A Phygital Approach to Playful Experience in Learning Process for Kids with Special Educational Needs

Gabriele Goretti*
Jiangnan University/School of Design, China

Benedetta Terenzi
University of Perugia/Department of Civil and Environmental Engineering (DICA), Italy

Elisabetta Cianfanelli
University of Florence/Department of Architecture (DIDA), Italy

Pierluigi Crescenzi
Gran Sasso Science Institute, L'Aquila, Italy

Carlo Colombo
University of Florence/Department of Information Engineering (DINFO), Italy

Enrico Civitelli
University of Florence/Department of Information Engineering (DINFO), Italy

ABSTRACT

Screen-based interactive devices stand as effective supports for playful experience in learning processes for kids with special educational needs. The paper presents a design path of the development of a new phygital tool able to support and to improve the treatment of some learning disorder. In line with the state-of-the-art of theoretical research about playful learning in children with special needs, the research moves from the development of '1,2,3 Stella!' app, that works with a screen-based interaction learning process, to the possibilities offered by product-screen interaction. The research, through tests on prototype provided by NuovaMente Children's Diagnostic Centre, concludes that the development of hybrid reality game, involving both physical and virtual reality, improves therapeutic treatment in children with special needs.

CCS CONCEPTS

• **Applied computing**; • **Interactive learning environments**; • **Human-centered computing**; • **Interaction devices**; • **Computing methodologies**; • **Computer vision**; • **Graphics input devices**;

KEYWORDS

In Kid-centred design, Interaction design, Phygital leaning process, Playful experience, Special education needs (SEN) students

ACM Reference Format:
Gabriele Goretti, Benedetta Terenzi, Elisabetta Cianfanelli, Pierluigi Crescenzi, Carlo Colombo, and Enrico Civitelli. 2020. A Phygital Approach to Playful Experience in Learning Process for Kids with Special Educational Needs. In *2020 12th International Conference on Education Technology and Computers (ICETC'20), October 23–26, 2020, London, United Kingdom.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3436756.3437049

*Corresponding author. Email: gabriele.goretti@qq.com

ICETC'20, October 23–26, 2020, London, United Kingdom

ACM ISBN 978-1-4503-8827-6/20/10…$15.00
https://doi.org/10.1145/3436756.3437049

1 INTRODUCTION

The Specific Learning Disorders (DSA) are a specific area of children's neurodevelopment which has attracted growing interest over the past few decades, allowing to spread more culture of this problem at different levels, from teachers to parents. According with Hammill [1], Learning Disability (LD) is defined as a group of disorders heterogeneous manifested by significant difficulties in the acquisition and use of listening skills, reading skills, but also math, spelling and writing (one or more of these) with different level of deficits in cognitive processes.

Specific Learning Disorders (SLD) and Logopedic Methods for Treatment

By SLD therefore we mean those more or less serious disorders, partly due at dysfunctions of the central nervous system, defined and classified on the basis of the failure to achieve the expected learning criteria (for which there is a broad consensus) to the general potential of the subject [2] [3]. For this reason, the precocity and the adequacy of the intervention significantly affect the subsequent course of the disorder encouraging learning and for a prognosis favorable to social and of the personality development of children with these problems. In cases where an alteration of the learning phases is noticed in the child, an in-depth diagnostic observation makes it possible to identify the type of problem and the most appropriate aid paths. When the diagnosis is made, the speech therapist identifies any factors that slow down what it is considered the normal learning process. It is important to underline that, although with different possible approaches, logopedic treatments are normally characterized by a recreational-training approach. The game, as a plastic activity and congenial to the individual in the years of growth, becomes an optimal and irreplaceable therapeutic tool. The playful participation in rehabilitation therapy is really considered essential for achieving results.

2 LEARNING DISORDERS AND TECHNOLOGY

2.1 Kids and Technology

There's a lot of debate over how much we can expose children to digital devices. Today children see adults using mobile devices and computers all the time, their natural instinct to imitate grown-ups drives their curiosity towards these objects [4]. According to the Common Sense Media [5] in the USA, 38% of two-year-olds have already taken their hands on a mobile device (in 2011, the percentage stopped at 10%). The study presents a general and clear picture of how children use devices today, and how this behaviour has evolved in recent years. It also provides information and guidance on how parents can also use technology to support learning, find new types of interactive games or support their children's growth. We no longer speak of the "digital natives" described by Marc Prensky [6] in 2001, but we are talking about "mobile born", of children who learn to use device before learning to walk.

According to the British Educational Communications and Technology Agency (BECTA) there are 4 types of impact of new digital technologies on "native" learning methods: (1) a strong increase in the propensity to research and exploration in learning compared to passive reception of the old generations, and a clear preference for learning by doing assisted by digital technologies; (2) a strong technological ability that leads the "natives" to consider the Web as the main means of researching, acquiring and sharing information; (3) a strong growth in collaboration and cooperation between more individuals implemented through social networks or blogs; and (4) a strong tendency to manifest one's own identity and ideas through blogs and social networks.

This new scenario of methods for the learning experience in kids can open areas of new design pathways able to generate tools and services particularly focus to the treatment of DSA. In fact, if the traditional learning approach is changing according to the new expectations of the "mobile born" it is equally predictable that the classical methods and solutions for the DSA can be improved thanks to the use of the new information technologies.

2.2 Analysis of the Relationship between Technology and Teaching

Information and Communication Technologies have already revolutionized and improved our lives in different way and sectors offering new types of products and service, in particular about the way we store and acquire information and knowledge. In fact, human computer interaction is widely considered an integral component of many education and training systems at various levels of technology access [7] [8] and many studies show that positive interaction increases motivation, attention and participatory learning in children [9] [10]. Among the most developed education and training systems in the last few years there are interactive learning systems based on computer games to support many teaching and learning activities [11], especially for children because in these age groups they are naturally motivated to play games [10] [12]. Studies show that the key factors in user acceptance of these systems are perceived ease of use, perceived usefulness, self-efficacy, and satisfaction [13] [14]. Moreover [15] talk about three aspects of interactivity in a computer-based learning system that correspond to three actions related and influenced by the response of each actor involved: initialization, response and feedback.

The educational technology is classified in: 1) learning analytics; 2) digital literacy/digital reading; 3) OER e MOOC; 4) immersive environments and videogames [16] and is proven that ICT has great potential for enhancing teaching and learning outcomes, but this potential depends much on how the adults (teachers, parents) help, favour and control the uses the technology and device for the children in the so-called 'guided play' [17]. Some general trends emerge regarding the 'educational technology' that can be summarized as follows [18]: diffusion of smaller, portable and flexible device; used to support learning activities; increasing availability of digital archives of educational and information resources to be used for increasingly personalized learning experiences; collaborative learning environments, peer interaction, connectivity and performance evaluation; more and more learning activities realized in authentic and meaningful contexts [16].

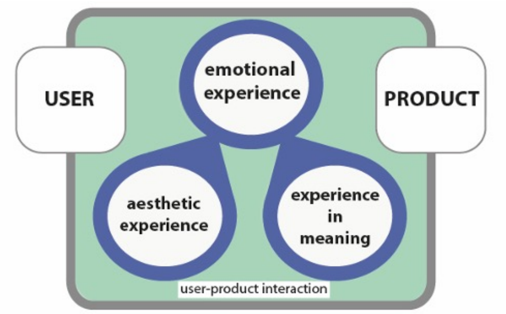

Figure 1: Three Types of Product Experience.

2.3 Products Experience and User Experience.

It is possible to distinguish three components or levels of product experience: aesthetic pleasure, attribution of meaning, and emotional response [19]. Desmet & Hekkert [20] define product experience as "the entire set of affects that is elicited by the interaction between a user and a product (fig. 1), including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning) and the feelings emotions that are elicited (emotional experience)".

The ISO 9241-210: 2010 talk about User Experience (UX) and defines it as the set of "perceptions of the person and results deriving from the use and / or expectation of use of a product, system or service ". At the same time defines the interactive system as: "the combination of hardware, software and / or services that receive input from, and communicate output to, users."

Speaking of human / product interaction, Schifferstein & Hekkert [21] say that this interaction is not necessarily limited to an instrumental and non-instrumental physical action, but can also consist of passive (often visual) perception, or even in the memory or thought of a product. Being defined as the awareness of the psychological effects induced by the interaction with a product, research in this field usually refers to the subjective relationships of people of their experiences with the products [20].

At the same time, technology-driven research focuses on how products can be created with new technologies that can benefit potential users. Digitization has opened up new opportunities to design new products and services that can support the new needs of children, therefore there is a huge opportunity to design specific experiences focused on the behavior of specific users such as children and the community of adults around them.

2.4 Phygital Experience and Learning Process

Starting from these assumptions and considering that today for children aged between 5 and 12 years the threshold between physical and digital does not exist, the research team focus on the development of a new generation of phygital Apps.

Regarding the learning process, is interesting to remember the thought of the American pedagogist Edgar Dale [22] found that our memory is deeply influenced by experiences: the more these are new, particular and full of emotions, the more we will remember them with ease. Not only that, Dale also studied the duration of the memories based on the experiences made.

In practice, learning can be passive and active:

1) passive: in terms of reading, listening to audio recordings, lessons in the classroom, watching videos, etc. and this style determines (in general) the lowest storage percentages.
2) active: if you put yourself in action. Repeating, speaking (even in a group) but above all putting into practice what you have learned, simulating an experience, doing the real thing.

A synesthetic approach is the right way, therefore, to make every activity of study active and engaging, involving all our senses in the learning process. From this assumption comes the need that many products/ games for children are highlighting, that is to implement the digital product (app) with a physical and material part, or vice versa, which brings the child closer to the practice of manipulation, tactics, considered particularly important for a complete learning process for children.

Following this consideration, the research team is developing a product-based interaction device as 1,2,3 Stella's next step, as playful gaming interaction. This further design frame is aiming at making all the App scenario and values developed in a 2D way, through a 3D dice directly connected to the screen.

Products that integrate a physical circumstances or tangible objects and digital experience are called 'phygital' (physical plus digital). Phygital learning relies on advanced technologies to increase meaningful and effective interaction among students, instructor, data and environment, and is a disruptive innovation in learning methods since its concept leverages and does not replace the potential of eLearning or blended learning [23].

Phygital learning was designed to improve quality and effectiveness of education particularly within the psychomotor domain which requires extensive practice to establish a tangible and developed skill. In according with Vate-U-Lan [24] phygital learning concepts also emphasize the learning process as a residual benefit which can be described as the 8Cs processes: 1) Connection, 2) Captivation, 3) Contexts, 4) Contents, 5) Communication, 6) Collaboration, 7) Consistency, and 8) Competence.

3 THE DESIGN METHOD

3.1 Children Centered Design

Today designing new products and services for children means for designers have on the one hand the child (user) with his needs and his new habits, on the other the parents (consumer) that have an active role in the purchasing process. This shared awareness is reflected today on the design of products for children, in which finally the real end user, the child, becomes an active part, also in the development and creation of product-service systems (PSS), i.e. with an integrated mix of products, communication strategies, services and spaces to offer innovative solutions [25]. Moreover, as an area of specialization in human factors and ergonomics, design for children is a new subject. The skills and knowledge necessary for this specialization are beginning to identify, on a case-by-case basis, thanks to specific works in this direction [26].

It is evident that the digital transformation further complicates the framework by introducing variables in continuous evolution. Understanding the rule of the new information technologies in the future development of tools, methods and services for the learning experience of kids (with or without DSA) includes a reflection on the set of disciplines involved in a design process addressed to this objective [27].

3.2 Design of '1,2,3, Stella!' App and Initial Screen-Based Interactive Prototype

The first phase of the research involved the development of a pilot project within the Master Design for Kids & Toys of the Polytechnic University of Milan that was carried out with the aim of understanding the impact of a new design approach in the development of support tools able to use the potential of new information technology in designing an innovative typology tools for the treatment of DSA (in particular the speech-language problems).

The purpose was to outline the guidelines to design a valid alternative to traditional speech therapy treatments, in particular in the field of apps. For the goal a multidisciplinary team was identified: the NuovaMente Children's Diagnostic Centre team (child neuropsychiatrists, neuropsychologists, psychotherapists, speech therapists, pedagogists, learning tutors and educators), product and graphic designers and computer engineers. The designers, the computer engineers, the programmers and the speech therapists started to operate doing a careful preliminary analysis on the products currently available

The process start with the analysis of app for children currently available, divided into three categories according to the type of use: specific apps for the treatment of speech therapy, non-specific apps, but which are used for some speech therapy treatments, apps with only a game goal. The app evaluation criteria were usability of children, enjoyment (ability of the app to entertain and enjoy the child), feedback for adults, adaptability (set activities according to the different needs of the child), interface design, and therapeutic suitability (fig. 2).

The results of this analysis leads to decide, on the one hand the speech therapists to work an treatment of children with difficulties in the prerequisites of the mathematical logic area, in particular the prerequisites of the logical-mathematical area in preschool for children aged between 4 and 6 years, preventing the occurrence of dyscalculia in school age [28]. On the other, the best setting to accommodate the logical- mathematical activities was considered to be 'the space', as it turned out to be particularly interesting and engaging for small users, as well as being suitable for the inclusion of the 4 activities necessary for treatment, which are divided into two macro categories related to the type of exercise: correspondence and counting [29].

app name	usability	enjoyment	adults feedback	adaptability	interface design	therpeutic suitability
DSA	3	1	2	0	2	1
Speak up too	2	2	0	0	0	4
Tachistoscopio	0	0	5	5	0	4
Lamparole	2	1	2	4	2	1
iWin ABC	1	0	5	5	0	5
iSequences	3	1	4	3	3	-
Alla festa con Tina Talpina	4	4	0	0	5	-
Pango Storytime	4	4	0	0	4	-
3 Porcellini	2	2	0	2	2	-
Prime parole	2	1	2	1	2	-
Articulation station	2	2	3	2	4	-
KidEWords	3	1	1	1	2	-
Re della matematica	4	3	2	0	4	-
Fantasea	4	4	4	0	4	-
Animal math	4	3	2	2	4	-
Fantafattoria	4	3	4	0	4	-
Lego Food	4	4	2	0	3	-
Timbuktu Pizza	3	2	2	0	3	-
Toca Kitchen Monster	4	4	1	0	4	-

Figure 2: Diagram that shows the App evaluations (grade 0 to 5) and allows their comparison.

3.3 The GUI Design for Kids.

Thanks to the initial research the team was able to better understand the relevance of design an effective interface for the app. We define the mechanism and the point of access to a system or software component with the term 'interface'. The user interface is the component of a software system that allows and abilities the interaction and communication of the system with the user. During the design phases of an application it becomes fundamental to maintain the focus on the user and on the type of experience experienced by the latter during use. The primary objective of the design of the interfaces is therefore to simplify human-machine interactions.

An interactive product, to be usable, must be easy to understand and pleasant, as well as adequate to the needs of the user to whom it is addressed. In this case, referring to children users, an essential configuration was chosen, immediate and simple to use, with intuitive icons and belonging to the children's imagination, that would be pleasant and engaging, with a high level of fun. In this first phase the objective was mainly to design an interface that was kids-centred, clear, simple, understandable and pleasant. using the heuristic principles of usability of Jacob Nielsen [30], The app has been designed with a friendly graphic user interface (GUI), with the aim at having an intuitive and playful instrument for all the users children, parents and speech therapists.

Another good practices in designing UI for young children is the necessity of not overloaded with information. At these age children still can't understand the hierarchy of the information we present them on the device, they still require some time to fully understand each and every object they see on screen, so putting too much stuff on a single screen can be overwhelming and confusing for them.

4 CARE DESIGN WORKSHOPS. A DESIGN CASE HISTORY BRIDGING SCREEN-BASED AND PRODUCT-BASED INTERACTION

In an additional phase, the research team had finally investigated on the possibilities offered by relations in between screen-based and product-based interaction in the areas of care design. From experiences in this sense, deriving from some workshops conducted by multidisciplinary team, the principles of possible applications were extrapolated to go to broaden the positive effects by applying them to the child-care.

Care Design workshops has been a specific research program of Design Campus of University of Florence, within the course of Advanced Product Design, Master program in Design. The program focuses on the concept of product performance, as a topic including gesture, intrinsic meanings and aesthetics generated from the relation in between user and device, human body and product-system. On this perspective, the concept of performance is going forward the anthropometric criteria and ergonomics, involving sensory and emotional contents.

The workshop projects are developed by user-friendly microcontrollers, including hardware (digital card) and specific user-friendly software package able to transform analogical input to digital output, and vice versa. The selected technology guides non expert users in setting interactive design concepts, avoiding complex programming systems. Through this software we can create sounds, images and we can control external instrumentations to do specific value calculations for the effect setting.

Design contribution in this field is aiming at including the care device in the daily life contexts, designing interactive tools (based on microcontrollers and sensors) developed by specific shapes and materials for real user scenarios. Within the workshops, the research team investigated how to correlate the screen-based input and output of 1,2,3 Stella App to physical objects. The results of the Care Device work program have shown that linking screen-based user experiences and product-based interactions could be a significant development opportunity in the learning process for children (an initial interactive prototype is described in [29]).

5 PLAYFUL INTERACTION IN SCREEN-BASED AND PRODUCT-BASED DESIGN

Assuming that play is one of the main ways in which children learn, as well as being present in the most varied cultural backgrounds [31], it can contribute to enriching learning and developing skills [32]. By playful interaction we mean an activity in which an effort is required by a user that is rewarded with a pleasant improvement of skills. The process is also characterized by the presence of stimulated emotions through and thanks to the use of the product (physical or digital). In short, one could therefore distinguish three different levels of playful interaction: selection, activation and guidance.

In the case of a digital product we can describe them. The playful selection is the first level of interaction; it is the one that enriches the user interface with game mechanics with learning that aims only for pleasure. The playful activation replaces basic interactions with small challenges that aim to increase the attention and interest of the user. Finally, the playful guidance provides integrated, just-in-time learning and help and hints as satisfying rewards or achievements.

Forlizzi & Battarbee [33] describe three types of user-product interactions:

1) Fluent interactions: automatic and well-learned interactions required without any conscious effort.
2) Cognitive interactions: improve skills and knowledge, or if negative, cause frustration or confusion.
3) Expressive interactions: aim to remodel the relationship between product and user.

These three points describe a model of interaction that goes beyond simple efficiency. Today we design interactions that are simple and immediate use, but that require something in exchange for effort. They therefore have the potential to make the user feel stimulated, challenged, curious and proud, but also frustrated, confused and even sad.In game design theory similar ideas exist. Challenge and effort is central and the gamer / user enjoyed by learning new things - or by adding a new pattern, or by adding data to better grasp an existing pattern [34].

5.1 Visual Recognition for a Product-Based Interactive Process

Taking in consideration the phygital learning processes achievements and based on the initial results achieved from Care Design workshops, the team explores interactive technologies able to reshape 1,2,3 Stella device as a product-based device. The research selected visual recognition as a bridge in between the screen-based app and physical 3D dices. In particular, involving this technology we avoid any programming complexity and informatics matters we highlighted within Care Design workshops.

This section explains how the Dice Visual Recognition (DVR) system is designed and implemented, and how it can communicate with a smartphone application. The core of DVR is a PC that acquires through a webcam a live video of a scene including three or more dice, analyses it with a computer vision algorithm that establishes the values of the dice, and then outputs this information to the smartphone via a web server. The vision algorithm is composed of the following computational steps.

System Calibration. In this offline phase, the user with four mouse clicks helps the system computing the homography function [35] that maps the upper face of a die onto a reference square. The main goal of this operation is to remove the nonlinear geometric distortion of the dice upper faces introduced by the camera. At runtime, the inverse homography will be applied to each video frame, with the result that the video will be perspectively rectified, and will appear as it was captured with a camera viewing the table perpendicularly (fig. 3).

Image Binarization. The idea behind this step is clearing the artefacts of the image that may affect the subsequent blob detector step. Binarization is done with Otsu's method [36], assuming that frame intensity histograms are bimodal—i.e., that pixel intensities are distributed around two main values. This assumption is consistent with the constraints set on the imaged 3D scene.

Dot Localization. The third step consists in locating the dots in each die (fig. 4). Since a dot can be modelled as a blob (that is, a group of connected pixels that share similar properties), in order to locate each dot a properly tuned blob detector is used. Our system uses the blob detector implemented in OpenCV [37]. In this step, the frame rectification carried out beforehand greatly simplifies the blob detector's work, as it brings back the imaged elliptical dots to their original circular shape.

Dot Clustering. Once each dot has been located by the blob detector, it is necessary to cluster the dots belonging to the same die face. This is achieved with the Mean-Shift algorithm [38]. This algorithm works by updating each centroid candidate to be the mean of the points inside a given region. Also, Mean-Shift automatically defines the number of clusters according to an input parameter (bandwidth) that the user can define to achieve the best result.

Dice Value Computation. This last step establishes the numbers on the die faces by counting the number of blobs inside each cluster. Indeed, thanks to the unique structure of our dice (recall that each dice has the same value on each face), the number of dots inside each cluster is exactly the same number that the die face represents. However, given the special die structure, simply counting the number of blobs in each cluster will produce a list of numbers that may contain some duplicates. In order to avoid this issue, it is sufficient to filter out the duplicate elements inside the list. Another fine point in the implementation of this step is deciding when it is actually possible to read the value of each die with a reasonable confidence. This can be done only if the frame is stable, i.e., the dice are still, and not rolling. To ascertain that, the algorithm checks if the centroids that Mean-Shift locates have changed their position in the last few video frames.

The communication between the application and our server exploits a simple HTTP server (fig. 5). Every time that the server

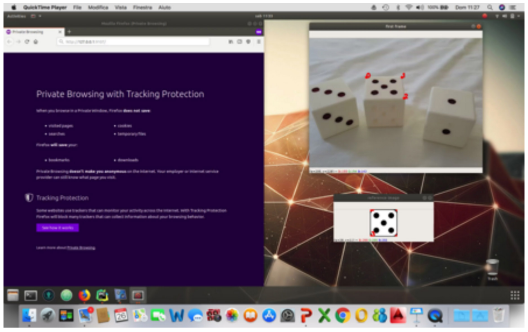

Figure 3: Die face recognition system.

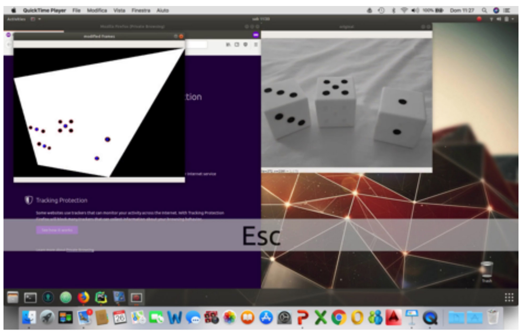

Figure 4: Visual recognition system of the die numbered faces on a surface.

evaluates a frame, it communicates the dice values to the HTTP server that can be reached through a standard smartphone application (fig. 6) The vision algorithm is able to recognize dice numbers even if the operational constraints are not fully fulfilled. However, to optimize performance, some parameters have to be tuned (like the number of user clicks to build up the homography or the bandwidth in Mean-Shift). Tuning these parameters can be cumbersome. Therefore, in order to overcome the initial system calibration step, a future development can be represented by the automatization of the homography computation, leveraging the homography of the table plane, that is parallel to the dice faces. Another improvement to be implemented is the ability to manage a regular dice instead of our modified one, in order to guarantee a greater coverage of scenarios to the therapist.

6 CONCLUSIONS: 1,2,3 STELLA! PHYGITAL PLAYFUL LEARNING

During the design process, the educational objectives that were to be achieved with the use of this phygital product were stable. The educational objectives are in fact characterized by levels of progressive complexity whose achievement allows to move from simple knowledge to skills.

Once a specific educational objective has been identified, at the same time it is necessary to specify the method by which it is possible to verify its learning. This allows to evaluate the quality of the educational objective itself. In practice, with the support of

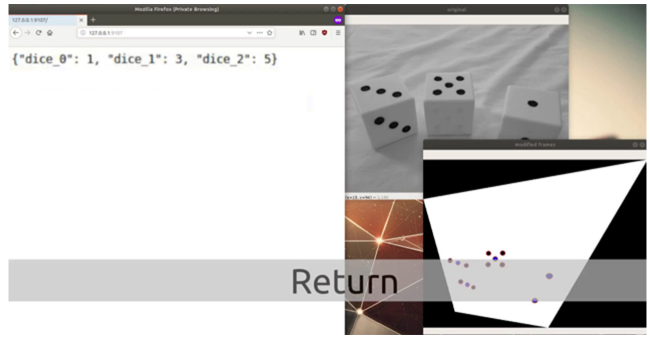

Figure 5: An example of the HTTP server.

Figure 6: Developing interactive scenario for 1,2,3 Stella! product-based interaction.

the speech therapists, for each educational objective, the value of the action coming from both physical and digital stimulation and the relationship with the expected reaction was evaluated, using the following questions: Is the command clear enough? Are there any possibilities for different interpretations? Is the child able to do what the command requires? Can I measure the result of what the child has done? This process helps to keep under control the design phase and to achieve the goals.

The developed prototype presents an intuitive interactive path. The children are requested to select either a decimal number or a dot number, by taking a physical dice according to the face that shows the selected number. All the die faces are identifying by specific indicators base on a visual recognition system. By classifying by vector tips the specific faces of the die, we can use the visual identification to count the numbers shown on the table. The software then can relate the dice numbers to the display graphics. Then, the app will respond to this interaction as if the children had clicked on the corresponding decimal/dot number on the screen. About the technology application, differently from a first prototype, in this specific case study we preferred visual recognition technology to sensors and microcontrollers embedding since visual recognition is faster and more intuitive, and it doesn't need embedded system, (so that the technology application doesn't limit in any way dice design and usability, differently from application of sensors and microcontrollers), and since no maintenance and no obsolescence of technological micro-components.

Thanks to these pilot activities the research team has been able to set up first findings for the improvement of knowledge in use design and new information technologies in the development of tools, methods and services able to support the learning experience in kids in the Digital Era. The research proposes a guideline to define new phygital products that could pervade different areas to help special education needs (SEN) students with playful learning experiences. Then, technology could stand as a support for the user connecting physical and digital experiences avoiding digital addictions and kids alienation due to excessive virtual gaming.

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