Peer-reviewed version available at *Information* **2020**, *11*, 70; doi:10.3390/info11020070

Article

Designing Internet of Things Tangibles for Children with Hearing Disability

Sandra Cano [1*], Victor Peñeñory [2] , César A. Collazos[3] and Sergio Albio[4]

[1] *Pontifica Universidad Católica de Valparaiso; 2340000, Chile sandra.cano@gmail.com*
[2] *Facultad de Ingeniería, Universidad de San Buenaventura Cali; vmpeneno@usbcali.edu.co, 760032 Cali, Colombia*
[3] *Facultad de Ingeniería, Universidad del Cauca; ccollazos@unicauca.edu.co, XXXXX Popayán, Colombia*
[4] *Aragón Health Research Institute(IIS Aragón), Universidad de Zaragoza, 44003 Teruel, Spain, salbiol@unizar.es.*

* *Correspondence: sandra.cano@gmail.com*

Abstract:

A Tangible User Interface (TUI) is a new interaction option that uses nontraditional input and output elements. A tangible interface thus allows the manipulation of physical objects using digital information. The exploration and manipulation of physical objects is a factor to be considered in learning in children, especially those with some kind of disability such as hearing, who maximize the use of other senses such as vision and touch. In a tangible interface, three elements are related - physical, digital and social. The potential of IoT for children is growing. This technology IoT integrated with TUI, can help for that parents or teachers can monitoring activities of the child. Also to identify behavior patterns in the child with hearing impairment. This article shows four case studies, where had been designed different products of Internet of Things Tangible applied a several contexts and with products of low cost.

Keywords: *Tangible Interfaces; Internet of Things Tangibles ;Children with Hearing Impairment*

1. Introduction

The Internet of Things (IoT) is a technology that allows physical objects to be interconnected through the Internet. Therefore IoT is a concept related with the transformation digital, where it has integrated several areas, as: electronics, computers and multimedia. In 2008 the European Commission [1] defines IoT as "*Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts*".

On the other hand, Tangible User Interface (TUI) was initially motivated by ubiquitous computing and augmented reality. In 1995, Fitzmaurice was the first to attribute the term User Interfaces, he introduces the notion of Graspable Interface, where graspable handles are used to manipulate digital objects [2]. After in 1997, Ishii & Ullmer presents a definition of Tangible Bits [3], using real world as a display and as medium to manipulate a digital interface.

An article presented by Angelini et al. [4], related Tangible Interfaces and IoT as Internet of Tangible Things (IoTT). Authors present a systematic review of tangible interaction applied to IoT, also they discuss the potential benefits of tangible interaction applied to the IoT. Today, IoT is applied to different areas, such as education, health, traffic, agriculture, and public services. For the implementation of physical or embedded objects components such as: sensors, software and network connectivity are required, which must be incorporated in these objects to store and exchange data.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2019 doi:10.20944/preprints201912.0417.v1
Peer-reviewed version available at Information 2020, 11, 70; doi:10.3390/info11020070

In several studies [5-9], it is observed that the design of tangible interfaces is incorporating IoT in a context of children. In 2017 Angelini et al.[5] propose a workshop related with IoT and Tangibles Interfaces, where they make a discussion about how best to bridge theoretical, technical, design and human considerations may be taken into account when designing for the IoTT (Internet of Things Tangibles). Other researchers had created a bear smart [6] with embedded sensors that measures child's heart rate, blood pressure, oxygen saturation, and body temperature and send the data using wireless technologies to parent's smartphone.

In 2018 Mahmoudi et al. [7] developed an interactive learning system for children in the teaching the colors. They incorporated IoT using the Raspberry hardware platform and a color sensor responsible for measuring the frequency of colored light. The information captured from the RGB sensor is sent using the MOTT protocol. In 2019 Ritembruch and Donovan [8] mention that IoT permits the interconnection of physical devices. owever, to design a scenario requires further investigate the interaction between IoT devices and users. Because feedback mechanisms and type of interaction can change according the type of user.

Other authors have focused on how to teach children to learn IoT. Divitini and Sejer [9], presented a workshop called Make2Learn, oriented to a child learning IoT concepts through the design and development of objects that can be interconnected following STEM (Science, Technology, Electronic and Mathematics) concepts. Authors incorporated cards created by Mora et al. [10] as a tool in the ideation stage, composed of 110 design cards, with the aim of supporting exploration and combination of user interface metaphors, digital services and physical objects. The cards are intended to inspire creation or generate new ideas in IoT products focused on the user. Different roles can make use of these cards, such as researchers who can use the cards as brainstorming to know how to include IoT components in their projects. Designers can also integrate the IoT cards into their design methodology, while teachers can use the cards to introduce basic IoT-related concepts in the classroom.

Few works are related with tangible interaction principles. TUI involves two terms user interfaces and interaction. Therefore, the interaction is related with physical world and type of user. In the interaction the data could be represented through physical objects and manipulated by physically handling the objects. Eva Hornecker and Jacob Buur [11] proposed on tangible interaction using a framework. The framework is focused on the user experience of interaction, so it includes physical and social aspects of interaction. The framework is structured around four themes, as: Tangible Manipulation, Spatial Interaction, Embodied Facilitation and expressive representation. This framework is applied in three case studies, but none is applied to children. Therefore, interaction principles can change for children, more if are children have some special need.

Most children with special needs have low economic resources. Moreover, children with disabilities are among the most stigmatized and excluded groups of children around of world. These children for their disability have less opportunity, in social, education among others. Also, these children have lower rates of primary school completion that those without disabilities and many cases the technology can help them to develop their learning capacity [12]. However, the growth of technology has led to the emergence of new forms of interaction integrating physical and digital objects interconnecting with others through internet.

A study made by [13], conclude that hearing impairment in Latin America is low priority for national health systems in Latin America, material and human resources are limited. In Colombia the schools

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2019 doi:10.20944/preprints201912.0417.v1

Peer-reviewed version available at *Information* **2020**, *11*, 70; doi:10.3390/info11020070

inclusive are limited and the technology continues to be very costly by regional. In Chile published a study by [14], where they found that people with hearing disabilities have a lower quality of life and have a higher frequency of physical and psychological ailments.

2. Background

2.1 Children with Hearing Disability and Technology

Children have different ways and rhythms of learning. If they have a disability or disorder, their way of learning may be affected. A child with a disability will acquire cognitive skills at a different pace and using other types of strategies than a child without a disability. Therefore, children with some type of disability or disorder require special education to receive an adequate educational development. Hearing impairment is related to an impairment of the auditory sense derived from a partial or total loss of the ability to listen. Therefore, the type of capacity is subject to levels of deafness, such as: mild (< 40 db), moderate (40-70 db), severe (71-90 db) and profound (> 91 db) [15]. Children with a hearing impairment have different communication alternatives: children with no access to a hearing aid will communicate by sign language, based on movement and expressions through hands, eyes, face, mouth and body. It is important to note that their first language is sign language, and a second language a written language such as Spanish. If children have a hearing support, such as a hearing aid or cochlear implant, their primary objective is to be helped in two senses (hearing and sight) to achieve language acquisition. For children with cochlear implants, the verbalization part takes more effort, since they must learn to listen and identify each of the sounds. Therefore, they must learn to use the implant as a means of extracting information. Also, their learning is different compared with other children without hearing impairment.

A learning style can be defined by Keefe [16] as *"Cognitive, affective and physiological traits that serve as relatively stable indicators of how students perceive interactions and respond to their learning environments"*. Cognitive traits are related to how students structure content, use concepts, interpret information and solve problems; affective traits are linked to motivations and they markedly condition learning levels; and physiological tasks using physical objects can favor a child's cognitive development (supporting the ideas of Piaget) and also allow the child to take advantage of this real-world experience when interacting with digital information. Another communication alternative is lip-facial reading. The children have to learn to read lips. For a child to be able to use this method, therefore, it is important to speak slowly and ensure that no objects hinder visibility of the lips of the person speaking.

Some works found have proposed design principles for children's technology. But the principles proposed are oriented a technology type and children group with special need specific. By example, Cano et al. [17], propose a model that it allows to identify a set of principles grouped in three categories: education, game mechanics and user profile. These principles are for children with hearing disability and oriented for serious games. In 2005 Chiasson and Gutwin [18] propose an initial catalogue of design principles for children's technology formed by three categories cognitive, physical and social/emotional. In the category physical development related 4 principles with tangible interfaces, as : (1) Children like tangible interfaces because they enjoy being able to physical touch and manipulate the devices, (2) Direct manipulatives allow children to explore and actively participate in the discovery process, and (3) physical props and having large input devices encourages collaboration, and (4) Superficial changes to the design can produce very different physical interactions. Different interfaces emphasize different actions but not considers if children have some need special.

An article published in 2019 by Revelle et al. [19], traditional interface use is often developmentally inappropriate and can be a stumbling block to learning. Using and manipulating physical objects is a key in the learning of the child. Therefore, designing tangible interfaces can be positive for a child with special. This can help in the cognitive development why interacting with task-appropriate

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2019 doi:10.20944/preprints201912.0417.v1
Peer-reviewed version available at Information 2020, 11, 70; doi:10.3390/info11020070

physical objects can be related with learning environment. According Piaget [20], where he mentions that the manipulation with physical objects can help in the cognitive development of the child. While, Vygotsky emphasized in social interaction for the child development.

The use of technology in children with special needs allow increasing the independence of the child and choose the speed learning. Also, to develop technology for special education, consider that the cost of a given solution and potential that can have in the learning process. Moreover, children today are born into world where technology is integrated in the daily life. Studies show a positive trend in the relationship between learning and technology integration [21]. Others authors as Ozgur and Seyhan [22] think that the use of technology may impede in children social, emotional, physical and cognitive development. But, if activities are controlled and integrated into classroom, and children can have as support the teacher can be positive.

2.2. Child-Computer Interaction and Tangible Interfaces

Human-Computer Interaction (HCI) is that area that fouses on the interaction between person and machine and Child Computer Interacion (CCI) is a sub-field in HCI relating concepts between children , computational and communication technologies. Therefore, it involves input and persperctive with multiple scientifc disciplines to design a interactive system for children. In 2011 Read and Bekker [23], define CCI as *"study of the activities, behaviours, concerns and abilities of children as they interact with computer technologies, often with the intervention of others (mainly adults) in situations that they partially control and regulate"*.

In 1980 Papert incializated with the computational technology for children. He started investigating how children could be benefited with the technology as tool of support [24], with the design of product called Logo [25]. Papert developed an approach, following Piaget's constructivism, which consists of placing challenges before children in such a way that these can be solved by developing programs using Logo. The Logo program was one of the first interfces where the concept of interaction changed: it was no longer a simple interacion with traditional computer devices, but it designed another type of non-conventional interaction to communicate with the computer. Therefore, Logo first began the creation of technological tools that support children's learning, developing exploration and interaction skills.

There are TUIs developed with a variety physical objects. However, are limited for a user type with need special, as children. Druin et al. [26] comment that children want in technology: control, social experience and expressive tool. Therefore, the technology must produce curiosity, motivation of repetition and need for control.

Nowadays, some problems include CCI and Tangible Interfaces, is related in how to evaluate Tangible Interfaces for children. Because there are 2 ways in that the child can interact with the technology physically and digital. It is now an area where have proposed many studies with new methods for evaluating technologies with children. However, most of these methods created are for children without special need. Read and Bekker [23], take into account that CCI must consider of the physical sizes and abilities, memory and processing abilities and the ability of children to read (by example deaf children), but it has the additional task of understanding the changes and the diversity in this space.

2.3. Tangible Interfaces and IoT

Advances in technology are creating new opportunities, services and mechanisms to provide a better quality of life. The way that all users can communicate from long distances is through the Internet. Connectivity between different elements is therefore of great interest in developing prototypes oriented to storing information in the cloud or connecting physical objects.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2019 doi:10.20944/preprints201912.0417.v1

Peer-reviewed version available at Information 2020, 11, 70; doi:10.3390/info11020070

The Tangible User Interface (TUI) was initially motivated by ubiquitous computing and augmented reality, as a more natural way to manage a device. It is believed that physical action is important for learning, and tangible objects are a form that the user can learn while interacting with physical objects. Ulmer and Ishii, of the Tangible Media Group of the MIT Media Lab, define TUIs as devices that give physical information as representations and controls of the computational data [25]. Historically children in the classroom have always interacted with physical objects to learn some functionality.

Ulmer and Ishii [27] describe some aspects that should be taken into account to design a tangible interface: (1) linking of the physical representations and their digital information, (2) design of interactive control modalities, taking into account tangible representations, and (3) perceptual coupling of tangible representations to intangible dynamic representations. Thus, it can be said that tangible interfaces allow physical representations through technology to make scenarios more real that can be interconnected using IoT technology.

The potential of IoT for children is growing. One example is Teddy the Guardian [6], a smart teddy bear with an internal accelerometer. On making a movement with the bear, he wakes up, remaining in a waiting mode when still. Teddy also has a temperature sensor that measures the temperature of the environment and the temperature of the child. The teddy bear is connected to a mobile application where he sends his data, and professional personal can monitor physiological responses of the child.

Other work is proposed in 2018 by Cano et al. [28], where used a teddy bear for teaching STEM education, where a nano-Arduino, RFID card reader and Neopixel have been added to the bear as feedback response, according to whether actions performed are correct or not. The bear connects to a mobile application, which includes three areas: Literacy, mathematics and programming.

It is important mention that type of Tangible Interfaces with Tabletop can be high cost. However, we objective is design products using electronic elements of low cost and reusing toys existents.

3. Case Studies

The following case studies are tangible interfaces in which IoT technologies have been included and using in children with impairment disability in different contexts, as: education, social and therapy. The participants were children with hearing impairment either who benefit from hearing supports, such as hearing aids or cochlear implants, or who lack any hearing aid and communicate by sign language. The children study in the Institute for Blind and Deaf Children in Valle del Cauca, Colombia. There are also children whose communication channel is sign language, from the Special Sense Therapy Institute of Club Leones (ITES), in Cali, Colombia, with ages from three to 12 years old. For each of these evaluations carried out with the children, informed consent was obtained from parents. Ethical principles established by the Helsinki declaration were also followed [29].

3.1. Case Study 1: Rehabilition Cognitive

Based on the analysis carried out, a set of mini-games aimed at stimulating cognitive processes is proposed [30]. Therefore, a tool was proposed that helps to stimulate a number of cognitive processes in children with hearing disabilities, called Stimulating with PhonaTIC (Figure 1), with the aim of capturing information about each process, such as: visual memorial, selective attention, auditory perception, perceptual discrimination and spatial orientation.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2019 doi:10.20944/preprints201912.0417.v1

Peer-reviewed version available at Information 2020, 11, 70; doi:10.3390/info11020070

Figure 1. *Tangible interface "Stimulating with PhonaTIC" for cognitive rehabilitation in children with a cochlear implant.*

The interface employs a number of activities such as visual memory, selective attention, auditory perception, and spatial orientation. For the physical and digital interaction part, working on visual memory and auditory perception activities was implemented. In the case of visual memory, the user must associate objects with the word, so the digital application will show the word and they have to associate it in the RFID cards with the figure that represents that word. Auditory perception relates to the child hearing sounds from different animals and selecting the animal to which the sound corresponds.

The information collected relates mostly to measuring their learning. It was thus decided to capture several indicators such as the time taken to perform each activity and the number of successful or failed attempts. The application is made in Android Studio, and web services in PHP are used in sending the data to the database. The mobile application therefore consumes the web services when the information is captured while the user interacts with the application.

3.2. Case Study 2: Toy Interactive

A teddy bear called Tobi (Figure 2) is proposed that is conditioned with sensors and other electronic components, so that it can become an interactive low-cost toy for children with special needs, supporting STEM education (Science, Technology, Engineering and Mathematics) as a fundamental pillar of learning.

Based on the concept of tangible interfaces, the starting point here is an appreciation of the toys children have and that technology can be integrated into them to become interactive. A hardware structure was thus designed for inclusion inside the body of a teddy bear, where the low-cost MFRC522 RFID sensor, Gyroscope GY-50 and HC06 Bluetooth sensor were added to Tobi's body to establish communication between the bear and a mobile application. The tangible interface has two ways of visual representation supported by the teddy bear and the mobile application. The action that the child must perform is to bring the card close to Tobi's chest and the application will validate if it is correct. The effect that occurs is that if it is a correct answer, the LEDs located in the bear's chest turn red, as if it will symbolically represent the bear's heart and that it is happy. If it is not correct, the LEDs have an effect of turning on and off, representing symbolically as if it were annoyed [28]. The IoT technology was integrated, saving the data in a database by connecting through web services in PHP, with the aim monitoring the different activities of child, as: number of errors, time, and levels completed.

This toy was created with the purpose of involving the STEM methodology for children without special needs, where activities related to literacy, mathematics and computational thinking are integrated. The IoT technology was integrated, saving the data in a database by connecting through web services in PHP.

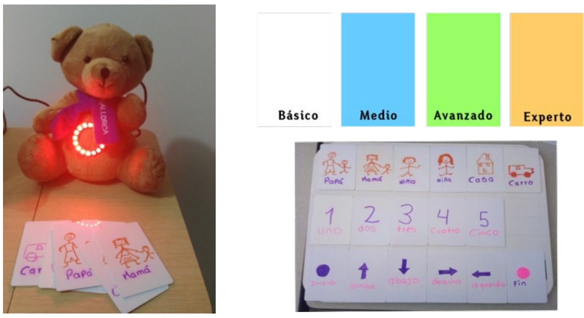

***Figure 2**. Interactive Toy called "Tobi" used to learn skills related to the STEM methodology. In [28].*

3.3. Case Study 3: Electronic Glove

In 2017, a group of researchers presented the design of an electronic glove for teaching vowels by means of fingerprint language for deaf children in the ITES [31]. They designed a tangible interface, which involves a physical and digital part. The physical part is a non-traditional input device, a glove with sensors to recognize the gesture of each of the vowels. The glove is connected via Bluetooth to a mobile application, where the child must perform different actions with the fingers to represent a vowel (Figure 3). It is important to mention that fingerprint language is used for spelling in written work. The IoT technology was integrated, saving the data in a database by connecting through web services in PHP, with the aim that teachers can monitor the different activities of child, as: number of errors and time, and tasks completed.

The evaluation was carried out with five deaf children aged between six and ten, whose communication channel is sign language. To evaluate the prototype, the metrics of number of errors and time taken for completed tasks were considered. Their evaluation was more quantitative, but they did not evaluate the child's experience on interacting with the glove, but rather variables related to cognitive effort. Meanwhile, in the tasks of the mobile application, a set of words had been selected, for which the children had to complement the vowels to form the correct word.

***Figure 3.** Design of an electronic glove for teaching vowels. In [31].*

3.4. Case Study 4: Solving Problem

The design of the tangible interface called "Perdi-Dogs" is aimed at the acquisition of skills related to computational thinking for children with cochlear implants [32]. A physical interface is proposed, which is a ladder board game (Figure 4), whose objective is for the child to find the best solution to the problem that arises. The mission that is recreated aims for each dog to reach his home, so that the child must make correct decisions to overcome the obstacles that arise. The digital interface is roulette type, which has the function of giving each child a turn in which the number of squares that the dog must move forward is obtained randomly. The way to connect the physical and digital interface is to use physical cards with a QR code. This code is read by mobile application. Children can interact in

Peer-reviewed version available at *Information* **2020**, *11*, 70; doi:10.3390/info11020070

group, and they support each other and are not inhibited in carrying out the activity. Neither are they afraid of being wrong. Data information is saved in a database, which the mobile application is connected to a web service.

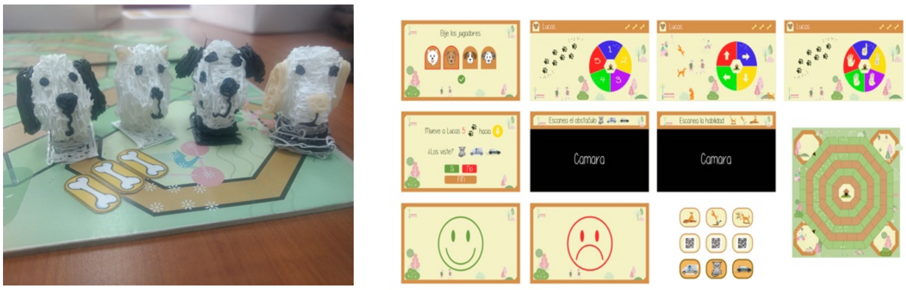

Figure 4. *Tangible Interface Perdi-Dogs.*

It is important to mention that each a case studies presented, each child must log in a user profile, where data recollected according his profile. Today, is in discussion to integrate the IoT into the digital application using a cloud service, as Firebase database in the Google Cloud. The data can access via a Google service, where the data is stored in JSON in real time.

4. Discussion

The case studies concerned the design of tangible interfaces applied to different use contexts for children with hearing impairment. Integrating IoT can help provide access to information for people that want to monitor the different activities of the child, also can see in time their progress. On the other hand, using IoT objects can help to explore different ways to interact. Also the way to integrate feedbacks modalities, as haptic vibrations. This modality for children with hearing impairment is positive, because children can poor level in literacy, so they can not read text messages. Other way is using motion gestures, as Electronic Glove. Children can information processing easily using two feedback modalities through of senses, as visual and tactile response. Also, when interacting with a TUI don't feel evaluated. Therefore, the teacher can observe different indicators captured that reflect progress toward goals. Some indicators can help to observe the advance in the activity and maybe to adjust his style or velocity of learning. Therefore, the data recollected allow to study behavior patterns in the child.

When children interact with real objects with others children their motivation grow. Because they don’t feel be evaluated. It was observed that when these types of tangible interfaces are evaluated in a group, rather than individually, the children provide more information as they are less inhibited in their answers. It was also identified that when interfaces have a learning objective for the child, interaction experience must be taken account of, since the main aim is to carry out a task oriented in an educational learning context. If the experience it not a positive one, learning will take longer, even causing a cognitive effort.

5. Conclusions

The growth of technology is creating new opportunities to provide individuals with a better quality of life. Advances are having an impact in the different ways in which there might be an interface between a person and technology. The internet has made it possible for people to interconnect and using the IoT has meant that devices or objects can do so too. Tangible interfaces and IoT technologies can support different types of contexts and populations, more so if they are children with special needs.

Peer-reviewed version available at Information 2020, 11, 70; doi:10.3390/info11020070

IoT can thus help provide access to information and interaction with other people, such as children with/without special needs. It can go on to support the creation of an inclusive environment with better access to information and interaction with others, and like this type of tangible interfaces, can support children by operating within the focus of a real - and at the same time digital – environment.

References

1. Internet of Things in 2020. Roadmap for the Future. European Commission for Information Society, 2008.
2. George W. Fitzmaurice, Hiroshi Ishii and William Buxton, Bricks: Laying the foundations for Graspable User Interfaces, Proceedings of ACM CHI 1995 Conference on Human Factors in Computing Systems, p. 442-449, 1995.
3. Ishii Hiroshi and Ullmer Brygg. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems* (CHI '97). ACM, New York, NY, USA, 234-241, 1997. DOI=http://dx.doi.org/10.1145/258549.258715
4. Angelini, L., Mugellini, E., Abou Khaled, O., Couture, N. Internet of Tangible Things (IoTT): Challenges and opportunities for tangible interaction with IoT. Informatics volume 5, 7, 2018.
5. Leonardo Angelini, Zuzanna Lechelt, Eva Hornecker, Paul Marshall, Can Liu, Margot Brereton, Alessandro Soro, Nadine Couture, Omar Abou Khaled, and Elena Mugellini. Internet of Tangible Things: Workshop on Tangible Interaction with the Internet of Things. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI EA '18). ACM, New York, NY, USA, Paper W14, 8 pages, 2018. DOI: https://doi.org/10.1145/3170427.3170634
6. Teddy the Guardian. *Available online:* http://teddytheguardian.com/ (accessed 17 April 2019).
7. M. Tayefeh Mahmoudi, F. Zamiri Zeraati, P. Yassini. A color sensing AR-based interactive learning system for kids. The 12th National and the 6th International Conference on e-Learning and e-Teaching, 2018.
8. Rittenbruch M., Donovan J. Direct End-User Interaction with and Through IoT Devices. In: Soro A., Brereton M., Roe P. (eds) Social Internet of Things. Internet of Things (Technology, Communications and Computing). Springer, Cham, 2019.
9. Monica Divitini, Michail N. Giannakos, Simone Mora, Sofia Papavlasopoulou, and Ole Sejer Iversen. Make2Learn with IoT: Engaging children into joyful design and making of interactive connected objects. In Proceedings of the 2017 Conference on Interaction Design and Children (IDC '17). ACM, New York, NY, USA, 757-760, 2017. DOI: https://doi.org/10.1145/3078072.3081312.
10. Simone Mora, Francesco Gianni, and Monica Divitini. Tiles: a card-based ideation toolkit for the Internet of Things. In Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17). ACM, New York, NY, USA, 587-598, 2017. DOI: https://doi.org/10.1145/3064663.3064699.
11. Eva Hornecker and Jacob Buur. Getting a grip on tangible interaction: a framework on physical space and social interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '06), Rebecca Grinter, Thomas Rodden, Paul Aoki, Ed Cutrell, Robin Jeffries, and Gary Olson (Eds.). ACM, New York, NY, USA, 437-446, 2006 DOI=http://dx.doi.org/10.1145/1124772.1124838
12. Sigdel, Sajana, "Technology and Learning Capacity of Children: A Positive Impact of Technology in Early Childhood", 2017. MBA Student Scholarship. 56. https://scholarsarchive.jwu.edu/mba_student/56
13. Madriz, Juan J. Hearing Impairment in Latin America: An Inventory of Limited Options and Resources: Trastornos auditivos en América Latina: Un inventario de opciones y recursos limitados. Taylor & Francis, Vol 39(4), 2000, doi: 10.3109/00206090009073081.
14. Campos, Valeria, & Cartes-Velásquez, Ricardo. Estado actual de la atención sanitaria de personas con discapacidad auditiva y visual: una revisión breve. Revista médica de Chile, 147(5), 634-642, 2019. https://dx.doi.org/10.4067/S0034-98872019000500634
15. Lai-Chong Law, E., Roto, V., Hassenzahl, M., Vermeeren, A.P.O.S., Kort, J. Understanding, scoping and defining user experience: a survey approach. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '09). ACM, New York, NY, USA, 719-728, 2009. DOI: https://doi.org/10.1145/1518701.1518813.
16. Keefe J. W. Profiling and Utilizing Learning Style. Reston, Virginia, 1988.
17. Cano A., Collazos C. A, Manresa-Yee C., Peñeñory V. Principles of Design for Serious Games to Teaching of Literacy for Children with Hearing Disabilities. In Proceedings of the XVII International Conference on

Peer-reviewed version available at Information 2020, 11, 70; doi:10.3390/info11020070

Human Computer Interaction (Interacción '16). Association for Computing Machinery, New York, NY, USA, Article 6, 1–2, 2016. DOI:https://doi.org/10.1145/2998626.2998650

18. Chiasson, S., Gutwin, C. Design Principles for Children's Software., Technical Report HCI-TR-05-02, Computer Science Department, University of Saskatchewan, 2005.
19. Revelle G, Zuckerman O., Druin A., and Bolas M. Tangible user interfaces for children. In CHI '05 Extended Abstracts on Human Factors in Computing Systems (CHI EA '05). Association for Computing Machinery, New York, NY, USA, 2051–2052, 2005. DOI:https://doi.org/10.1145/1056808.1057095
20. Piaget, J. & Inhelder, Bärbel. The Psychology of Child. Basic Books, 1969.Read J.C, Bekker M.M, The Nature of Child Computer Interaction, in: Paper Presented at the HCI2011, Newcastle, UK, 2011.
21. Guiding principles for use of technology. *Available online:* *https://tech.ed.gov/earlylearning/principles/* (*accessed on 30 December 2019*)
22. Ozgur, E., Guler, G., & Seyhan, N. Mobile phone radiation-induced free radical damage in the liver is inhibited by the antioxidants n-acetyl cysteine and epigallocatechingallate. International Journal of Radiation Biology, 86(11), 935-945, 2010. http://dx.doi.org/10.3109/09553002.2010.496029
23. Read J. and Bekker Mathilde M. The nature of child computer interaction. In Proceedings of the 25th BCS Conference on Human-Computer Interaction (BCS-HCI '11). BCS Learning & Development Ltd., Swindon, GBR, 163–170, 2011.
24. Papert S. Redefining Childhood: The computer presence as an experiment in developmental Psychology. Paper delivered at the 8th World Computer Congress. 1980.
25. Papert S. What is Logo? And who needs it?. Essay from Logo philosophy and implementation (Logo Computer Systems), 1999.
26. Druin, A., L. Hanna, et al. The Design of Children's Technology, Moran Kaufmann Publishers, Inc, 1999.
27. Ullmer, B. and H. Ishii. Emerging frameworks for tangible user interfaces. IBM Systems Journal, Vol. 39 (No. 3/4, 2000.
28. Cano S., Mosquera S. P., Peñeñory V.M, Bejarano P.A. Design of interactive toy as support tool in STEM education for children with special needs. 4th Iberoamerican Workshop, HCI-Collab, 2018.
29. World Medical Association. (World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects.. Bulletin of the World Health Organization, 79 (4), 373 - 374. World Health Organization, 2001.
30. S. Cano, C.A. Collazos, Habib Fardaun, Daniyal M. Alghazzawi.Design of a set Serious mini-games as support in cognitive rehabilitation for Children with Auditory Impairment.Workshop on ICTs for improving Patients Rehabilitation Research Techniques, Lisboa. Portugal, 2016.
31. Sotelo J., Duque J., Solano A., Cano S. Designing an Electronic Hand Glove for Teaching Vowels to Deaf Children. In: Meiselwitz G. (eds) Social Computing and Social Media. Applications and Analytics. SCSM. Lecture Notes in Computer Science, vol 10283. Springer, Cham, 2017.
32. Henao, C., Naranjo, J.S., Cano, S., Peñeñory, V.M. 2018. Designing an Interactive System as support to the development of Computational Thinking for Children with Cochlear Implants: Extended Abstract. In *Proceedings of the XIX International Conference on Human Computer Interaction* (Interacción 2018). ACM, New York, NY, USA, Article 11, 2 pages, 2018. DOI: https://doi.org/10.1145/3233824.3233866.