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# CoMo-education: Collective and Embodied Storytelling in Kindergarten Using a Gesture-sound Interactive System

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Storytelling is an essential practice in preschool. Recent advances in digital tools for multimodal and collective interactions represent opportunities for new approaches in storytelling. Motivated by an embodied approach of storytelling, we developed CoMo-education, an interactive system where whole-body movements and sounds are in play. Moreover, this application enables storytelling as a collective and multimodal experience. Using gesture recognition with screenless smartphones, the teacher and pupils can use movements to play various soundscapes, which enliven the story. The aim of this article is to present the overall project, which has spanned more than 3 years of iterative developments. Importantly, it was developed through an iterative co-design process including designers, teachers, early-development experts and engineers. A user study was carried out in two kindergarten classes which allowed us to gather feedback from teachers and children, and formalize a series of guidelines for future works. A workshop was also dedicated to educators to evaluate how educators can appropriate the application to create interactive stories by themselves.

CCS Concepts: • **Human-centered computing** → **HCI design and evaluation methods**; **Human computer interaction (HCI)**.

Additional Key Words and Phrases: child-computer interaction, storytelling, embodied interaction, early childhood education, gesture-sound interactive system

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## 1 INTRODUCTION

Storytelling is an essential practice in preschool. Storytelling is indeed a major support for the language acquisition - oral and written - which is the main objective of preschool education in France [13]. Language is a means of expression, communication and creativity for children, who thus develop their relationship with others and the world surrounding them [30]. It is also a valuable tool for play and imagination, two essential elements of early childhood development [43, 44].

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In France, storytelling activities usually take place at the beginning of the day, before/after lunch, and at the end of the day. These narrative moments rhythm the children’s learning journey and punctuate the day in class. Generally, the use of illustrated paper books is still favored by most teachers. In this case, they typically tell stories while showing the pictures to the children. Audio stories are also sometimes used, either directly played to the entire class by the teacher or used by children on their own who choose to hear a story during individual times. In such a case, the paper book is then replaced by a disc player, a computer or a tablet.

It is worth noting that, in these contexts, the storytelling is usually considered as an intellectual activity, being disconnected from physical activities: the children are supposed to listen calmly in a sitting position. Physical activities are reserved for exercises in the gym-room. Such a separation in so-called physical and intellectual activities reflect a general pedagogical approach characterized by a mind-body divide. Nevertheless, developmental studies demonstrate the importance of linking the body and the mind to promote active learning and the mobilisation of all cognitive skills [22, 25, 38]. Theories concerning the fundamentals of child development indeed consider that children explore the world around them, first of all through their body, well before the acquisition of language. It is therefore essential to encourage sensory-motor interactions from an early age [8]. Moreover, a direct link has been established between experiences involving body movements with motivation and memorization, two essential vectors for learning from an early age [3, 20]. Also, the playfulness made possible by these bodily experiences [42], a notion widely explored in the Progressive Education movement led by Maria Montessori and others [7], constitutes a third vector for learning. Such embodied experiences can also be linked to the notion of “learning by doing”, as defined by John Dewey [14].

Inspired by pedagogues such as Montessori and Dewey, digital tools designed for multimodal interactions—linking senses of sight, hearing, touch and movement—have already emerged in the field of child-computer interaction (CCI) [50]. For example, tangible interfaces designed for very young children (before the age of 6), both manipulable and multisensory have been developed [33, 33]. Such approaches encourage embodied learning which was found to be beneficial for early childhood development [6].

Directly inspired by these approaches, we have developed the CoMo•education application, which supports full-body collective interaction for storytelling in preschool. Precisely, it enables teachers and pupils to collectively experience stories in motion, shaped by various soundscapes generated by the pupils’ gestures, as illustrated in Figure 1. CoMo•education makes use of screen-inactivated smartphones, taking advantage of their motion sensors and speakers.

The present article describes the 3-year interdisciplinary project, implying design and technological developments, that enabled us to converge toward a functional system that has been evaluated in classes. After describing related works, we describe the design processes, the application, and the evaluations that were carried in schools and with practitioners in the field of early childhood education.

## 2 THEORETICAL BACKGROUND AND RELATED WORKS

The project is interdisciplinary, crossing pedagogy and human-computer interaction. In this section, we review first the role of storytelling in pedagogy, second, we present related digital interfaces in digital storytelling and third, related sound and music interfaces.

### 2.1 Storytelling in preschool classrooms

Storytelling is considered to be a powerful tool for teachers who engage in narrative practices throughout the day. The storytelling is generally carried out from a book, a support of oral (and visual) transmission for the teacher with children, on collective times [48]. There are numerous developmental benefits to storytelling. First, it encourages early

literacy leading to the acquisition of reading and writing, the main competencies needed for other types of learning [23, 28]. Secondly, storytelling develops children’s imagination, their creativity, and their ability to invent, which are necessary to respond to the various problems of everyday life and of society [31]. Finally, storytelling is a playful way to develop children’s social skills, to give them the keys to express themselves correctly, interact with others, and promote active participation in their learning process [15]. Moreover, storytelling is practiced both at school and at home, illustrating a form of pedagogical continuity between the two environments mainly frequented by young children [47]. All these benefits put together, demonstrate the importance of this activity in kindergarten education.

## 2.2 Digital Storytelling

Through the use of digital technologies, storytelling has evolved into what is termed “digital storytelling”. As mentioned by Yuksel-Arslan et.al [47], the Digital Storytelling Association (USA, 2002) defined “digital storytelling” as the use of “digital media to create media-rich stories to tell, share, and to preserve”. Traditional story books are then associated with classical digital tools such as computers, cameras, speakers, micros and video projectors, as well as digital manipulatives. Used as a medium for creativity [34], these digital learning environments provide new means of expression [29] and even encourage the creation of stories by young children.

This is the case, for example, with the *POGO* learning environment, created by an interdisciplinary team, which support the development of narrative competencies in children through many digital activities that encourage the child to explore, inspire, product and share storytelling [35]. Another example is the *PStory-Mat* project that promotes children’s fantasy and storytelling through playful interaction that “listen to children rather than talking to them” [9]. Tangible User Interfaces (TUIs), very popular when designing for young children [5] also support digital storytelling. *TOK* (for Touch, Organise, Create) is an example of TUI using digital blocks for manipulating story elements and empowering young children to create their own original stories [39, 40]. Finally, another interesting project enhancing tangible interaction is *STTory*, which promotes multisensory storytelling through smell, taste and touch in preschool [32]. The last two projects mentioned offer hands-on manipulation of digital information through physical objects [24].

## 2.3 Sound & Music Interfaces

Sound and music interfaces are technologies that have been used for children’s developments, and often closely related to digital storytelling interfaces, [46]. Sound and music are essential development resources for young children in terms of communication and listening, as well as creativity towards an artistic awakening of the toddler [45].

Several projects and products based on multimodal interaction made aim at encouraging children’s musical expression. The *Place&Play* project enhances the musical experience by allowing young children to record music and manipulate musical objects through a spatial configuration specifically designed for these target users [4]. In contrast, the Music Pets project offers screen-free musical interaction through the manipulation of tangible, musical toys that allow the child to record messages and store audio [41]. Combining physical objects and a screen interface, the *OVAOM*[2] and *DIRTI*[37] projects allow young children to create sound interactions through the manipulation of physical objects, respectively, through the use of joysticks especially designed for kids, and exploratory sound control using a tray filled with tapioca grains.

Research projects proposing immersive sound environments have also appeared in the field of child-computer interaction. These environments have the particularity of proposing whole-body interactions, as in the Bendable Sound project. To improve the sensorimotor regulation of children with severe autism, the elastic multisensory surface allows children to play sound in a natural way [10]. Child Orchestra, a musical playground for kindergarten where children

can manipulate musical tracks through body movement [12]. The *MoBoggie* allows for children to randomly play sound loops with smartphones [18].

All these references, in digital storytelling and sound interface have the particularity to promote bodily interactions through gesture and multisensory approaches. Actually, the use of digital technologies enhances multimodal interactions and directly links the body to cognition to promote new ways of learning [21].

### 3 COMO•EDUCATION: CONCEPT AND DESIGN PROCESS

The aim of the CoMo•education is to develop a movement-based application that supports storytelling practices in preschool. The central idea is that certain parts of the story are “performed” collectively by the teacher and the children, by miming certain gestures and movements (Fig. 1). Using a gesture recognition system, the children’s movements trigger specific soundscapes, designed to accompany and enliven specific parts of the story (see section 4 for technical details). The sound narrative is aimed at mobilising the whole-body, promoting kinaesthetic and collective interactions. In this section we first describe the design process and requirements we progressively established throughout the project. The CoMo•education was conducted through an iteration process involving different stakeholders of the preschool environments, with an ecological approach, by grounding experiments and evaluation in kindergarten. Importantly, our approach was inspired by the work of Eleanor J. Gibson and Anne D. Pick’s work on “Perceptual Learning and Development”. This ecological approach takes into account the richness of the child’s environment [17] and their diversity.



Fig. 1. Use of CoMo•education in a classroom.

### 3.1 Research through Design Approach

As described below, CoMo-education was developed using a Research through Design (RtD) approach [49], an iterative approach building from a dialogue between theory and practice, involving several disciplines [19]. Specifically, we follow a co-design approach, in fostering “the creativity of designers and people not trained in design working together in the design development process” [36]. As described below, designers, engineers as well as education professionals and child’s development experts were involved in this co-creation process.

**Education:** 6 preschool teachers were involved throughout the co-design process in order to conform with current educational practices in kindergarten and meet the preschool objectives. [13].

**Child’s development:** an occupational therapist, as well as researchers in developmental psychology, were involved through meetings and interviews all along the co-design process.

**Design:** designers, including sound and narrative designers, were at the core of the co-design process, from ideation to testing in kindergarten with children.

**Engineering:** engineers and developers were involved in the technical development of the application (described in more detail in section 4), which was derived from previous systems developed for embodied interaction.

### 3.2 Design requirements

The multidisciplinary inputs we gathered enables us to formalize a series of different requirements we summarize below:

**R1 - Pedagogy:** matching recommended learning area in preschools.

In order to be integrated in the preschool environment, any application must target specific Learning Areas (LA) defined by French educational policies [13]. CoMo-education, being a tool for embodied storytelling, is directly concerned by the following objectives: developing communication, understanding and oral expression (LA-1); acting, and feeling through the body (LA-2); exploring and refining listening skills (LA-3). As an interactive system it also concerns the goal of digital tools use (LA-5). In this case, the policies specify that teachers have the responsibility and the commitment to integrate any new device into their teaching practice. This implies for us that teachers is primary stakeholder of the application.

**R2 - Embodied interaction:** stimulating sensorimotor development.

As mentioned already, the main idea behind the development of our application is to follow child development theories that stress sensory-motor interactions as fundamental supports for learning. In particular, the role of concurrent feedback to create perception-action loop is primordial [17]. Therefore, the application is built around the principle of real-time sound feedback for the children’s movement. This implies that the agency of the interaction must be carefully considered.

**R3 - Interaction design:** collaborative and versatility of uses.

The application is designed with the aim of favoring collaborative behaviors between teachers and children. It is also thought of as a tool supporting creativity, with the possibility to co-create a story collectively in the classroom. Therefore, the application should support different modes: playing, modifying or creating a story. Importantly, we also aim at the autonomous use of CoMo-education] in the classroom by the teacher with the young pupils, which is linked to technical features described in R4.

**R4 - Technical implementation:** portable and simple to install.

Finally, the interactive system must be easy to install and set up in the classroom, since this can be a limiting factor especially when digital technologies are used with young children. For example, setup time and space use must be similar to other activities in the classroom (for example, painting or music workshops). In terms of technological development, this pushes to use wireless tangible interfaces that enable children to move freely. Also, following the R2 requirement, each child should be able to hear the sound she/he produced through her/his movements, the sound rendering should thus be individualized. Concretely, this means that the tangible device should be a personal sound device, embedding a small speaker.

### 3.3 Scenario Iteration Process

In our case, applying the ecological research approach meant to design and develop our application by being constantly in contact with the preschool environment. We therefore implemented an iterative research process allowing us to develop scenarios and test them directly in preschools with children aged 3 to 5 years old. This iterative process is composed of 4 stages - forming an iteration loop:

- (1) Co-design of an interactive storytelling: story, sound, and gesture selection.
- (2) Tests with children in kindergarten, in small groups of 6 to 8 children. Feedbacks from tests with children and teachers interviews.
- (3) Interactive system and interaction design improvements.

Precisely, we conducted this iteration process with 6 classes in 4 preschools, involving 6 teachers and about 150 children (aged 3 to 6 years old) over 7 months. For this, we used a single story and scenario based on the novel *We're Going on a Bear Hunt* (by Michael Rosen & Helen Oxenbury), which we will describe in more detail in the user study. The scenario was developed through sessions performed in small groups of children (6 to 8) with a storyteller (described later in section 4.5). In order to avoid bias in our process, we performed only one iterative loop per class - and made improvements after each loop at several levels. For example, we have adapted the overall scenario, including the approach to introduce the system to the children, to perform the story, and collect feedback from children. From a design perspective, we also adapted the choice of gestures and sounds used for a given story, and several technical features in the applications. In parallel, we conducted interviews with teachers to get their critical feedback on this new pedagogical tool. Collecting feedback from children and their teachers during this iteration process, confirmed the interest of the approach and led us to the finalized application, scenario and user studies protocol we describe in the next sections (Sections 4-5).

## 4 COMO•EDUCATION: APPLICATION DESCRIPTION

### 4.1 Iterative technical development

CoMo•education project is part of an ecosystem of applications called *CoMo* dedicated towards movement-based collective sound interaction. As a technological framework, *CoMo* is built upon the *Soundworks* library [26, 27], a library for building real-time distributed applications using Web technologies, and the *XMM* library [16], a library dedicated to gesture recognition using machine learning techniques. CoMo•education can be seen as a variation, designed for interactive storytelling experiences in kindergarten, of the generic open source *CoMo-Elements* web app [1].

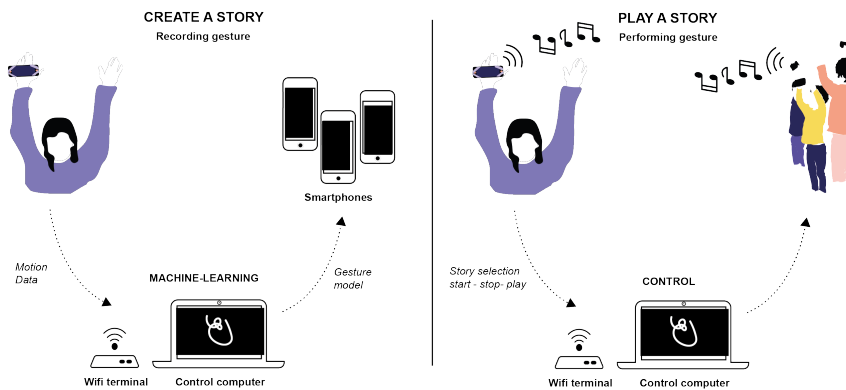


Fig. 2. The different uses of the CoMo•education application

## 4.2 Interactive System

CoMo•education requires the use of a computer connected to a WiFi antenna and running the server application. The computer is set up to create a local WiFi network, and run the server-side of the application. All the smartphones are then connected to the computer through the local WiFi and run the application through a Web browser. Optionally, external speakers can also be added.

As illustrated in Figure 2, the application uses the motion sensors (3D accelerometer and 3D gyroscope) of the smartphones that are used by a gesture recognition module to select and play a sound file using the WebAudio API. The gesture intensity measured by the accelerometer is used to modulate the volume of the rendered sound file. The system is designed to enable users to define themselves the gestures and the mappings between the gesture and the sound produced. As such, it suffices for a user to record the gestures with their smartphones and to associate them with specific sound files, sound files that themselves can be managed by the teacher.

## 4.3 Interaction Modes

As defined in the third design requirement (R3), we wanted teachers and children to be able to use the CoMo•education app and create their own stories. We then created two operating modes (Fig. 2): *teacher* and *pupil*.

In teacher mode, the application exposes 3 main functionalities:

- **Create a story:** A new story is created through the following steps: 1) naming the story 2) recording each gesture twice 3) choosing sound files to be associated to each recorded gesture.
- **Modify a story:** This allows for modifying either the sound selection and modifying the gestures.
- **Play a story:** This allows for collectively playing a story with pupils. The interface allows the teacher to select the story, start and stop.

In pupil mode, only the functionality *Play a story* is available, and the start and stop are remotely controlled by the teacher. Most important, the pupil screen is black and does not provide any graphical user interface. Furthermore, the screen can be blocked.



#### 4.4 Sound and Gesture Design

The *CoMo* applications require making choices on sounds, gestures, and their relationships. While each sound is first selected by the gestures, the players are also influenced by the sound feedback since it accompanies the unfolding of the gesture. This creates an action-perception loop, favoring sensorimotor adaptation and learning, recommended by early childhood experts for digital interaction systems (as specified in Section 3.2) [11].

*4.4.1 Sound design.* Sounds, typically of several seconds, are looped in the application, and the start and end of the sound file should be designed to produce a smooth and ideally imperceptible loop. This is relatively easy to achieve with “textural” sounds, as it is often found with environmental sounds such as “wind” or “water”. Attention should be drawn to use sound with frequency ranges compatible with smartphone speakers, and thus typically avoiding low frequencies.

*4.4.2 Gesture design:* we follow the principle that the gesture should typically evoke actions that could trigger the sound, or evoke the sound at a metaphorical level.

Since the gestures are captured through accelerometers and gyroscopes, it is important to consider for each gesture a different combination of hand orientation, rotation velocities and movement intensities. Such characteristics can be used by the algorithm to differentiate and to recognize the different gestures. If confusion occurs during the recognition process, the gestures can be modified and recorded again.

#### 4.5 Pedagogical Scenario

Through our iterative design process within the preschool environment (Section 3), we developed a pedagogical scenario, combining an interaction scenario [8] with an approach for introducing and discussing the application and experience. This meets the institutional learning objectives of the preschool program (R1).

Before starting the scenario, children are equipped, thanks to a wristband, with smartphones on their right hand, blocked on a black screen.

The pedagogical scenario is composed of 3 steps:

- (1) **Demonstrating the gestures:** the teacher shows the children the gestures that make up the story, inviting them to imitate him/her. This step is carried out in silence, the smartphones being “muted”.
- (2) **Interactive storytelling:** the application is started, and the interactive story is told by the teacher. Both children and the teacher move together at specific moments, producing the soundscape collectively.
- (3) **Group discussion:** once the story ends, a group discussion is held with the teacher and the children.

### 5 USER STUDIES

After the initial phase of co-designing the application implying teacher and various tests in classrooms with children, we conducted two different types of user studies described in the next sections.

#### 5.1 User study 1: preschool environment

The purpose of this study, conducted with two preschools was twofold: 1) the technical evaluation of the current version of the application and 2) the qualitative evaluation in an ecological setting during regular teaching days at preschools, including observation, group discussion and individual interviews with teachers and children.

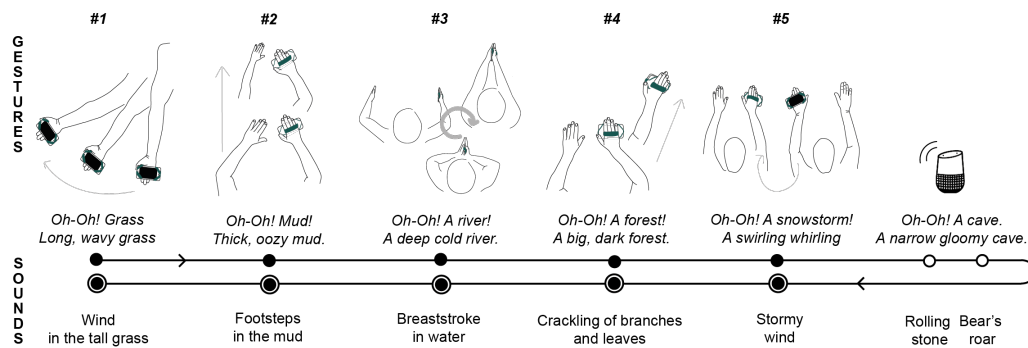


Fig. 3. The pedagogical scenario of CoMo-education with the storytelling *We're Going on a Bear Hunt*

**5.1.1 Participants.** The intervention involved 27 children (13 girls and 15 boys) aged from 4 to 6 years old from two preschools with a medium of 5,7 yo. None of the classes had participated in the design of the application, or had heard about it before the intervention.

**5.1.2 Material.** The user study is based on the sound and motion narration of a story created from the book *We're Going on a Bear Hunt*. Prior to the intervention, we pre-recorded the gestures and selected the associated sounds that would animate the story, as described in Figure 3. The choice of this story results from a discussion with other teachers during the development phase.

**5.1.3 Method and data collection.** The user study took place in June 2021 (end of the French school year). The children were divided into small groups of 6 to 8, in order to facilitate the implementation of the study. For each school, the intervention took place in a room adjacent to the classroom to avoid to disrupt the rest of the class. The procedure was composed of the implementation of the pedagogical scenario (section 4.5), followed by individual children questionnaires and interviews (Annex D Table 2), and then individual teachers semi-directed interviews.

The storyteller was the regular class teacher in one class and first author in the other class (this point will be later discussed). After each scenario, the children answered a series of questions individually, conducted by a researcher. The implementation of the pedagogical scenario as well as children interviews were recorded on video. The video recordings were sent to the teachers of the classrooms participating in the study before interviewing them individually a few days after the experiment. These interviews were audio recorded. All audio and video recordings were finally reviewed and annotated by the researchers who were not present in the classroom.

**5.1.4 Results. Technical assessment.** From a technical point of view, the system operated smoothly and the smartphones responded as expected for all children (total = 27). Several improvements concerning the interfaces for the teacher have been noted, such as the need to be able to mute all smartphones with a central button, or the possibility to discreetly activate a sound on an additional speaker (which was performed by an assistant). This will be the object of future improvements (see 6. Discussion).

**Questionnaire responses.** Following the analysis of the responses to the questionnaires (described in Annex D, table 2) we extracted a first set of results (Annex D, table 3). First, all children reported they enjoyed the interactive storytelling (A.1), confirming the observed children's engagement and motivation to follow the story. Overall, the majority of the children (78%) understood the main thread of the story as a bear hunt. But they referred to the story in

different ways using words and/or gestures. In class 2, a majority of children were able to put words on the story (B.2), while in class 1 the majority of children were able to convey the story by gestures (B.3).

Regarding the understanding of the interaction system, all children were able to mention that the sound came out of the phone (C.1). While the vast majority (82%) understood that the sounds were motion activated (C.2) (a child spontaneously said “*if we do the right gestures, it makes the right sounds*”), only half of the children believed they used a real phone (C.3). In the qualitative analysis of the children interviews (post-experiment), some children mention the fact that they could not “*make a call*”, “*play games*” or “*order food*” with these phones (which were indeed blocked on black screens).

**Qualitative analysis of video recording.** All annotators independently notice the following points. All the pupils showed commitment and motivation in the interactive storytelling, as all children were active and moved according to their ability. The handling of the smartphone or performing the gestures required some adjustment during the demonstration phase. This was easily achieved by the storyteller conjunctively showing and explaining gestures verbally (“*arms up*”, “*one arm after the other*”, “*slowly*” or “*go faster*” for example). During the story, the children could perform all the gestures without apparent difficulty and seem to enjoy the immersive and collective experience, as evidenced by smiles and laughs.

During the interactive storytelling, most children appear attentive and collaborative. For example, the fact they stop moving collectively when asked to do so by the teacher, inducing then silence in the class, represents marker of such “attentiveness” at a group level. Such a behaviour is notoriously usually difficult to achieve in a class at this age.

During the discussion groups, the children gave interesting and creative feedback about the soundscapes. For example, they were imaginative in describing the bear [*The bear was hairy and green with big teeth*], [*The bear hid a big diamond in his cave*] or the sensations felt while crossing the landscapes [*The water is super cold, I can't swim anymore*] (#2), [*The snow comes into my eyes I can't go on*] (#5).

**Teacher interviews.** The interviews with teachers brought additional important points. First, they all found the approach fruitful at a pedagogical level, beyond being just playful. Precisely, it appears pertinent to offer children different type of ways of telling a story, some preferring words and some others gestures. Moreover, the teachers appreciated the fact that they were able to see their pupils in a different way [*I have seen children who are usually 'inhibited' in class, or who have difficulty engaging in a purely academic activity, become more involved, more participatory, and more successful*] - Teacher 1]. It also validated certain observations concerning the development of these children [*Being able to observe the children as a spectator allowed me to confirm characteristics in my pupils that I had already noticed. For example, I observed that some children were uncomfortable with their bodies and I noticed that these are the children who also have difficulties with handwriting*] - Teacher 2]. Second, the teachers insisted on the relevance of controlling sounds collectively in real time. According to them, these sound environments are great supports for the understanding of a story, which are still too little used in kindergarten [*Thanks to the app, we produce movement which is immediately associated with a sound by immediate feedback of our actions, something we rarely have in class I think or not in the same way. / In this scenario, the staging and the sound universe are at the service of understanding the story*] - Teacher 1] Finally, the introduction of technology into the classroom has also opened up perspectives for changes in pedagogical practice, beyond the mere use of technology [*I usually tell stories sitting down. Using the app in my classroom pushes me to tell the stories in motion, to change my posture*] - Teacher 2.] [*I think that using the app change the way I tell stories in class. I find it of pedagogical interest for rambling stories, with a succession of repetitive elements*] - Teacher 1].

## 5.2 User Study 2: Workshop with Educators and Media Specialist

Following our first study, we conducted a one-day workshop with several early childhood experts and educators. The first objective of the workshop was to experiment with the story creation and modification modes. The second objective was to discuss with different practitioners in the field of early childhood education, of the possible extended uses of the application: during school time, but also during extracurricular time, digital awareness workshops for children or for uses in healthcare for children.

**5.2.1 Participants.** Following our multi-disciplinary approach, this workshop brought together several professionals in the field: an occupational therapist, a preschool teacher, a digital mediator, and a Montessori educator. These four professionals had never used the application before.

**5.2.2 Method and Data Collection.** After the general presentation, we demonstrated, with the workshop participants, the interactive story of *The Bear Hunt* (used in preschool in User Study 1). Then, we proposed to create a new story from scratch by groups of 2 participants. They were helped by a booklet with a story template, including a grid to support the creation of an interactive story with different story phases, as well as a set of possible gestures. The application included pre-loaded sounds. Then, we pursued a collective discussion, followed by individual semi-directed interviews. In particular, we asked them to describe their experience, the possible improvement and whether/how this application could be integrated in their professional practices.

**5.2.3 Results.** The section presents important points that were discussed about the current application features and the possible use in different professional practices.

**Use of the application.** In general, participants found the application easy to use and the story creation process easy to follow: *"In the end, it's quite simple to use, there are few steps to follow, few things to do to create a story - it's quite intuitive!"* (preschool teacher). The current sound library was considered to be *"quite extensive"* to create interactive narratives (Montessori educator). However, some drawbacks were mentioned in the workflow of the creation mode that followed then a too strict linear step by step process. It was asked to have the possibility to return easily to previous steps, as well as the possibility to test the recognition during the design process. Also, the possibility to mute all smartphones in "pupil" mode from the "teacher" mode was also recommended. These design issues have been corrected since this workshop.

**Integration into professional practice.** The professionals showed interest in using CoMo-education for pedagogical purposes (to tell a story differently, involving the body, movement and sound, all in a collective way): *"I see the interest of the tool since it allows us to narrate differently and to make the children participate in the narration, - it makes them work on their motor skills, the attention of the gesture, the concentration, the cooperation since for the sound universe to be harmonious everyone must produce the same sounds at the same time, so we must listen to each other, look at each other"* (kindergarten teacher). The use for rehabilitation was also noted: *"I would use CoMo-education in rehabilitation activities to work on memorization, attention and concentration. Finally, the attention paid to the sound could help the children to remember the gestures they made, their intensity, their movement, their direction, etc."* (occupational therapist).

Finally, the possibility to use the application for digital mediation, in order to promote a different use of the smartphones by students, was proposed, and could avoid a form of "fascination" of smartphones: *"Thanks to the creation of one's own interactive narrations: CoMo-education could allow us to develop a relationship with the smartphone that does not go through the screen and thus become more aware of the other embedded tools [sensors] that are inside it. This allows for a collective experience that is both physical and narrative"*. (digital mediator).

## 6 DISCUSSION

We presented the CoMo•education project which goal was to design and implement a generic application for collective embodied movement storytelling in preschool. The gesture and movement based interactive system was developed through an iterative co-design process with the stakeholders of the preschool environment. In this section, we first discuss the lessons learned from the design process and user studies evaluations, then we propose a set of design guidelines that are specific for this type of project.

### 6.1 Lessons learned

Overall we have confirmed that the system is functional in an ecological situation, by running sessions with teachers in preschool. It could be then deployed in several other schools. By design, other stories can easily be added by the teachers themselves, allowing them to include the application in several pedagogical contexts. Globally, the user studies seem to indicate that CoMo•education could stimulate both children, and teachers, to experiment different paths. As several teachers pointed out, CoMo•education creates a situation that is fundamentally different from quieter, seated forms of storytelling. The teachers noted that some children generally inattentive in “seated storytelling” were surprisingly active and attentive in this case. More generally, it appeared that an embodied approach to storytelling could be beneficial to children with different abilities. This aspect, favoring global inclusivity, represents a promising element that should be further evaluated.

Importantly, the teachers reported that CoMo•education could be a “*complementary tool*” for storytelling: “*Using CoMo•education in the classroom allowed me to observe the children differently, i.e. to confirm or refute observations on the development of pupils, particularly in their relationship with the body*” (Teacher 2). Thus, the aim is not to substitute current storytelling practices in preschool, but rather to promote embodied ways of telling stories, with or without the use of digital technologies: “*I think it is going to change the way I tell stories: I think I’m going to use more gestures and tone in my storytelling with children*” (Teacher 1). Such observations are very encouraging and invite further ecological evaluations.

In terms of use, CoMo•education could be used throughout the year in a class with different approaches. As we mentioned, CoMo•education fulfills several learning areas of the official French educational program for kindergarten (see section 3.2). Nevertheless, one could also evaluate potential long-term beneficial effects of repeating several stories, and how different or similar gestures could be used across a collection of stories. Importantly, CoMo•education could be developed as a pivotal activity to develop several other activities such as creating a story with children, recording sounds, and inventing gestures collaboratively.

Finally, we must note CoMo•education makes use of smartphones, which can be seen as controversial in preschools. We can discuss this choice considering different aspects. First, as we mentioned several times, we do not use the screen, and promote collective physical activities. Therefore, the rationale of our application is precisely to avoid the pitfalls that are generally associated with smartphone uses. Moreover, the teachers confirmed that such digital tools could indeed be introduced smoothly in kindergarten, following a the co-design process involving all the school stakeholders. Alternatively, similar dedicated devices with both motion sensors, processing power, batteries and speakers could also be alternatively built to avoid the use of smartphones. Such an option will also be considered in future. In particular, nano-computers (such as Raspberry Pi) could be used to reduce the overall cost and facilitate the installation.

## 6.2 Synthesis of design choices

The design process of CoMo-education follows design guidelines proposed by Child Computer Interaction Researchers, such as co-design with stakeholders or designing scenario taking favoring action and cognition interaction [5, 19]. In addition, we would like to stress here some specific points that appeared during our project as starting points for future research and development:

**Supporting designers involvement in the classroom:** Due to preschool constraints, teachers were not always able to participate in the experiment and test the digital tool with their pupils. The designer (and first author of this article) therefore sometimes became the storyteller of the experiment. This role proved to be very useful for the design process, allowing for a better understanding of the challenges in preschool education. Nevertheless, it remains to evaluate how teacher could appropriate on the long term such a application.

**Allowing adaptable context-dependent scenarios:** The pedagogical scenario we describe was co-designed with teachers and pupils in a pre-school context. Various discussions showed us that the CoMo-education system could be used in other contexts. For this, it is crucial to keep the application sufficiently adaptable in other contexts (e.g. in healthcare or extracurricular activities). For this reason, several aspects of any story can be easily modified: the sounds, the gestures can be easily modified and can be performed in any order or timing.

**Promoting screenless interaction for young children:** Using smartphones in kindergarten was discussed extensively with teachers during the co-design process. The decision not to use the screen of the smartphone during interactive storytelling was a design choice from the start of the research. This choice was particularly well received by practitioners, since it foster embodied interaction and sensori-motor development. Interestingly, perspectives on existing technologies opens up opportunities for digital education, even with very young children.

**Paying attention to inclusive digitalization:** Overall, We found the use of whole body interaction and sound without screen opens interesting opportunities for the inclusion of different capabilities in the educational context. Throughout the design process, we tested the application/scenario in several preschools with children from different socio-cultural contexts, including children with disabilities. We also reached the teachers with very different backgrounds and teaching practices. This also raised complex questions and issued that remains to be investigated and critically discussed.

## 7 CONCLUSION AND FUTURE WORKS

In this article, we presented CoMo-education, a playful and pedagogical tool for digital and embodied storytelling resulting from an ecological co-design process and bridging several disciplines such as education, cognitive sciences, engineering and design. Designed to fit specific objectives of the French education program in pre-schools, the application could be further deployed, tested and evaluated within a larger group of classes. Our application represents one possible approach in integrating digital technology in the education systems. It remains to investigate further how such digital tools could promote, on the long-term, alternative embodied approach in storytelling practices in kindergarten, as it was suggested by teachers in our user study.

Designed as a tool with customizable contents, such as gestures and sounds, it also enables for the creation of users' own stories, and could then become a support of creativity for both teachers and children, which we are currently investigating. We believe that such screenless digital tools could stimulate teachers to experiment and question different learning methods, that could potentially promote complementary practices, even without using technology.

Our user study also leads to questions for future fundamental research on early childhood development and education, such as the lasting effects on long-term use of embodied interaction. In particular, our interactive system raises questions about body coordination as well as memorization that we hope to address through collaborations with researchers in early childhood development and practitioners. In this regard, CoMo-education could be further developed as a generic platform for both applied and fundamental research.

Finally, although the CoMo-education system was designed in the French educational context, we believe that this application could be easily adapted and fit in other educational contexts (including children with disabilities) and countries.

## 8 ACKNOWLEDGMENTS

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## REFERENCES

- [1] . *como-elements*. <https://github.com/ircam-ismm/como-elements>
- [2] . OVAOM. <https://www.ovaom.com/>
- [3] Karen E Adolph and Sarah E Berger. 2010. Physical and motor development. In *Developmental science*. Psychology Press, 249–310.
- [4] Yasushi Akiyama and Sageev Oore. 2008. PlaceAndPlay: a digital tool for children to create and record music. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 735–738. <https://doi.org/10.1145/1357054.1357170>
- [5] Alissa N Antle. 2007. Designing tangibles for children: what designers need to know. In *CHI'07 Extended Abstracts on Human Factors in Computing Systems*. 2243–2248. <https://doi.org/10.1145/1240866.1240988>
- [6] Alissa N Antle. 2013. Research opportunities: Embodied child–computer interaction. *International Journal of Child-Computer Interaction* 1, 1 (2013), 30–36. <https://doi.org/10.1016/j.ijcci.2012.08.001> Publisher: Elsevier.
- [7] Henry Bienen. 2017. *The Montessori Method*. Routledge.
- [8] John M Carroll. 2003. *Making use: scenario-based design of human-computer interactions*. MIT press.
- [9] Justine Cassell and Kimiko Ryokai. 2001. Making space for voice: Technologies to support children’s fantasy and storytelling. *Personal and ubiquitous computing* 5 (2001), 169–190. <https://doi.org/10.1007/PL00000018> Publisher: Springer.
- [10] Franceli L Cibrian, Oscar Peña, Deysi Ortega, and Monica Tentori. 2017. BendableSound: An elastic multisensory surface using touch-based interactions to assist children with severe autism during music therapy. *International Journal of Human-Computer Studies* 107 (2017), 22–37. <https://doi.org/10.1016/j.ijhcs.2017.05.003> Publisher: Elsevier.
- [11] Daniela Corbetta, Abigail DiMercurio, Rebecca F Wiener, John P Connell, and Matthew Clark. 2018. How perception and action fosters exploration and selection in infant skill acquisition. *Advances in child development and behavior* 55 (2018), 1–29. <https://doi.org/10.1016/bs.acdb.2018.04.001> Publisher: Elsevier.
- [12] Cristina Core, Andrea Conci, Antonella De Angeli, Raul Masu, and Fabio Morreale. 2017. Designing a musical playground in the kindergarten. In *Electronic visualisation and the arts (EVA 2017)*. BCS Learning & Development. <https://doi.org/10.14236/ewic/HCI2017.41>
- [13] Ministère de l’Éducation nationale. 2015. Bulletin officiel spécial n° 2 du 26 mars 2015. [https://cache.media.education.gouv.fr/file/MEN\\_SPE\\_2/84/6/2015\\_BO\\_SPE\\_2\\_404846.pdf](https://cache.media.education.gouv.fr/file/MEN_SPE_2/84/6/2015_BO_SPE_2_404846.pdf)
- [14] John Dewey. 1986. Experience and education. In *The educational forum*, Vol. 50. Taylor & Francis, 241–252. Issue: 3.
- [15] Urška Fekonja-Pekljaj, Ljubica Marjanovič-Umek, and Simona Kranjc. 2010. Children’s storytelling: The effect of preschool and family environment. *European Early Childhood Education Research Journal* 18, 1 (2010), 55–73. <https://doi.org/10.1080/13502930903520058> Publisher: Taylor & Francis.
- [16] Jules Françoise and Frederic Bevilacqua. 2018. Motion-sound mapping through interaction: An approach to user-centered design of auditory feedback using machine learning. *ACM Transactions on Interactive Intelligent Systems (TiiS)* 8, 2 (2018), 1–30. <https://doi.org/10.1145/3211826> Publisher: ACM New York, NY, USA.
- [17] Eleanor Jack Gibson and Anne D Pick. 2000. *An ecological approach to perceptual learning and development*. Oxford University Press, USA.
- [18] Megan K Halpern, Jakob Tholander, Max Evjen, Stuart Davis, Andrew Ehrlich, Kyle Schustak, Eric PS Baumer, and Geri Gay. 2011. Moboogie: creative expression through whole body musical interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 557–560. <https://doi.org/10.1145/1978942.1979020>

- [19] Juan Pablo Hourcade and others. 2008. Interaction design and children. *Foundations and Trends® in Human-Computer Interaction* 1, 4 (2008), 277–392. <https://doi.org/10.1561/1100000006> Publisher: Now Publishers, Inc..
- [20] Francesco Iani. 2019. Embodied memories: Reviewing the role of the body in memory processes. *Psychonomic bulletin & review* 26, 6 (2019), 1747–1766. <https://doi.org/10.3758/s13423-019-01674-x> Publisher: Springer.
- [21] Marianna Ioannou and Andri Ioannou. 2020. Technology-enhanced embodied learning. *Educational Technology & Society* 23, 3 (2020), 81–94. Publisher: JSTOR.
- [22] Thea Ionescu and Dermina Vasc. 2014. Embodied cognition: challenges for psychology and education. *Procedia-Social and Behavioral Sciences* 128 (2014), 275–280. <https://doi.org/10.1016/j.sbspro.2014.03.156> Publisher: Elsevier.
- [23] Rebecca Isbell, Joseph Sobol, Liane Lindauer, and April Lowrance. 2004. The effects of storytelling and story reading on the oral language complexity and story comprehension of young children. *Early childhood education journal* 32 (2004), 157–163. <https://doi.org/10.1023/B:ECEJ.0000048967.94189.a3> Publisher: Springer.
- [24] Hiroshi Ishii and Brygg Ullmer. 1997. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*. 234–241. <https://doi.org/10.1145/258549.258715>
- [25] Markus Kiefer and Natalie M Trumpp. 2012. Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education* 1, 1 (2012), 15–20. <https://doi.org/10.1016/j.tine.2012.07.002> Publisher: Elsevier.
- [26] Benjamin Matuszewski. 2019. Soundworks-a framework for networked music systems on the web-state of affairs and new developments. In *Proceedings of the Web Audio Conference (WAC) 2019*. <https://hal.science/hal-02387783>
- [27] Benjamin Matuszewski. 2020. A web-based framework for distributed music system research and creation. *AES-Journal of the Audio Engineering Society Audio-Acoustics-Application* (2020). <https://doi.org/10.17743/jaes.2020.0015>
- [28] Irena Y Maureen, Hans van der Meij, and Ton de Jong. 2018. Supporting literacy and digital literacy development in early childhood education using storytelling activities. *International Journal of Early Childhood* 50, 3 (2018), 371–389. <https://doi.org/10.1007/s13158-018-0230-z> Publisher: Springer.
- [29] Eleni Papadimitriou, Alexandros Kapaniaris, Dimitris Zisiadis, and Evangelia Kalogirou. 2013. Digital storytelling in kindergarten: An alternative tool in children’s way of expression. *Mediterranean Journal of Social Sciences* 4, 11 (2013), 389–396.
- [30] Jean Piaget. 1960. *The child conception of the world*. Littlefield, Adams [and] Company.
- [31] Jean Piaget. 2005. *Language and Thought of the Child: Selected Works vol 5*. Routledge.
- [32] Michela Ponticorvo, Raffale Di Fuccio, Fabrizio Ferrara, Angelo Rega, and Orazio Miglino. 2019. Multisensory educational materials: five senses to learn. In *Methodologies and Intelligent Systems for Technology Enhanced Learning, 8th International Conference 8*. Springer, 45–52. [https://doi.org/10.1007/978-3-319-98872-6\\_6](https://doi.org/10.1007/978-3-319-98872-6_6)
- [33] Sara Price. 2013. Tangibles: Technologies and interaction for learning. *The SAGE handbook of digital technology research* (2013), 307–325. <https://doi.org/10.4135/9781446282229.n21> Publisher: Sage London.
- [34] Mitchel Resnick, Brad Myers, Kumiyo Nakakoji, Ben Shneiderman, Randy Pausch, Ted Selker, and Mike Eisenberg. 2005. Design principles for tools to support creative thinking. (2005). <http://www.ted.selker.com/documents/resumefiles/other%20publications/DesignPrinciples%20for%20Tools.pdf> Publisher: Carnegie Mellon University.
- [35] Antonio Rizzo, Patrizia Marti, Françoise Decortis, Job Rutgers, and Paul Thursfield. 2003. Building narrative experiences for children through real time media manipulation: POGO World. In *Funology: from usability to enjoyment*. Springer, 189–199.
- [36] Elizabeth B.-N. Sanders and Pieter Jan Stappers. 2008. Co-creation and the new landscapes of design. *CoDesign* 4, 1 (2008), 5–18. <https://doi.org/10.1080/15710880701875068> Publisher: Taylor & Francis \_eprint: <https://doi.org/10.1080/15710880701875068>.
- [37] Matthieu Savary, Diemo Schwarz, Denis Pellerin, Florence Massin, Christian Jacquemin, and Roland Cahen. 2013. Dirty tangible interfaces: expressive control of computers with true grit. In *CHI’13 Extended Abstracts on Human Factors in Computing Systems*. 2991–2994.
- [38] Lawrence Shapiro and Steven A Stolz. 2019. Embodied cognition and its significance for education. *Theory and Research in Education* 17, 1 (2019), 19–39. <https://doi.org/10.1177/1477878518822149> Publisher: SAGE Publications Sage UK: London, England.
- [39] Cristina Sylla, Clara Coutinho, Pedro Branco, and Wolfgang Müller. 2015. Investigating the use of digital manipulatives for storytelling in pre-school. *International Journal of Child-Computer Interaction* 6 (2015), 39–48. <https://doi.org/10.1016/j.ijcci.2015.10.001> Publisher: Elsevier.
- [40] Gabriela Sá, Cristina Sylla, Vitor Martins, Ana Caruso, and Douglas Menegazzi. 2019. Multiculturalism and creativity in storytelling-Visual development of a digital manipulative for young children. In *Proceedings of the 2019 Conference on Creativity and Cognition*. 369–381. <https://doi.org/10.1145/3325480.3326571>
- [41] Martin Tomitsch, Thomas Grechenig, Karin Kappel, and Thomas Költringer. 2006. Experiences from designing a tangible musical toy for children. In *Proceedings of the 2006 conference on Interaction design and children*. 169–170. <https://doi.org/10.1145/1139073.1139078>
- [42] Lev S Vygotsky. 1967. Play and its role in the mental development of the child. *Soviet psychology* 5, 3 (1967), 6–18. <https://doi.org/10.2753/RPO1061-040505036> Publisher: Taylor & Francis.
- [43] Lev S Vygotsky. 2012. *Thought and language*. MIT press.
- [44] Donald Woods Winnicott. 1991. *Playing and reality*. Psychology Press.
- [45] Susan Young. 2008. *Music 3-5* (1 st ed. ed.). Routledge.
- [46] Susan Young. 2018. *Critical new perspectives in early childhood music: Young children engaging and learning through music*. Routledge.
- [47] Pelin Yuksel-Arslan, Soner Yildirim, and Bernard Ross Robin. 2016. A phenomenological study: teachers’ experiences of using digital storytelling in early childhood education. *Educational Studies* 42, 5 (2016), 427–445. <https://doi.org/10.1080/03055698.2016.1195717> Publisher: Taylor & Francis.



- [48] Pauline Davey Zeece. 1997. Bringing Books to Life: Literature-Based Storytelling. *Early Childhood Education Journal* 25, 1 (1997), 39–43. <https://doi.org/10.1023/A:1025633914983> Publisher: ERIC.
- [49] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 493–502. <https://doi.org/10.1145/1240624.1240704>
- [50] Oren Zuckerman, Saeed Arida, and Mitchel Resnick. 2005. Extending tangible interfaces for education: digital montessori-inspired manipulatives. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 859–868. <https://doi.org/10.1145/1054972.1055093>

## A SELECTION AND PARTICIPATION OF CHILDREN

The study was approved by the ethical committee of the Université Paris-Cité (IRB : 00012020-07). Firstly, we recruited teachers who were willing to engage their class and therefore their pupils in this study. The teachers then took charge of sending the information letters and consent forms to the families. Once the consent forms were returned and signed by the families, we were able to conduct the experiments in the classroom during school time. On the day of the experiment, the teacher explained to the children that we were researchers and that they were going to participate, if they wished, in a study in the form of a school workshop. We included in the study only those children from families who agreed to their child’s participation. We also obtained parent permission for video recording of their children and explained to them that the video recordings are for use in scholarly presentations or publications serving to help other professionals understand the research.

## B ONLINE RESOURCES

A webpage describing CoMo-education is available:

<https://www.premierscris.org/como-education>, including a demo video:

<https://www.youtube.com/watch?v=0ajKrSuENWI>.

## C DESIGN REQUIREMENTS

Table 1. CoMo-education Design requirement

Design requirements	Discipline	Actors	Means
R1 - Pedagogy	Education	Teachers	Tests in preschool environment + teachers interviews all along the iteration process
R2 - Embodied interaction	Early Child Development	Occupational therapist, research in developmental psychology, music therapist	Early childhood specialists interviews all along the design process
R3 - Interaction design	Design	Designers (UX, space, sound, narrative, object)	Interdisciplinary and iterative design approach
R4 - Technical implementation	Engineering	Developers & Engineers	Iterative Development of Multimodal Interfaces

## D QUESTIONNAIRE AND RESULTS

Table 2. Questionnaire used for children's individual interviews

Criteria	Question	Expected Answer
A. Appreciation of the story	A.1. Did you enjoy the story?	Yes (No)
B. Understanding of the story	B.1. What was the story about ?	Story's topic: The bear hunt
	B.2. Can you remind me of the different landscapes we crossed ?	#1 / #2 / #3 / #4/ #5 (#A / #B) - Table 4
	B.3. Can you repeat the gestures associated with the sounds I am going to play? (play sounds randomly)	#1 / #2 / #3 / #4/ #5 - Table 4
C. Understanding of technology	C.1. What is the phone for?	The smartphone produces the sounds
	C.2. How does it work?	Smartphone produces sounds when you move it
	C.3. Do you think it's a real phone	Yes (No)

Table 3. Results of the questionnaire

Criteria	Answer	Class- 1	Class- 2	Total
A. Story Appreciation	A.1. Enjoy the interactive storytelling (%)	100%	100%	100%
B. Story Understanding	B.1. Mention the subject of the story: the bear hunt (%)	75%	81%	78%
	B.2. Number of landscapes mentioned (/5)	2.8/5	3.8/5	3.3/5
	B.3. Number of gestures (associated with the sounds played)	3.5/5	2.6/5	3/5
C. Understanding Technology	C.1. Mention that the smartphone produces the sounds (%)	100%	100%	100%
	C.2. Mention that the smartphone produces the sound when moving it (%)	92%	73%	82%
	C.3. Mention that the smartphone is a “real” one (%)	58%	40%	49%