Educacaoacessivel.pt: A Case Study of Production and Application of Videogames for Teaching Mathematics to Deaf People

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ABSTRACT

The pedagogical resources in Portuguese Sign Language (LGP) for the deaf teaching support are very limited, and largely dependent on teacher's dynamics and improvisation skills. A work with several obstacles to technical and pedagogical quality, such as the technical conditions that the school provides for this work, or the fact that these contents in general do not come out from the school.

The project Educacaoacessivel.pt aims to contribute to mitigate that problem, with the production and distribution of free educational videogames for teaching mathematics to deaf students.

This paper deals with two distinct project areas: the development process by students of the bachelor's degree on videogames of a Portuguese University (PU) and the videogames application in the math classes for deaf students on a Deaf Education Related Institution (DERI). About the development process, the paper focus is on the methodology used in the classroom and its critical reflection, as well as a brief description of the videogames and tangible interfaces already available; regarding the videogames application in DERI, it will give account of the process of adoption of those video games by the school and on the impact of videogames on learning process of deaf students.

At this stage of the project, some positive conclusions can be drawn: regarding the development of videogames, students are held accountable for a real project and it's clear that is possible to produce, in a unique two semester's discipline of a bachelor's degree, usable videogames for deaf students, despite the complexity of the resources and partners involved. As for the results of the videogame application in deaf students, it has been observed that the students are motivated to use the games and can contribute to the consolidation of mathematic principles.

Keywords: Videogames; Deaf; Teaching; Learning; Mathematics.

Introduction

The project Educacaoacessivel.pt, rather than being a mere research project, is a collaboration between two institutions with a view to remedy as soon as possible a pedagogical problem identified in one of them. The institutions in question are the PU, via its research centre, and CPL through the DERI; already the pedagogical problem in question is the general lack of pedagogical supports in Portuguese Sign Language (LGP) for the school support of the deaf student in Portugal, which was delimited here to Mathematics teaching. The starting point of the project is as simple as an informal conversation between a DERI Mathematics teacher, who was looking for technical and creative support for her LGP contents and a videogames First Cycle Degree teacher looking for themes for his students with potential social impact.

This is thus a project that, at first, aims to respond to a need identified by a professional in a work context, and whose satisfaction with the results obtained in the first phase lead the institutions involved to continue it and invest on its disclosure to the outside. As an example we could point out the meeting "Mathematical Communication in the learning process of the deaf student"[1], which had as its motto the dissemination of the project to the Reference Schools for Bilingual Education of Deaf Students (EREBAS); this communication aims to contribute to a discussion about the pedagogical potential of the videogame for the deaf student as well as to identify pedagogical processes that allow for the development of projects of this type in a common curriculum of a Degree in Videogames. However, before describing the process of developing the Videogames at the PU, and addressing its application in the DERI, it is important to frame the study problem by means of a brief literature review.

Videogames in the teaching of deaf students

Deaf Children and Learning

The estimates from the General Directorate of Education and Science Statistics (Direção Geral de Estatísticas da Educação e Ciência - DGEEC), regarding the academic year 2015/2016, indicate that there were 63540 children with Special Educational Needs (SEN) attending basic education in the Portuguese educational system, both public and private. Of these students, about 19,3% have "serious

difficulty" or "total difficulty" in communicating, requiring 16,3% of them the use of technologies to support learning and 0,5% of adaptations in the teaching process, mainly associated with the insertion of the Portuguese Sign Language (Língua Gestual Portuguesa - LGP) (DGEEC, 2016).

Because of the language delay in deaf children, the acquisition of multiple literacies and numerical skills can be significantly later and more complex than in their hearing pears (Edwards & Crocker, 2008). When considering the inclusion of deaf children in the educational system, there are several identified barriers, associated with different developmental factors. Firstly, about 98% of deaf children have hearing parents, and most of the times they are unable to speak the same language of their children (LGP). If we explore this problem, it's also possible to denote that most of the parents only notice their children's impairment around two or three years old, by which time they search for professional attention, affecting definitely the global developmental process. Secondly, and related with the first reason, it's common that deaf children only start to learn their own language (LGP) at three years of age, which induces a significant delay, comparing with hearing children of the same age. This aspect frequently roots difficulties in the acquisition of scientific notions that are more abstract or complex. Thirdly, deaf children's native language is LGP, which is different from the official scholarization language, Portuguese. Therefore, a deaf child in the Portuguese educational system represents the integration of a learning process in a non-native language, what is very demanding when compared to their hearing peers (Nunes, 2013; Barroco & Nunes, 2014).

In the specific context of mathematics learning, the severe lack of mathematical gestures in LGP adds another layer of complexity to concepts acquisition by deaf children, and even more complex when considering the non-existing adaptations in the curriculum, for this specific population (Nunes, 2013; Barroco & Nunes, 2014). In addition, it is estimated that deaf children are about three and a half years behind hearing children in mathematics achievement (Nunes, 2004), having more difficulties in basic concepts, operation and application (Noorian, Maleki, & Abolhassani, 2013). Nevertheless, research also supports that deaf children are not inherently behind in number representation. So, these difficulties can be due to the differences in how well deaf children can process simultaneous and successive information, affecting their performance in number representation tasks

(Nunes et al., 2008). Other type of explanations for this fact are the ones related with more contextual/systemic factors, like the language barrier as an obstacle to parents' and teachers' feedback and to the comprehension of complex mathematical problems (Swanwick, Oddy, & Roper, 2005).

Games and Learning

Games have been applied in many educational contexts and their potential in the learning process has been extensively documented (Gee 2013), being able to be integrated into the educational process in several ways (Van Eck, 2006).

In addition, the potential of "serious games" in increasing cognitive functions has also been documented, revealing a significant and positive influence in several areas of cognition, when compared with interventions based on "traditional approaches" (Rosa et al., 2016). This potential of action on cognition is a key point in increasing multiple skills, resulting in improved performance in several areas of knowledge such as mathematics (Ke, & Grabowski, 2007; Barkatsas, Kasimatis, & Gialamas, 2009; Chang, 2009). A Meta-Analysis study, considering a sample of 14 experimental interventions in the field, concluded that Game-Based Learning (GBL) approaches can increase the learning process outcomes by at least 28%, and perchance by as much as 47% in comparison with traditional approaches, like expository or self-study, among others (Sousa & Costa, in press).

Moreover, a study conducted with teachers and pedagogical directors of the participating schools in GamiLearning research project show a positive attitude to videogames and learning in particular for Math, ICT, Geometry and Literature (Henriques, Sousa & Costa, 2017). Notwithstanding, there are a lack of specific research on GBL regarding deafness in particular. Considering a recent literature review of peer-review article from scientific databases, from a sample of 52 studies in GBL, there were no studies referring deafness or hearing impairments and only two sources studied games as a pedagogical strategy for people with visual and motor impairments (Costa, Tyner, Henriques & Sousa, 2016). Although gamified pedagogical strategies have shown results in the enhancement and facilitation of learning and skills acquisition process in deaf students, similar to the results of their hearing peers (Mertzani, 2011; Bouzid, Khenissi, Essalmi, & Jemni, 2016; Kamnardsiri, Hongsit, Khuwuthyakorn, & Wongta, 2016).

In terms of game usability, tangible interfaces popularity has increased in education and videogames, since they reflect the idea of thinking as tied to a body that has experiences in the world (Gee, 2013). This aspect has a relevance, when considering the learning process of deaf people and how it relies mainly on visuospatial cognition systems (Mascio, Gennari, Melonio, & Vittorini, 2013; Melonio, & Gennari, 2013). The study of Shelton & Parlin reported positive outcomes with mobile games when teaching mathematics for deaf children, mainly regarding logical deductive reasoning, but also improvements in vocabulary, resulting from the process of playing (2016). Other studies also reported positive outcomes with deaf children, when using interactive interfaces involving, for example, gesture recognition (Lee et al., 2005). The complex relationship between game design and learning gains in GBL interventions with deaf children is also studied as process, which gains are improved when students and teachers are actively involved (Portugal, 2012).

When designing videogames for deaf children, the traditional usability heuristics and principles are not enough and new ones are needed mainly relying on adaptations to implement the gameplay, text amount and positioning, feedback and avatar usage, based on identified gaps in text comprehension, memory, visual attention, focused attention and social interaction (Mascio et al., 2013; Melonio, & Gennari, 2013).

In the Portuguese context, most of the pedagogical resources available online are mainly made by teachers, normally videos explaining concepts in the main school subjects in LGP. Since these resources result only of teachers' efforts, they are not frequently updated, neither adopt innovative pedagogical strategies, like GBL ("Academia LGP", 2015).

Considering the presented framework, this study intends to explore the potential of videogames in the deaf children's process of learning mathematics, through a game design process where multiple stakeholders are involved (game developers, teachers and students).

Development of Videogames at PU

Curricular structure

As stated above, we are not aware of videogame development projects for the teaching of the deaf student in Portugal, and there are few examples of pedagogical resources with integration of Portuguese Sign Language (LGP)[2]. However, this lack of examples of studies identified with the Portuguese reality, was filled in this project by the long-accumulated experience of the DERI in the teaching of the deaf, whose structure is based on three pillars: teachers of the curricular unit, with and without specialization in the field of deafness, deaf LGP teachers and interpreters. It is in the dialogue with this critical mass of solid interdisciplinary knowledge, that it soon becomes clear that the development of the project implies a series of components and actors that would require not less than a school year for its conclusion. It was then decided to adjust the contents of a second-year course—second semester, with another of the third year—both taught by the same teacher.

Let us now proceed to a synthesis of the syllabus contents of the mentioned curricular unit[3]:

a) Project Jacob 1 (production dossier) - the objective of the curricular unit is the completion of a Dossier Project and study of mechanics in Unity with a view to the production of educational videogames, with integration of original tangible interface, for the teaching of mathematics to deaf students; it focuses on the following programmatic content:

- Introduction to the field of tangible interfaces—differentiating characteristics for videogame and immersive potential; application of the principles of affordance and emotion; techniques of drawing, visualization and prototyping;
- Introduction to Arduino platforms as interface support technology and interaction with Unity;
- Presentation and planning strategies in a real project;
- Particularities and objectives of serious games;
- Questions of communication and perception of the deaf person.

b) Project Jacob 2 (Videogame and tangible interface) - the objective of the course is the completion of an educational videogame, with integration of original tangible interface, for the teaching of mathematics to deaf students; it focuses on the following programmatic content:

- Serious game conception with LGP integration and affordance principles adjusted to the deaf person;
  Design, prototyping and production of original tangible interface with laser cutter and 3d printing;
  Project management - budgeting, task planning and team management;
- Integration of tangible interface based on Arduino platform to control applications developed in Unity;
- Video capture and editing techniques for communication in LGP;
- Execution of simple electronic circuits - general principles and techniques of welding;
- Presentation and communication strategies with real clients;
- Structuring of documentation for the sharing of design methodologies and reproduction of prototypes.

The above structure could be summarized as follows: in the first curricular unit, the entire videogame production dossier is executed, and the technical and conceptual bases necessary for its development are taught, as well as some of the technical bases necessary for its production; in the second curricular unit, the technical and conceptual knowledge is complemented and, based on the production dossier approved by the project partner, the videogame and its tangible interface are then produced.

Milestones

Having presented the structure of the curricular units and general lines of the development of the project, it is important to identify the milestones that set the pace and are the guarantee of its conclusion.

Curricular Unit 1:

- Week 3 | Research at the level of serious games, tangible interfaces and deaf culture;
- Week 4 | Contact with the partner and target audience - visit to the DERI for dialogue with the project's teachers and deaf students;

- Week 7 | General design concept - general concept of videogame and interface sketches;
- Week 9 | Narrative and gameplay; main layouts of the graphical environment and characters; tangible interface definition (interaction, design, materials);
- Week 13 | Presentation to DERI students of the videogame based on: concept and objectives; synopsis; gameplay supported by storyboard logic with reference to interaction with tangible interface; realistic mock-up of the tangible interface; frame diagram/game sequence; main layouts (characters and environments);
- Week 15 | Closed and revised dossier, after feedback from partners, with: concept and objectives; synopsis; gameplay; diagram; all planned layouts; aesthetic argumentation; definition of the interface tangible with materials and technical drawings; technical, aesthetic and conceptual research; application in Unity with demonstration of the general mechanics of the game.

Curricular Unit 2:

- Week 1 | Delivery of schedule, distribution of tasks and budget;
- Week 3 | Three-dimensional study of the interface (object in cardboard or fast 3D printing);
- Week 6 | Presentation partners and test with deaf students of the mechanics of videogames (alpha version 1), graphic environment and formal basis of the tangible interface;
- Weeks 7 and 8 | Capture of videos in sign language;
- Week 9 | Delivery of the edited videos to the partners for review;
- Week 10 | Review of budget and final list of materials;
- Week 12 | Delivery to the partners of the videogame version completed at the content level for validation (alpha2 version); videogame test and final format of the tangible (non-functional) interface;
- Week 15 | delivery to partners of Beta 1.0 version of the videogame and tangible interface - the project will always be open to corrections and improvements.

These milestones seek to reconcile a coherent logic in the production of a videogame with the schedule of the project partners, and the chronology and content have been corrected throughout the three phases of the project, which have been covered; the stages that we present here are already aimed at the fourth phase that will begin in February 2018.

Particularities of a Project for Deaf Students

It has been evident that there has been a gradual increase in the complexity of content throughout the three phases of the project. This is since it has risen from each study cycle (see "Educacaoacessivel.pt: videogames and tangible interfaces"). As would be expected, questions and concepts increase in complexity and abstraction as the cycle progresses, which justifies the introduction of glossaries with explanation of concepts in some of the games for the third cycle. By itself this is a factor that differentiates the games of the first and third cycles at the level of the time to be assigned in the planning for the capture of the videos in LGP. This planning, cannot be done solely based on the texts that will be interpreted for LGP, under penalty of becoming misaligned. This is so, because the process of interpreting the message of the Mathematics teacher for LGP is quite distinct from a simple reading, since she will always be an interpreter of LGP, which will not only guarantee good communication between the parties, but will also play a crucial role in the good performance of the gesturing deaf (the native of the language in question); it will be by his/her gestures that he/she will perceive or not the exact content of the original message. Since LGP is a language of visual acquisition and motor spatial production, generally applied in a concise and direct message (dactylology[4] is always a last resort), it is sometimes complicated to transmit abstract concepts as is the case of much of Mathematics.

Referring again to examples of this project, in questions like "how many wheels a tricycle has?" (Rodopia game - first cycle), it was enough to read the text and a brief exchange of ideas between the interpreter, Paulo Ataíde, and the deaf gesturing Marisol Coelho, so that progress could be made for the LGP video. Already when the term "arrival set" was gestured for the Math Quiz game (third cycle), although there was already a gesture filmed in the DERI for reference, the explanation of the concept was considered unclear and could be improved. Since the mathematical concept did not say anything to the gesturing person or to the interpreter, it was

necessary to explain it first to him so that he could transmit it to the gesturing person in a rigorous way; Once the concept was acquired, a three-way analysis and discussion process was followed until a more efficient gestural sequence was found. For this contributed the fact that the gesturing person not only has extensive experience in this kind of work, as she is herself a teacher of LGP; also, relevant, was the fact that she was accustomed to working with that interpreter in her day-to-day professional life. We conclude that it would not be possible for these videogames to efficiently promote the mathematical communication to the deaf student in the absence of the competences of one of the three mentioned players: teacher of mathematics, interpreter and deaf gesturing person.

Regarding the formal issues of the videos, special attention should be paid not to create any type of visual noise that would disturb the LGP message. At the level of minimizing shadows, such as the hands on the body or the silhouette projected on the background, or any kind of strange irregularity on the background surface.

Another example of how the visual acuity of the deaf influenced the development of videogames, has to do with their graphic interface and in particular with the informative elements of the game, such as points, time and the like. In the dispersion of these elements and their animation. This is a constraint that we have removed from the test of a game of the second cycle, phase in which the games began to have a more competitive strand. Although the concentration of the informative components of the game and the avoidance of the animation of these components seem to us consistent with the general good practices of usability applied to videogames, it was evident in that particular case that if this was a usability problem that did not deserve special relevancy to the players who tested the game, it was unanimous for the deaf people to point out that the animation of informative elements and their dispersion on the screen were a distracting factor of the main action to be avoided.

Also related to the visual perception of deaf people, it should be noted that there was a widespread preference among deaf students for bright and saturated colours, especially when, invited to comment on the very saturated and luminous colours of the Triple File game, they were especially pleased with them at the expense of a less saturated colour palette. Another reference in this field has to do with the background chosen for the videos, where the saturation of the blue

chroma did nothing to disturb the deaf gesturing person, demonstrating even preference for it when, in the games of the second cycle, it was confronted with the grey background option adopted in the first games.

Educacaoacessivel.pt: Videogames and Tangible Interfaces

With the questions of the design methodology and the peculiarities of a project for deaf students dealt with, it is now important to divulge the games produced so far, and it is opted not to put the third phase here as they enter now (February 2018) in the validation phase. Let us go on to a brief description of the first and second phase games, organized by name, cycle, game synopsis, interaction format, and authors.

Figure 1. Phase 1: 1st cycle and preschool: Rodopia, Magic Box, Card Box, Forest Game; 2nd cycle: Pinball.

Rodopia

Synopsis: mini-game aimed at pre-school children. It is based on the logic of the Quiz with multiple answers (16 possibilities), combining questions asked in LGP with association of illustrated forms. It deals with colours by associating them with everyday objects, and numbers by counting these same objects; also contributes to the knowledge of LGP's basic gesturing.

- Interaction: with tangible interface - answers the questions by turning the wheel and confirming the answer by pressing the black button; To repeat

the question press the red button; with keyboard - answers the questions by pressing keys 1 to 9, whose numbers appear on the screen associated with colour; To repeat the question press the "R" key. Authors: João Henriques, João Rodrigues, Daniela Policarpo, Christian Rigstad.

Magic Box

Synopsis: mini-game indicated to pre-school children and first cycle. It is based on the logic of the Quiz with multiple answers (3 possibilities), combining questions asked in LGP with association of illustrated forms. It treats the sum and subtraction up to 10, sequences of shapes and colours, and contributes to the acquisition of the basic LGP gesturing.

- Interaction: with tangible interface - answers the questions by touching the can with the colour corresponding to the answer that appears on the screen; with keyboard - answers the questions by pressing the "A/S/ D" keys. Authors: Alberto, Diogo Coelho, Diogo Reis.

Card Box

Synopsis: mini-game indicated to students of the first cycle. It is based on the logic of the Quiz, combining questions asked in LGP with an association of illustrated forms and numbers. It deals with the basic gesture, quantity, counting, addition and subtraction.

- Interaction: with tangible interface - answers the questions by supporting at the top of the interface one of the fifteen available letters; with keyboard – one answers the questions by pressing keys from zero to ten. Authors: Artur Rosário, Diogo Simões Melo, João Fernandes.

Forest Game

Synopsis: mini-game indicated to students of the first cycle. It is based on the logic of the Quiz, combining questions asked in LGP with an association of illustrated forms and numbers. It deals with the basic gesturing, quantity, counting, addition and subtraction.

- Interaction: with tangible interface - answers the questions by supporting at the top of the interface one of the fifteen available letters; with keyboard

- answers the questions by pressing keys from zero to ten. Authors: Filipe, Sérgio, António Cabaço.

Pinball

Synopsis: mini-game for students of the third cycle. It is based on games of motor skill and mental calculation, where the goal is to subtract or add numbers along a course of mobile platforms to arrive at the proposed result. Treats the sum and algebraic subtraction of integers.

- Interaction: with tangible interface - control of the ball's course by tilting the interface to the right and left, and a button starts the game or pauses it; with keyboard - follow the above functions using the directional keys and the Enter key. Authors: Andreas Capri Melo, Bruno Catarino, Fernando Soares.

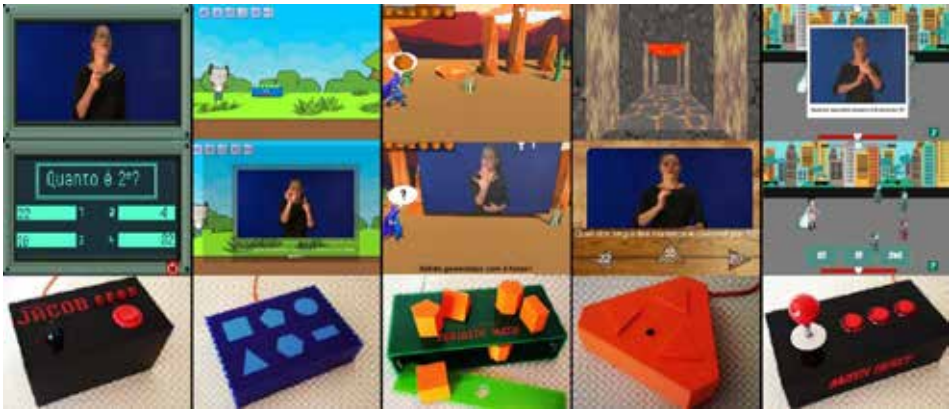

Figure 2. Phase 2: 2nd Cycle Games: Jacob's Quest, Jacob's Knight, Funthastic Math, Labyrinth, Math Hero

Jacob's Quest

Synopsis: mini-game indicated to students of the second cycle. It is based on the logic of the Quiz with multiple answers (4 possibilities), with questions asked in LGP and by writing, in which the player must complete three areas of study organized in the form of continents. It treats the powers, the criteria of divisibility and geometry.

- Interaction: with tangible interface - responds to the question by turning a knob to four-positions, which corresponds to the lighting of a LED, and confirming the option by pressing the red button; with keyboard - answer the questions by pressing the "1/2/3/4" keys plus the Enter key to confirm. Authors: David Filipe, Gonçalo Moura, Gonçalo Reis.

Jacob's Knight

Synopsis: mini-game indicated to students of the second cycle. It is based on the logic of the adventure game, where a warrior has to clear a path full of strange geometric compositions answering the questions posed, in written form and in LGP, selected one of the six available geometric forms. Treat geometry.

- Interaction: with tangible interface - answer the question by pressing the button with the corresponding geometric shape; with keyboard - answer the questions by pressing the "1/2/3/4/5/6" keys which in the graphic interface have an associated geometric shape. Authors: André Fernandes, André Reis, Eric Spenner, Rodrigo Bulhões, Luís Picareli.

Funthastic Math

Synopsis: mini-game designed for students of the second cycle. It is based on the logic of the adventure game, in which the punctuation depends on the answer to the problems presented during the course of a deaf superhero, by three distinct environments; some problems require the rapid association of other forms, others are questions posed in written form and in LGP. It deals with Geometry.

- Interaction: with tangible interface - responds to problems by putting the corresponding three-dimensional form at the top of the interface; with keyboard - responds to problems by pressing the "1/2/3/4/5/6" keys which in the graphical interface have an associated geometric shape. Authors: Tiago Oliveira, Marco Rodrigues, Rodrigo Azevedo, Tiago Jesus.

Labyrinth

Synopsis: mini-game indicated to students of the second cycle. It is based on a labyrinth, in which the doors that block passages open with the right answer given to problems that are presented in written form and in LGP. It deals with divisibility criteria.

- Interaction: with tangible interface - the pathway is controlled and answers the questions by pressing the three directional keys of the interface; with keyboard - follows the above functions using the directional keys. Authors: Vitor Pais, João Santos, Ana Brito.

Math Hero

Synopsis: mini-game indicated to students of the second cycle. It is based on the logic of the adventure game, where a superhero has to fight various animals and robots to complete, within a limited time and lives, each of the six scenarios presented; its success depends on how it responds to multiple-response problems (3 possibilities) that are presented in written form and in LGP. It deals with divisibility criteria.

- Interaction: with tangible interface - opponents are selected to fight by means of a joystick and to answer the questions by pressing one of the three available buttons; with keyboard - select the opponents with the mouse and answer the questions by pressing the "5/6/7" keys. Authors: André Santos, João Almada, Rafaela Pereira.

We conclude this synthesis with a general observation regarding the tangible interfaces, which were defined from the beginning as a mandatory part of the project, not only because their study and prototyping are competences that the structure of the Videogames degree leaves for the disciplines involved, but also considering by the DERI that its immersive and playful potential would be an asset to the deaf student. Since in technical terms there has been an evolution of processes, in which in the first phase we used primarily acrylic laser cutting techniques, in the second phase we have already combined that technique with 3D printing and integration of more advanced input systems appealing in the third stage, which we did not document here, all the commands were made in 3D printing and the laser technique used in the storage boxes.

As for the processing-sensor platforms used in the interfaces and the software used in the production of the game, in the first phase, two of them used Adobe Flash (AS3) in conjunction with the Phidgets platform, while two others resorted to Unity with MakeyMakey. Both options produced good results, however the choice of Phidgets raises issues of dissemination and updating, as it requires the

installation of drivers and an operating system configuration; as far as Flash, it no longer makes sense from the moment the degree removed it from the curriculum. Unity's conjugation (degree curriculum and degree software) with MakeyMakey proved to be the best solution, by avoiding the previous problems, although the rather high cost of the board was considered a problem. So, in the second and third phases, the Arduino platform was chosen in its Leonardo and Micro models, which also allows us to work with the keyboard input logic that characterizes MakeyMakey and at a more affordable price.

Application of Videogames in DERI

It is important to mention that there is a systematic study of the application of videogames among students, these supports being taken for a team of Mathematics teachers of the DERI as a tool of daily work without scientific study objectives. For this committed and dynamic team of teachers, the urgency expressed in the seminal project meeting remains the same: to improve the way of communicating Mathematics to the deaf student in a reality where the pedagogical support resources in LGP practically do not exist. The following brief text seeks to frame the application format of videogames, identify problems and gains, while pointing to a positive response from the deaf student to this pedagogical format that serves us all as an incentive.

Classroom Application Methodology

Videogames have been applied regularly during the weekly 45 minutes that the 28 deaf students have foreseen in the time for application and development of the Mathematics Incentive Project. Usually students play in pairs, taking into account that there are no computers for everyone, and in the second and third cycles of Basic Education, that game dynamics also has a pedagogical purpose, in the sense that one of the students registers the answers so that they are later discussed in group and with the teacher. In addition to the project curricular units, videogames have also been used in Mathematics classes, when it is intended to consolidate or revise a topic already addressed in one of the videogames. The videogame is then applied in the performance of consolidation exercises or review of learning through a non-traditional approach, and that is very appealing to the deaf student: "playing" on the computer.

Problems, Capital Gains and Results

These videogames have contributed to fill some of the problems felt in the teaching of Mathematics, such as there are no pedagogical or playful materials for deaf students, or the fact that the Portuguese Sign Language does not have gestures for most of the mathematical terms. This deficit is, in general, circumvented by the autonomous creation of codes within the classroom, information that the student loses when he or she changes school or teacher, since its validity boils down to that school or room. The glossaries of terms that were integrated in some of the games of the third cycle, will be an asset here, as they will allow the expansion of that gesturing beyond the DERI.

Other positive factors that stands out in these videogames are their dimension of pedagogical tool for students, teachers and families that do not dominate LGP. Its playful nature encourages the informal learning of Mathematics and contributes to a more solid learning that will tend to endure over time.

Regarding the observation of the impact that the games have had on the learning of Mathematics, it should be noted that its application is still recent, and no sustained analysis of results has yet been made, however some suggestions are already possible. First, the fact that we have not observed any problems of understanding the gameplay or the handling of the tangible interfaces. This is a general indicator that contributes to the notion of a positive impact of videogames on the learning of deaf students with a specific individual curriculum, a conclusion supported by the fact that, despite the above-average learning difficulties, they are also able to answer questions that are proposed until it becomes common for students to stand out, in spite of having with greater difficulties in relation to the curricular unit. The game in pairs, being the answers discussed and explained in pairs, proves to be advantageous, since students use the game to communicate and discuss mathematical reasoning.

Conclusion

We conclude this exposition, with an observation regarding the quality of the games, the commitment of the students and the interfaces. Thus, it is important to note that we place these mini-games at a level that allows them to be applied in the classroom in an area as deficient in pedagogical content as the teaching of Mathematics to the deaf, but we are aware that they would have to be profoundly improved, to attain a level of commercial demand. However, in line with the DERI, it has been decided to make all the games available, if they are functional and correct in their content, leaving the validation process in the hands of the deaf students and their respective teachers. An example that this may be a wise decision, can be found in the game Labyrinth, which, although strict in content, we consider having problems of layout and gameplay that called into question its delivery. However, it has proved to be one of the most sought by Jacob's deaf students.

As for the commitment of the students of the Videogames degree throughout the two curricular units involved in the project, it is necessary to emphasize a common sense of responsibility that is expressed in the conclusion of all projects that have reached the stage of development (the second discipline), although many of the times it has forced a logic of commitment to the students that went beyond the moment of evaluation. As such, it was common to most projects to request improvements and corrections of contents at a date after the conclusion of the course.

Regarding one of the most obvious problems in the games, the fact that short-term ones quickly exhaust their pedagogical potential for the same student, in two of the games of the third phase has already been included a question-and-answer editor that will allow teachers to update problems as they see fit.

At the time we publish this text, we are already working on the fourth phase of this project. The approval of both partner institutions for a further cycle and the positive impact on the learning of deaf students observed in the DERI, leave a validation aspect that is indispensable to the continuity of the project, however, we are aware that this is an opportunity of excellence to make a study, according to the good practices of gauging the collection and study of data, of the effective impact that videogames have on the learning of deaf students: "does mathematical knowledge differ among deaf students who use these supports from those

who do not?", "the results obtained by deaf students are different from those obtained among hearing students?", "is the tangible interface really an asset in the interaction with the game?". These are just some of the questions that need to be answered in future studies.

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Notes

1 The meeting "Mathematical Communication in the learning process of the deaf student" took place at the Centro Cultural Casapiano, 12 January 2018 and was organized by DERI with communication support by HLHT.

2 The LGP Academy is an exception, and consists of a repository of LGP videos for various areas of study; is a project that results from a partnership between DERI and the Portugal Telecom Foundation and has an address at <http://videos.sapo.pt/academialgp>.

3 We opt in this case for giving a general name to the curricular unit because the current name does not reflect its contents.

4 Dactilology consists in the formation of words by means of the reproduction of the respective letters in manual alphabet.