negotiate, place and remove the tangibles, take turns, get mutual inspiration, plan the story, watch the animations, listen to the aural stimuli, narrate	Exploratory + ontological, internal or external
StoryBox (2018)	***Purpose****:* intergenerational communication and connectedness ***Content***: daily situations ***Context****:* home ***Audience****:* family members	Building blocks of the narrative originally crafted by the user	Crafting and assembling objects, narrate, listen to the other's stories	Ontological, internal or external
Mobeybou (2019)	***Purpose****:* social (role)play, development of narrative competences and intercultural awareness ***Content***: different cultures ***Context****:* intercultural environment ***Audience****:* the narrator himself + peers	Building blocks of the narrative combine content/story elements	Grasp, hold, share, order, negotiate, connect and disconnect the TUIs, take turns, get mutual inspiration, plan the story, watch the animations, listen to the aural stimuli, narrate	Exploratory + ontological, internal or external

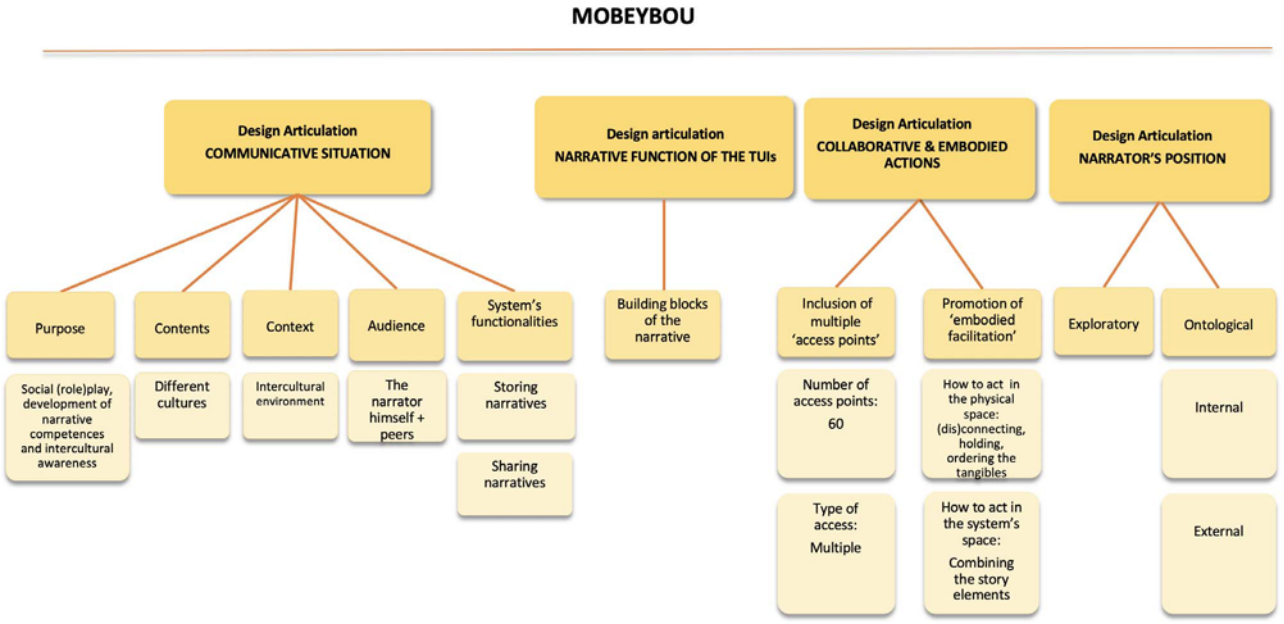

FIGURE 5. Design articulations of Mobeybou.

of the system promote this communicative situation, i.e. the system's affordances allow the user to record the narrative in different modalities—by pressing a button, the users can take pictures of the objects they crafted; a second button allows recording audio samples—and send them immediately to the audience (without storing), who can access the recordings asynchronously or synchronously and send a feedback message or story. This possibility to send feedback is intrinsically related to the purpose of supporting communication. In this sense, SB is a genuinely interactive system, since it fosters a two-sided effort to create a feedback loop of interaction (Ryan, 2011:35). Finally, since the intention is to share personal stories, users can freely personalize the inputs.

Narrative function of the tangible objects: In Storybox, the objects are building blocks of the narrative that can be randomly crafted or appropriated. They can take different forms and are used to create visual (static images) and aural content. Even though the objects do not have interactive properties, they are central to the narrative production, and the stories unfold around them. There is no limit regarding the quantity of such objects in a single story.

Collaborative and embodied actions: The Storybox interface is, as a whole, a central access point that can be used by multiple users if they take turns (i.e. only one user can share his/her tangible memories at a time using the system's sharing functionality); however, the actions in physical space, i.e. crafting and assembling their objects by drawing pictures or building artefacts, can be carried out collaboratively (e.g. by siblings, or children and their parents). The request to share personal stories strongly calls for the author's agency while creating stories and sharing tangible memories with family members (Wallbaum *et al.*, 2018). Regarding the actions in the system's space, users are able to freely create their own story content. All these 'doings' underpin the 'narration' process.

Narrator's position: Users can assume an ontological position, both from an internal and external point of view. However, the conceptualization and the design of SB privilege the internal position, since there is a complete open space for customization of the story world. Thus, the users can be authors, narrators and characters of their narratives (Fig. 6).

2.4.3. *TellTale (TT)*

TellTale has the form of a caterpillar with a head and a body of five pieces and allows children to record parts of their story into each body piece.

Communicative Situation: TellTale aims at promoting social play and to develop narrative competences, especially the comprehension and acquisition of a story sequence (*purpose)*. Thus, both the *content* and the *context* are not predefined, and the *audience* is either the narrator herself or her peers. To promote this communicative situation, the design decisions regarding the functionalities of the TT system include an option to record parts of the story with around 30 seconds of audio into each tangible object, the possibility to change and reorder the tangible objects and the possibility of listening to the whole recorded sequence. Moreover, although there is no thematic context specified to the narrative, the purpose of developing the comprehension and acquisition of a story sequence is fostered by the original shape of the tangibles, i.e. a modular caterpillar

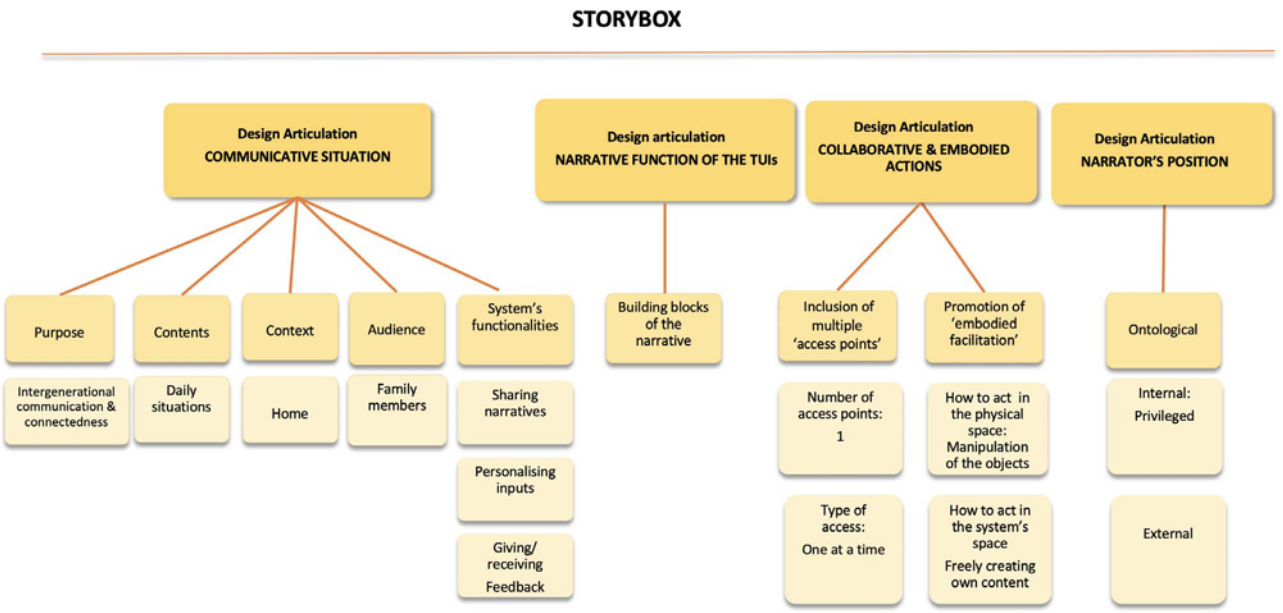

FIGURE 6. Design articulations of Storybox.

that allows trying out and exploring different sequences of a story.

Narrative function of the tangible objects: The objects are empty containers-to-be-filled with children's original verbal creations, acting, then, as the building blocks of the narrative and allowing the combination of the story content created by the users. The tangible object's manipulation supports the sequencing of the narratives, helping children to organize the events in their story according to temporal and causal relations. The number of tangible elements is reduced as content creation is free and relies on the users.

Collaborative and embodied actions: The design of TT system provides five 'access points', that is, each of the five pieces of the caterpillar's body provides access to the system. Children create their stories by pulling the tangible objects apart, rearranging and re-connecting them to each other, while playfully trying out different story combinations and sequences. By attaching the head piece to the body, children can hear the whole recorded sequence. Thus, the users can freely create their own story content and reorder parts of the story as many times as they want to. The actions carried out with TT can be explored, for instance, to scaffold children's agency, building coherent stories, with a beginning, a middle and an end.

Narrator's position: Since there is no previously available narrative content, the users are prompted to take an active narrative position and create their own personalized narratives, taking an internal or external ontological narrative position. There is an open space for customization of the story world. The users can also plan and attribute narrative roles to each other by recording them in the different pieces and perform a narrative in which each character has his own voice (Fig. 7). After creating (recording) the story elements, the possibility of playfully trying out different story combinations and sequences provides opportunity for an exploratory narrator's position.

As represented in the Figs 5, 6 and 7, these three exemplars present different combinations of design decisions, which resulted in different artefacts. The combinations of the design articulations of 'narrating by doing' are almost uncountable, thus opening up many possibilities for empirical work, this way contributing to bridging the gap between theory, practice and design.

3. CONCLUSION

The bridging concept 'narrating by doing' is underpinned by established notions about (i) the major role of language, and the interaction and collaboration with others in learning and developing social and emotional skills; (ii) narratology and (role)play as fundamental enculturation activities, and as the primary way through which children engage with the world; (iii) children's learning, which takes place when they are active 'builders', constructing knowledge through manipulations of tools that are meaningful for them and their surrounding environment; and (iv) how body and mind are inseparable coupled in meaning making and learning. These theoretical foundations led to design articulations for designing TUIs for storytelling. The articulation of these parameters are important guidelines for different possibilities for storytelling offered by 'narrating by doing', as illustrated through the selected exemplars.

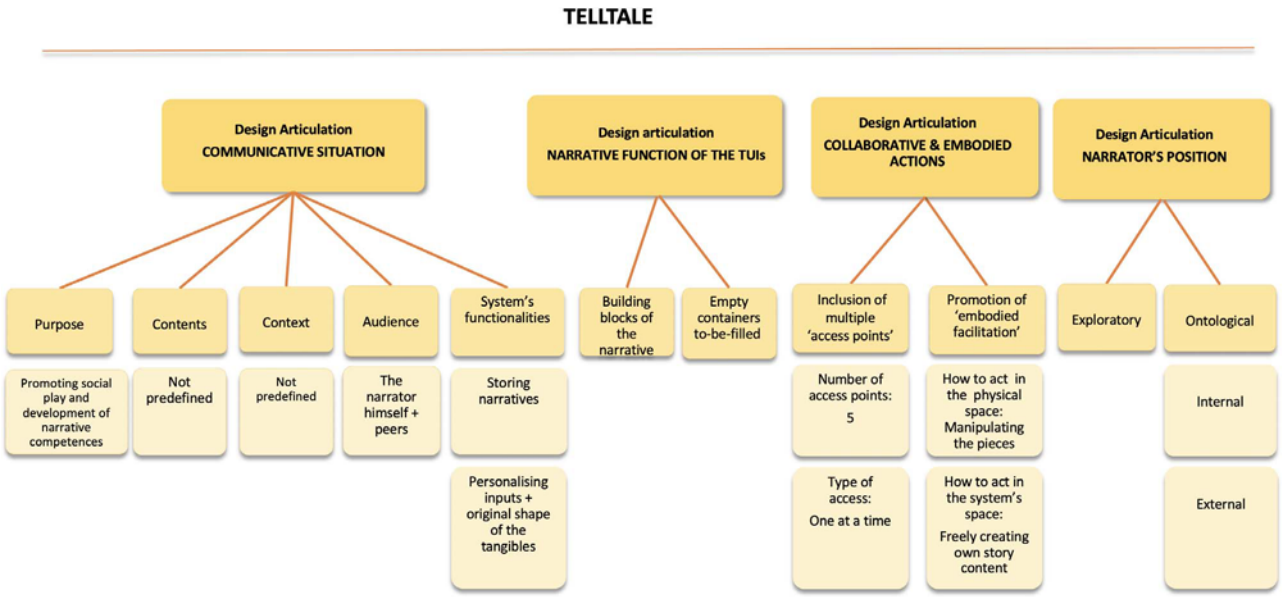

FIGURE 7. Design articulations of TellTale.

The decisions made regarding each design articulation will have implications on the users' agency and engagement, and on the scaffolding of the storytelling and of the learnings supported by the tools. In 'narrating by doing', it is the 'doing' that creates and shapes the storytelling; without 'doing' narrating does not take place, so the actions that are performed by the users are central to their telling. As such, different choices and combinations of the design articulations will result in uncountable possibilities for the design of TUIs for storytelling that will offer the user's different narrative experiences.

In this sense, we argue that this bridging concept contributes to spanning the gap between theory and practice in the design of TUIs for storytelling directed to young children, contributing to creating intermediate level knowledge in CCI, therefore addressing claims for the development of models and guidelines that inform design, previously voiced by other studies, such as Read and Markopoulos (2013). Our contribution is in line with previous theoretical work that informs the design of TUIs, such as Horneckers' framework for the Design of Tangible Interaction for Collaborative Use, particularly the concepts of Embodied Facilitation and Multiple Access Points. The concept of 'narrating by doing' also dialogues with the Child Tangible Interaction framework (Antle, 2007), particularly with the themes, space for action (embodied cognition) and space for friends (collaboration). And finally, the concept of 'narrating by doing' also contributes to expanding Harley's Framework for Tangible Narratives (Harley *et al.*, 2016) by including more systems and categories. Together they provide guidelines for designers to assess how to create new stories or storytelling tools for tangible narratives aimed at young children.

The relevance of establishing 'narrating by doing' as a bridging concept is 2-fold: (i) the concept encompasses different theoretical approaches in an integrated and meaningful way that can inform decisions for the development of tangible interfaces for storytelling targeting young children; (ii) its 'design articulations' can offer guidance for the design and development of tools for storytelling. As exemplified in the exemplars that were briefly scrutinized, 'narrating by doing' encompasses the creation of different types of stories through the combination of different design approaches. In future work we will continue to investigate further articulations that can inform the design of tangible interfaces for storytelling.

Finally, this possibility of bridging theory and practice by bringing together a set of understandings and developments highlights the importance of the establishment of bridging concepts, as well as other kinds of intermediate-level knowledge, in CCI investigations and designs. The point that we wish to make here is that each 'narrating by doing' environment finds its potential originality in the holistic articulation of the different design decisions and possible combinations and interdependencies described in the previous sections. 'Narrating by doing' opens way for untried design opportunities and theoretical advances, as reclaimed by Dalsgaard and Dindler (2014), which we consider to be an important final theoretical argument supporting our claim that 'narrating by doing' is a 'bridging concept'.

ACKNOWLEDGMENTS

This work has been financed by national funds through the Portuguese Foundation for Science and Technology (FCT)

and by the European Regional Development Fund through the Competitiveness and Internationalization Operational Program under the reference POCI/01/0145/FEDER/032580.
This work is funded by CIEd—Research Centre on Education, Institute of Education, University of Minho, projects UIDB/01661/2020 and UIDP/01661/2020, through national funds of FCT/MCTES-PT.

SUPPLEMENTARY MATERIAL

Supplementary data is available at *Interacting with Computers* online.

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