ABBOT: A Smart Toy Motivating Children to Become Outdoor Explorers

Federica Delprino
Politecnico di Milano
Dipartimento di Design
Italy
ferica.delprino@mail.polimi.it

Chiara Piva
Politecnico di Milano
Dipartimento di Design
Italy
chiara1.piva@ mail.polimi.it

Giovanni Tommasi
Politecnico di Milano
Dipartimento di Elettronica, Informazione e Bioingegneria
Italy
giovanni2.tommasi@mail.polimi.it

Mirko Gelsomini
Politecnico di Milano
Dipartimento di Elettronica, Informazione e Bioingegneria
Italy
mirko.gelsomini@polimi.it

Niccolò Izzo
Politecnico di Milano
Dipartimento di Elettronica, Informazione e Bioingegneria
Italy
niccolo.izzo@mail.polimi.it

Maristella Matera
Politecnico di Milano
Dipartimento di Elettronica, Informazione e Bioingegneria
Italy
maristella.matera@polimi.it

ABSTRACT

This article illustrates ABBOT, a pervasive interactive game for children at the early years of primary school that aims to stimulate exploration of outdoor environments. ABBOT combines a smart tangible object to play outdoors, with a mobile app to access new content related to the discovered natural elements. The tangible object helps children capture images of the elements they find interesting in the physical environment. Through simple interactive games on a tablet, at home children can continue to interact with the collected digital materials and can also access new related content. The article illustrates the design of ABBOT; it also reports on an exploratory study with 160 kids of a pre-school and a primary school that helped us assess the attitude of kids towards the game.

CCS CONCEPTS

• **Human-centered computing~Mobile devices** • *Human-centered computing~Interaction paradigms* • *Human-centered computing~Empirical studies in interaction design* • *Information systems~Web interfaces.*

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KEYWORDS

Smart Toys; Outdoor Learning; Outdoor Exploration; Pervasive Games; Smart Object Design; Mobile Apps.

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1 INTRODUCTION

Technology has become a fundamental ingredient of our life. We live in a digital-rich society where different kinds of devices support many of our activities. Besides mobile devices (smart phones and tablets), smart objects [2], i.e., tangible and pervasive devices equipped with electronics and embedded software, are also gaining momentum in different domains.

Not only adults, but also children use technology extensively each day [17]. Some studies assessed that this new digital context offers opportunities for children's learning, but it also highlights the tension between the increased media-literacy skills and the reduced attitude towards exploring and interacting with the surrounding natural world [1,9]. Indeed, smartphones and tablets are becoming a sometimes-abused way to entertain children, forgetting that the natural world is a rich and positive resource for the kids' growth and personal development. As a result, restrictions of technology use by children are very often recommended or applied, based on the assumption that nature exploration and technology use are contrasting activities.

Pervasive games, exploiting unobtrusive smart objects and focusing on the physical aspects of the real world, have initiated a trend towards solving the tension described above. They bring real-word elements into games while still utilizing the benefits of computing [10,15]. Along this line of action, we wanted to design a pervasive game that could use technology to encourage kids to have in-depth analyses of the surrounding natural world. We wanted to exploit the attraction that technology plays on children to lead them to be also attracted by open-air activities and by outdoor exploration. We conducted a user research to understand in which way technology could be used to motivate children to explore the open-air environment and also learn new content, still keeping technology "invisible" during the exploration phase. We named the project ABBOT, as this is the name of a famous entomologist, ornithologist and botanist. With our system we indeed aim to have kids becoming true explorers!

We thus conceived an interactive system composed of a tangible object complemented by a tablet application: the first one encourages outdoor exploration of natural elements; the second one facilitates the retrieval and exploration of related digital content. Children's curiosity for the natural world and learning are thus stimulated by combining open-air activities with virtual, digital ones, each one amplifying the effectiveness of the other.

This article reports on the design, the implementation and the evaluation of ABBOT. It is organized as follows: Section 2 illustrates the user research that we conducted to elicit the main personas of the interactive service. Section 3 introduces the design of a "learning-by-exploring" process responding to the identified requirements and user profiles. Section 4 reports on the technical implementation of the ABBOT smart toy and of the companion tablet app. Section 5 then illustrates the results of an exploratory study that we conducted with 160 kids from a pre-school and a primary school. In Section 6 we compare ABBOT with some related work, and in Section 7 we finally outline our future work.

2 BACKGROUND AND USER RESEARCH

The primary aim of ABBOT is to promote an unobtrusive use of technology to motivate children to explore nature's elements during their open-air activities. This concept follows a research line laying at the intersection of ubiquitous computing and games, which addresses different forms of pervasive games that motivate users to play outdoors and that promote physical interaction as an integral part of game play [3,13,14]. In particular, ABBOT is based on the concept of Head-Up Games (HUGs) [14, 16]. HUGs are outdoor pervasive games for children that, in contrast to games that mainly use mobile devices as gaming interfaces, exploit embedded gaming technologies that do not force the players to attend to a screen, and also fit seamlessly into play, thus encouraging physical activity and social engagement. HUGs especially emphasize non-display-based interaction and promote other types of interactivity that do not interfere with the social sphere that characterizes outdoor games. With ABBOT, we tried to apply this paradigm in the specific domain of nature exploration and learning by children.

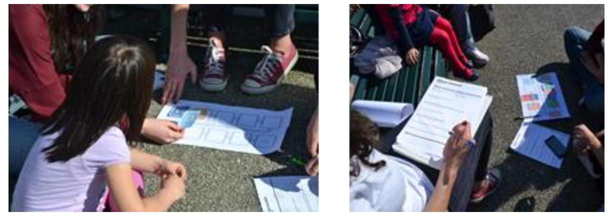


Figure 1: Elicitation study at the park: activity-card game and interviews with kids.

Given the general goal of our research, we conducted an elicitation study to understand in which measure kids love to go outdoors, which activities they love to have at the open air, but especially in which way they could be encouraged to go outdoors, explore nature and learn. We wanted to collect opinions from a variety of families. After asking for an informed consent, we interviewed a dozen kids and their parents in two locations in Milan. One is a green area, a place for families but also for people of every age and nationality. The other one is located in a residential neighborhood between an elementary school and a kindergarten; it is considered a gathering place for parents and children after school classes.

Kids aged between 5 and 7 years were asked to express their playing preferences through a card game. As shown in Fig. 1, they had to sort cards representing games and activities: doing sports, reading books, playing in playgrounds (swing, slide, ...), playing group games, watching television, using parents' mobile phone, exploring nature and, more generally, staying at home or outdoors. We also talked directly with the children and tried to understand if parents influenced their answers.

From the collected data, we understood that kids mostly love staying in nature and being involved in open-air games. They also like using mobile apps; nevertheless, outside they prefer dynamic activities. We thus identified two different profiles:

- Some children are shy and are used to play mostly alone, sometimes requiring the attention of their parents. They need a safe space to play, either alone or with friends. One couple said that their child "is lazy, it's not easy to bring her out; however, once she is at the park she has great fun".
- Some other children always look for other kids to play with; they are autonomous and their parents watch them calmly. They love and need to be continuously in movement, get closer to lots of children and play different games. "She is always looking for new friends to play with, while we are sitting on a bench to chat a bit and watch her from afar" – a couple said about their daughter.

It also emerged that parents love to spend time with their children when they are at home, especially for education activities. During open-air activities they watch kids, but they mostly left them playing autonomously. Exploring nature is not a frequent activity. We therefore identified the following challenges for the design of our interactive system: i) to capture kids' attention on nature by means of new (and unusual) activities able to stimulate their curiosity; ii) to involve kids in new discovery

Figure 2: The ABBOT "learning-by-exploring" process.

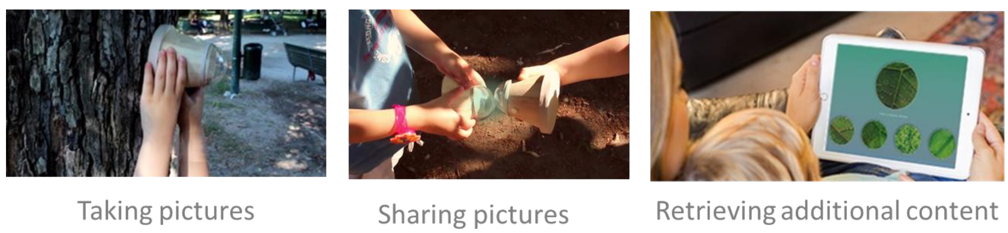


Figure 3: Main ABBOT activities.

tasks and, at the same time, make them feel safe and comfortable by means of activities that do not require much effort; iii) to favor the interaction with other children; iv) to enforce a learning phase to be held at home with the help of parents.

3 DESIGN OF THE "LEARNING-BY-EXPLORING" PROCESS

Based on the previous analysis, we conceived a "learning-by-exploring" process (Fig. 2) that combines the use of a smart toy and of a tablet app to stimulate kids' curiosity on nature and let them learn new contents. The kid explores the nature and gets involved in a world of materials thanks to the smart toy. This is a tangible device (see Fig. 3) that allows kids to take pictures of their findings during environment exploration, and records such pictures in a personal digital collection. It consists of a truncated conic box with a semi-transparent, lighten-up spherical cap. This simple shape was chosen to recall nature: the first prototype was indeed built by adapting a wooden birdhouse.

The object exploits sensing and actuating technology that allows kids to take and store pictures. On the other hand, it purposely does not require accessing and interacting with any digital material during the outdoor exploration. A microcontroller is mounted on the box base together with an embedded accelerometer. Shacking the toy activates a camera to take pictures. The spherical cap shows the prevalent color of the photographed material. These interactive features were added to stimulate the interest and curiosity of kids. The colorful cup was in particular designed to give feedback once a photo is taken, and to make the toy look "alive". The toy also enables the interaction with other children. As reported in Fig. 3, two kids can share the collected materials by bringing closer the cup of their devices.

Thanks to the app running on the tablet, children can then view photos taken during their outdoor activities and all materials collected over the course of several usage sessions. When they are at home, together with their parents, they can play with the digital materials collected during open-air activities and retrieve additional content (see Fig. 3). Simple interactive games invite kids to revisit what they discovered at the park and to match their photos with other images suggested by the system. Related multimedia content explaining the main characteristics of their discoveries is then presented. This in particular accommodates the identified attitude of parents to spend time with their kids for education activities, while they let children to explore autonomously the outdoor environment.

As a first validation of the ABBOT concept, we conducted a preliminary technology test and field exploration by asking two 5-year-old children to use the ABBOT smart toy. We built a first low-fidelity prototype (ABBOT 1, see Fig. 4a) by using an adapted wooden birdhouse. Our aim was to assess the feasibility of embedding sensors into the toy box, and to understand whether the resulting object, equipped with its smart functions, would result interesting and acceptable by children, and would motivate them to explore outdoor environments and learn. The involved children liked very much playing with the toy and appreciated its interactive features. They said they would love using it at the park and then watching the captured images at home together with their parents. They however showed some difficulties in manipulating the wooden device due to its size and weight.

a) b)

Figure 4: Prototype building: (a) the first wooden prototype, ABBOT1; (b) comparison between ABBOT1 (on the left) and the second 3D-printed PLA prototype, ABBOT 2.

We therefore decided to use a lighter material, and to design a more ergonomic shape. We built a second prototype in 3D-printed PLA that is 12 centimeters high and has a base diameter of 8 centimeters (ABBOT 2, see Fig. 4b). We also added a slight concave grip to let children hold it better. PLA still resembles wood; the aesthetic connection to the natural world is indeed fundamental for having a device fitting well in an open-air experience. With respect to wood, PLA is lighter, gets less dirty, and is cheaper in terms of production costs.

4. TECHNICAL IMPLEMENTATION

The implementation phase consisted in building the digital devices, i.e., the smart toy and the tablet app, and in refining their mutual interactions. In the rest of this section we describe the development of these two components.

4.1 Smart Object Design

The ABBOT smart toy has been developed around four main functions: *image capturing*, *shake and movement sensitivity*, *colored feedback* and *data transmission*. Images are captured thanks to a camera module placed on the bottom of the device, then stored inside an internal flash memory, or an optional external microSD memory. The camera is set to work in low-light conditions, since it's proximity with analyzed objects works as a darkening factor. Furthermore, the ludic nature of the smart toy leads to continuous movements. Thus, particular attention is also given to image focus and stability.

A tri-axial accelerometer (±16g) and a gyroscope are used to control the device. All the functions are activated with special movements. When the smart toy is shaken horizontally over a certain force threshold (for a minimum time interval), it exits its low-power state and captures an image. Likewise, when the smart toy is rotated over 60 degrees from its natural position, the Bluetooth LE radio is powered on. In this way, the user is provided with an intuitive way to control device connectivity while maximizing the battery duration.

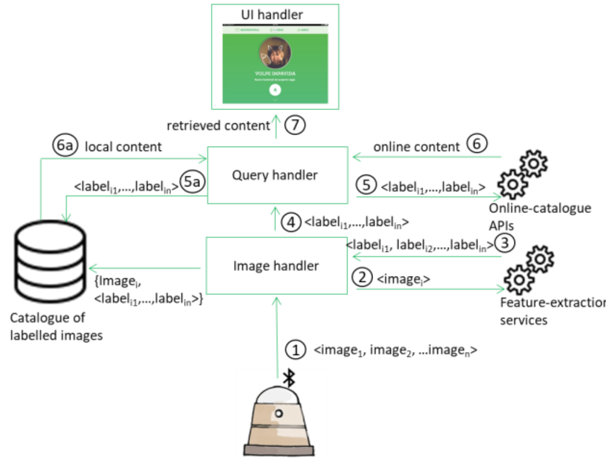


Figure 5: Architecture of the tablet app.

The smart object then provides feedback to the user through a 4x4 RGBW LED matrix, which is placed in the spherical cap of the ABBOT device. Upon a successful image capture, the LED matrix shows first a colored animation, then a color pattern that resembles the color of the image just captured. A white-colored cap simply indicates the ON state of the device, while a blue animation suggests that data are being transferred to the app.

By means of a Bluetooth LE data protocol, the captured images can be transferred to the companion mobile app for their content analysis (see next section). Moreover, bringing close two devices' spherical caps allows kids to share their internal data. Bluetooth LE doesn't require any pairing process, hence the only prerequisite for this functionality is the proximity. The device is powered by a Lithium Polymer rechargeable battery, and can be charged via a micro-USB port. Modest computational power is required for the ABBOT functions; therefore, an ARM Cortex-A53 is used as microcontroller.

4.2 App Design

Fig. 5 shows the architecture of the tablet app and illustrates the flow of data along its different components. We adopted a lightweight paradigm, which means that running the app does not necessarily require a back-end for data storage and processing. We indeed aimed to maintain on the user devices all the data and functions. Moreover, the architecture is open for connections towards external online services. Of course, the app could also leverage a remote back-end, should a heavy processing of images or an extensive storage be required.

During the initialization phase, the app synchronizes with the smart device via the Bluetooth connection; each time a device is detected, the app content is updated. In the app, the transferred photos are stored in a local database, which plays the role of an indexed catalogue.

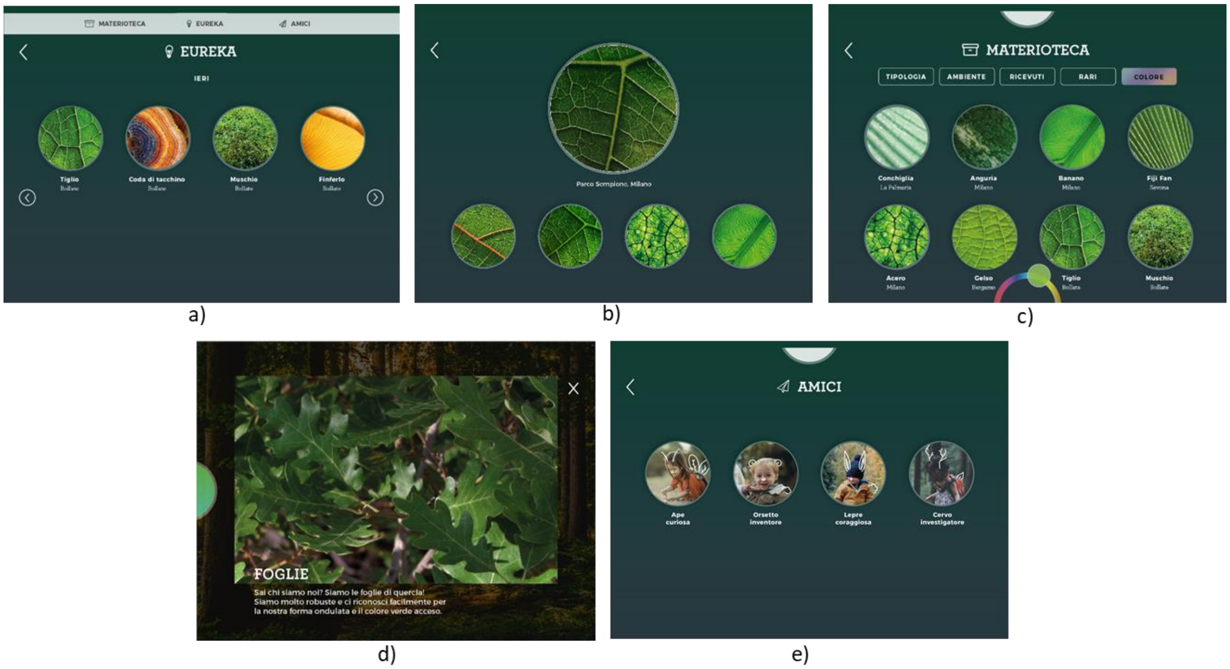


Figure 6: Screenshots of representative pages for the main areas of the tablet app.

By invoking external services [1], the *Image Handler* module extracts features from any single photo (e.g., semantic labels indicating that an image reports a leaf or a wood of a specific plant) and stores the images and the related tags in the local database. In order to avoid the storage of non-pertinent photos, a pre-loaded set of 1500 words is used to compare retrieved tags and establish the consistency of photo subjects to the natural world. Starting from successfully matching tags, additional knowledge is proposed to the kids. A *Query Handler* module exploits tag similarity to retrieve related multimedia content from the local catalogue, as well as some selected online sources [2]. A *User Interface (UI) Handler* then manages the visualization of such materials in three main areas. In the *EUREKA* area (Fig. 6a), all the pictures captured during outdoor exploration are shown in a photo library sorted by data. Kids can play by looking for the right association with other images offered by the system (Fig. 6b). The game consists in dragging their photo upon the right images. The app then shows a "matched" reward message, depending on the correspondence (i.e., similarity) of the tags of the two materials. The goal of the game is getting all the photos matched.

In the *Material Collection* area (*MATERIOTECA* in Italian), kids can see again the discovered materials and can also access educational material retrieved through the tag-based queries. The material collection can be browsed by "typology", "discovery ambient", "color", "rare materials" and "shared with friends" categories and filters (Fig. 6c). In each category, photos are displayed in a grid of circular images identified by their own category name (e.g., material "Maple leaf"). Any photo can be visualized full screen by clicking on it. In the new reached page (Fig. 6d), additional material retrieved through tag-based queries is then visualized.

In the *Friends* area (AMICI in Italian), kids see materials taken from the other ABBOT devices they have been in contact with. A list of friend profiles is presented (Fig. 6e) and the storyline of all the interactions with other abbot devices is shown. Kids also have the possibility to compare the found materials. Additional content is proposed by the app also for friends' materials.

5 EXPLORATORY STUDY

We conducted an exploratory study to assess kids' attitude towards collecting materials and learning new content through ABBOT, to verify whether different ways of approaching the game exist according to the kids' age, and to get further indications on the ergonomy of the two physical objects. We were able to involve 160 kids aged between 3 and 7 years, 82 kids from a pre-school (3-5 years old), 88 kids from a primary school (6-7 years old), both the two schools being part of a same education institute. Kids' parents were asked to sign an informed consent, including explicit agreement for each child to appear in video recordings and for using the collected data in our research.

[1] The current prototype exploits the Google Cloud Vision API. However, any other service, both local and remote, can be used as well since the app architecture is open to connect to any service that is external to its core engine.

[2] The current prototype connects to Wikipedia and the National Geographic APIs.

a)

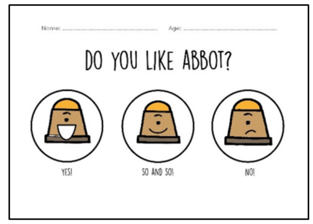
b)

Figure 7. Kids exploring the school garden during the free play (a) and focus groups in a classroom (b).

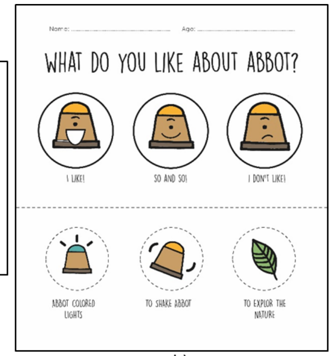
The study was organized into five phases: introduction, free-play, structured-play, experience evaluation through focus groups and individual interviews. The entire study lasted about 8 hours, including breaks, and it was supervised by 4 researchers. The school teachers also attended the study sessions and helped the researchers, when needed, in the explanations given to children during the introductory phases. Following our requests, they did not interact directly with children during the following activities. Data collection involved structured observation based on video recordings to analyze play behavior, and questionnaire-based interviews and focus groups to evaluate the subjective player experience.

The first phase was held indoor, in one of the school classrooms. One researcher gave a 5-minute introduction, to explain the topic of exploring and finding nature materials, what ABBOT is and how it works. She illustrated in detail the concept of “material”, which is fundamental in the ABBOT exploration paradigm. She explained the interactive feature of the tangible device and the way the tablet app is structured.

After the introduction, groups of 15/20 kids each were asked to go outdoors, in the school garden, and play with ABBOT freely. Each group was given an ABBOT device. Kids were asked to play with it and examine its feature to understand how it works (Figure 88a). This phase lasted 15 minutes. The aim was to let kids get familiar with the toy interactive features, and analyze how they instinctively play with the smart toy and how they interact with each other. One researcher video-recorded kids, while the others took notes. This observing protocol was also adopted in the following phases.



a)



b)

Figure 8: Questionnaire forms using the smile-o-meter scale: likeability of the tangible device (a); likeability of the device interactive features (b).

During the structured play, we asked individuals or couples of children to explore the outdoor environment and discover material by using the ABBOT toy. To monitor the discovery activity, we asked children to use stickers to mark the photographed material. We indeed wanted to gather indications on how kids explore the environment when looking for natural or artificial objects, and assess in which measure they are stimulated by ABBOT to find new materials.

After playing, back to the classroom, the 88 children (45 males and 43 females) of the primary school were asked to fill out a questionnaire. The adopted measurement instrument is an iconic form (see Fig. 7) that allows children to express their preferences by means of a “smiley-o-meter” based on a 3-point Likert scale. The original questionnaire defined in [12] was adapted with the help of educators to take into account the kids’ ability in reading and comprehending textual content. This phase involved only kids of the primary school, as the smaller ones would not be able to read at all. Two researchers also talked individually with 44 children from the primary school who showed their willingness to be interviewed. These 44 children were also asked to interact with the tablet app. Talking individually with them, we wanted to assess how much they understood the game, which interactive feature they preferred most, and if they would have liked to use the tablet app.

While single kids were interviewed, the other 2 researchers took care of the other children, asking them to fill out the questionnaire (see Fig. Figure 88b) and perform alternative activities that provided us with additional useful material to assess their satisfaction. Some kids colored the ABBOT mascot; this was useful to identify their attitude towards the object and how much they influence each other (e.g., coloring it in the same way). It was also a nice approach for organizing a “kind of” focus groups where kids could comment on the experience. Some other kids played with material cards: they were provided with a photo of a natural environment (e.g., beach or mountain), and they had to identify the right match with a number of cards representing nature elements (e.g., sand, leaves, gravel, plastic bottles). This simulated the interactive game offered by the tablet app. We used the card game instead of the app prototype because within groups it could create more engagement. This was also reasonable with respect to the study goals: we were not interested very much in evaluating the app usability (this will be the object of future studies); rather, we wanted to assess in which measure some types of stimuli could increase the kids interest towards nature materials and their attitude to learn. Another aspect that we observed in focus groups was how kids communicated their game experience to the others, and what feelings they wanted to communicate.

5.1. Results

The data we collected from the study are still tentative, due to the number of variables involved and the execution of a single session. Children tendency to evaluate their experience with high scores has also to be considered. However, the enthusiasm of children when using ABBOT was evident. During the free play kids marked with stickers from 6 to 10 found materials. The interactive features of the tangible object and of the app were learnt and used with interest by the majority of kids.

Besides giving us indications on the game acceptability by children, the study highlighted other interesting aspects. First of all, it allowed us to identify better our target. 5/6-year-old kids played consciously and were excited to see their materials on the app. Younger kids didn't understand completely all the ABBOT's features; however, they participated with enthusiasm to all the activities and interacted a lot within groups and in couple, challenging each other in finding new materials. The 7-year-old kids instead mostly preferred to play alone.

Almost all kids enjoyed the experience. Nobody was reluctant to take part to the playing activities. Considering the data collected through the smiley-o-meter questionnaire, 90% of kids said they like ABBOT a lot; the remaining 10% said they like it "so and so". We then asked them to associate pictures representing the ABBOT interactive features to a smile icon (see Fig.7b). 43% of them said their most favorite feature was the enlightened cap, 34% enjoyed most capturing, 23% preferred shaking the device.

To evaluate the physical characteristics of the tangible device, we asked kids to manipulate both the prototypes and, as a confirmation of the preliminary assessment of this aspect, most of them preferred using the 3D-printed version, Abbot 2. They said it is easier to hold, smaller and smoother than Abbot 1. They also liked its finishing details and the more transparent cap, since this allowed them to see more vividly the changing colors.

Most kids expressed a positive opinion on the tablet app. They especially interacted with the EUREKA area to see their captured photos and access additional material. Indeed, given the short duration of the interaction session, the other areas were not populated with substantial content. 85% of the interviewed children showed great interest and stated they would love to use it at home with their parents. When seeing unknown materials in the Material Collection, they were continuously asking "What is it?", and "Where can I find it?", showing interest towards nature elements and will of exploring into detail further related content. They were very interested in the interactive elements of the app: they were attracted a lot by the circle buttons for selecting images. Yet, they were also really interested in the additional content provided by the system and liked a lot to listen to the researchers reading the textual descriptions.

6 COMPARISON WITH OTHER WORKS

Recently, some research communities have been focusing on the domain of nature exploration, and more specifically on the problem of exploiting mobile technologies to enhance the user interaction with and the experience of nature [7]. A number of digital systems encourage exploration of the natural world. However, they mostly use mobile phones/tablets as intermediaries for nature exploration. For example, Geotagger [6] is a collaborative platform developed to engage children (primarily ages 6-11) and adults as they explore outdoors. Geotagger encourages people to observe the world around them, document what they observe, share it, and foster discussion based on tagged items. Mobile devices are used to find content and to connect and collaborate with other peers. Similar to ABBOT, the main objective of Geotagger is to exploit the proliferating use of technology to encourage the observation of natural world. A basic idea is also to build an enlarged community around crowdsourced content, so that people can ask and collectively answer questions about the world around them. ABBOT also supports collaboration through the sharing of materials collected outdoor. However, ABBOT stresses the socialization dimension: material sharing happens only when two ABBOT devices - thus two kids - get close. Additionally, ABBOT intentionally decouples the exploration phase from the access to digital content through the mobile app. The aim is to make children focus on natural elements when they are outdoors, without any kind of mediation through digital content. This is a notable aspect to let children identify the limits between the real and the virtual (i.e., digital) world, which is instead not considered by the majority of systems so far proposed for nature exploration and learning.

Other works adopt augmented-reality paradigms. In [1] the authors illustrate the design of a mobile augmented-reality game that supports learning on nature elements by children outside the classroom. The paradigm is based on the definition of visual markers, i.e., selected elements of the environment that, if recognized by machine vision algorithms running on mobile phones, trigger the visualization on the device of related questions plus 3D models that represent possible answers to be selected. The game consists in selecting the right answer for these questions. With respect to this work, ABBOT offers an unrestricted exploration of the environment, which is not constrained by an a-priori identification of visual markers. Every element in the open air could be in principle captured by kids.

The LeafSNAP game [8] proposes a mobile app that identifies plant species through automatic visual recognition, and visualizes nearby species localized on a map. In [16] the authors propose a tablet app that augments nature elements framed with the camera of a mobile device with a virtual layering of perspectives, narratives or otherwise inaccessible information. These systems have similarities with the ABBOT technology, as they support learning processes on nature by means of mobile technologies and automatic recognition of images. However, still ABBOT stands out for its capability of encouraging nature discovery in a way that is totally independent of the tablet app usage. Moreover, the two previous works especially focus on the effectiveness of their machine-vision algorithms to recognize nature species, while they neglect the aspect of motivating outdoor exploration.

The adoption of a tangible smart object is, to our knowledge, an original characteristic introduced by ABBOT, which brings notable advantages especially for kids. First of all, the interaction with tangible objects favors emotions and engagement and improves the kid's attitude towards learning and understanding [18]. Also, physical manipulation provides an additional channel for information gathering that activates real-world knowledge and improves memory [12]. The study reported in [4] highlights that, in order to design interactive tools that really motivate children to play outdoors, essential factors are the direct interaction with nature elements (e.g., plants and animals), as well as allowing children to play and collaborate with others. ABBOT largely favors physical manipulation of real-world elements; by means of material sharing, it also allows kids socializing among them. In line with the finding illustrated in [4], the results of our exploratory study also encourage us to think that these features really motivate kid's exploration.

7. CONCLUSION

This article has presented the design of the ABBOT interactive game as a means to encourage kids to explore nature. A relevant goal of ABBOT is to lead children to interact directly with nature. Indeed, it is first of all a toy that can be shaken and scraped, letting kids get their hands dirty. Thanks to the proper use of technology, through ABBOT open-air activities also become an opportunity to explore and acquire knowledge in the context of a smart and educational setting.

The ABBOT system is still in a prototype version. So far our work has especially concentrated on designing the interactive service and on analyzing its acceptability by kids and its feasibility by means of state-of-art technologies. Recently (December 2017), Google launched a computer-vision kit for Raspberry Pi[3], which resembles very much the implementation of the ABBOT smart object. This confirms the technical feasibility of our project, and encourages us to go on with the development of our idea, as it could also encounter the interest of a larger audience, even for different purposes and in different application domains. For example, the ABBOT paradigm could be extended for supporting the crowdsourced creation of catalogues of material and for community building centered on nature or other topics.

We will dedicate our future work to refine the technical implementation, especially for the front-end app, and to improve the algorithms for content recommendation. The machine-vision algorithm can be also improved. In this first prototype we didn't want to stress and test extensively this aspect, as we were more interested in evaluating the validity of the overall concept as a tool for outdoor exploration and learning. Merging the results of different machine-vision services, and also customizing the underlying algorithm for the recognition of nature-element photos would improve the effectiveness of the tablet app, and especially the retrieval of the additional education material. The experience of capturing materials could also be extended by recording audio during the exploration. This would increase the interest of the kids when interacting with the collected material within the tablet app. It would also allow kids to recall the whole experience and especially the feelings that they perceived outdoors.

We will also improve the flexibility of the whole service, for example by giving parents the possibility to customize the behavior of the smart object. Some recent results on the definition of visual paradigms for smart object programming [5] will be exploited for extending the ABBOT app with a composition environment dedicated to the creation or customization of the rules that govern the behavior of the smart toy and the tablet app. In the long term, as also proposed in [15], we plan to work on tools for rapid prototyping of interactive outdoor games. This implies the analysis of a considerable number of applications and the generalization of requirements for the identification of modeling abstractions. Some results in this direction have already been achieved in a different domain [2]. We will try to identify how this results can be adapted to the specific domain of pervasive outdoor games for children.

The refined prototypes will allow us to conduct more extensive evaluation studies, to assess the effectiveness of the ABBOT process in terms of learning. The first exploratory studies especially focused on assessing children engagement and satisfaction. The achieved results were encouraging; however, further investigation is needed to assess the ABBOT impact on motivating children to paly outdoors and learning.

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