Short paper

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Developing pedagogical videogames to support math learning in deaf children: a work in progress (phases 1-3)

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Developing pedagogical videogames to support math learning in deaf children: a work in progress (phases 1-3).

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Abstract: The shortage of pedagogical resources to support the teaching of deaf children is a reality in the context of teaching in Portuguese Sign Language (*Língua Gestual Portuguesa* - LGP). This problem is mainly due to the lack of technical resources in schools and the lack of dissemination of the existing resources, which decisively influences their technical and pedagogical quality and makes them highly dependent on each teacher's improvisation skills and motivation. *Educaçãoacessível.pt* aims to contribute to the mitigation of such problems, with the production and distribution of free educational videogames for teaching mathematics to deaf students. Based on a collaboration, active since 2015, between a secondary school for deaf people and a bachelor's degree on Videogames, 21 mini games were already produced. The present poster is a work in progress that aims to systematizing the main pedagogical resources already developed, and to provide deaf-related particularities and constraints experienced during the production process, as well as data on classroom dynamics. At this stage of the project, some positive conclusions can be drawn: it's clear that it is possible to produce usable videogames for deaf students in a bachelor's degree class context, despite the complexity of the resources and partners involved. As for the results of the videogame application with deaf students, it has been observed that the students are motivated to use the games, which can contribute to the consolidation of math principles. About future work, project positive results and acquired expertise founded GBL4deaf (Game-Based Learning for Deaf Students), a larger and supported action-research project aiming to study and document the impact of such pedagogical tools on deaf children's maths learning process.

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

1. Framework

The estimates from the General Directorate of Education and Science Statistics (Direção Geral de Estatísticas da Educação e Ciência - DGEEC), regarding the academic year 2017/2018, indicate that there were 68.465 children with Special Educational Needs (SEN) attending basic education (1st to 9th grades) in the Portuguese educational system, both public and private. Of these students, about 19,35% are classified as having "serious difficulty" or "total difficulty" in communication. Of all the students needing specific curriculum adaptations (1.543), it is estimated that 32,53% are related to LGP-based learning. When considering only basic education, in a universe of 1.228 students needing curriculum adaptations, 26,71% are related to LGP implementation. In 2017/2018, there were 1.016 specialized SEN workers in the Portuguese public education system, being 17,03% of them LGP interpreters and/or trainers (DGEEC, 2018).

In the specific context of mathematics learning, the severe lack of math signs in LGP adds another layer of complexity to concepts acquisition by deaf children, even more complex when considering the lack of adaptations in the curriculum for this specific population and subject (Barroco and 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 and Abolhassani, 2013).

Games have been applied in many educational contexts and their potential in the learning process has been extensively documented (Gee, 2013). A Meta-Analysis study, considering a sample of 14 experimental interventions in the field, concluded that Game-Based Learning approaches can increase the learning process outcomes by at least 28%, and perchance by as much as 47% comparing with traditional approaches (Sousa and Costa, 2018). Though there is a lack of scientific data on the effectiveness of these approaches in the deaf population, some gamified pedagogical strategies have shown results in the enhancement and facilitation of learning and skills acquisition in this population (Bouzid et al., 2016). Moreover, 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 relevance, when considering the learning process of deaf people and how it relies mainly on visuospatial cognition systems (Mascio et al., 2013).

The present poster is a work in progress that aims to document such educational practice, systematizing the main pedagogical resources already developed, and to provide deaf-related particularities and constraints experienced during the production process, as well as data on classroom dynamics.

Table 1: List of *Educaçãoacessível.pt* videogames (1 to 3 phases)

Videogame Title	Cycle of Education				Tangible Interface
	Preschool	1st Cycle (1st-4th grade)	2nd Cycle (5th-6th grade)	3rd Cycle (7th-9th grade)	
Rodopia	X				Figure 1
Caixa Mágica	X	X			
Card Box		X			
Jogo da Floresta		X			
Pinball				X	
A Busca de Jacob			X		Figure 2
Cavaleiro Jacob			X		
Funthastic Math			X		
Labirinto			X		
Math hero			X		
Café Jacob			X	X	Figure 3
Ficha Tripla				X	
Matemática Furiosa				X	
Portal2				X	
MathQuiz				X	

2. Existing pedagogical resources

As schematized in Table 1, 15 videogames developed in the scope of the project are already being used in the school. Of those videogames, 2 are being used with preschoolers, 4 can be used in the 1st cycle of education, 6 are being used in the second cycle of education, and 6 are being used in the second cycle of education. Further information about the videogames can be found at *https://educacaoacessivel.ulusofona.pt*.

When framing the developed games by type, it is possible to refer a quiz logic, combined with adventure environments as transversal to most of them. Although this frequently compromises the gameplay flow, it was the best solution to implement the math questions, provided by the teachers (and partners in the projects) in the gameplay. The recognition of this limitation was fundamental to follow a different approach in the GBL4Deaf project, where a set of mini games aims to better embed math contents in the gameplay, avoiding the "traditional" knowledge assessment questions. Nevertheless, those questions must be framed in GBL4Deaf's game, since the math teacher and project consultant found it indispensable for the learning process, they are limited to a specific area of the game and can't be considered its main genre.

Regarding the technical characteristics of the tangible interfaces for *Educaçãoacessível.pt*, there was an evolution since the beginning of the project. From the first developed games (Fig. 1), the production process has evolved from acrylic laser cutting techniques, to an integration of laser techniques and 3D printing. The processing sensor-sensor platform and software evolved from Adobe Flash (AS3) (conjugated with the Phidgets platform) or Unity (conjugated with MakeyMakey) to Unity integrated with Arduino in its Leonardo and Micro models. This last solution used until now, since it offers better costs and development dynamics.

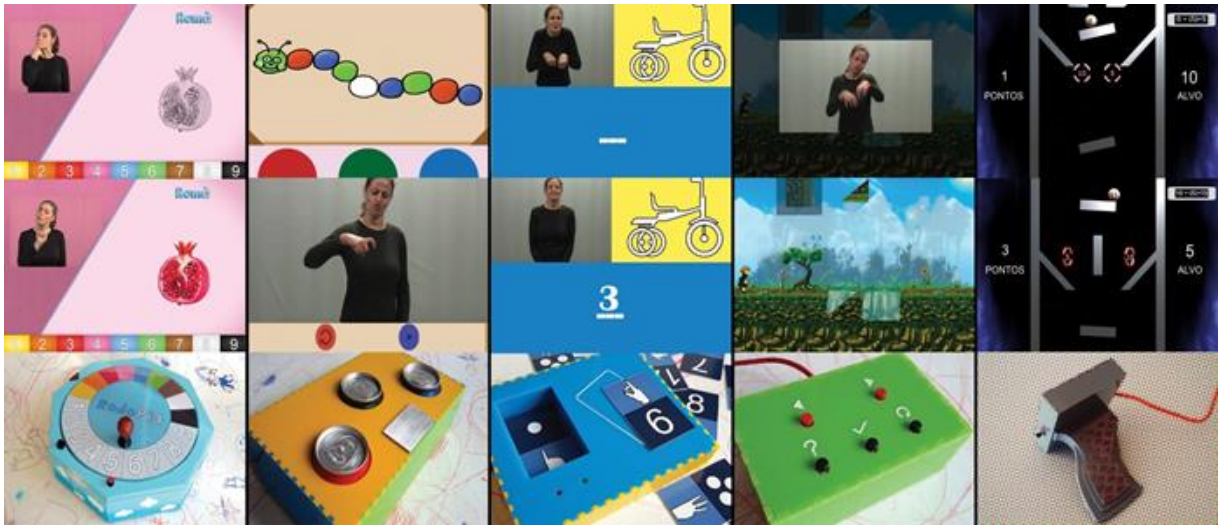

Figure 1: Phase 1 — *Rodopia*, *Caixa Mágica*, Card Box, *Jogo da Floresta*, and Pinball.

Figure 2: Phase 2 — *A Busca de Jacob, Cavaleiro Jacob,* Funthastic Math, *Labirinto,* Math Hero

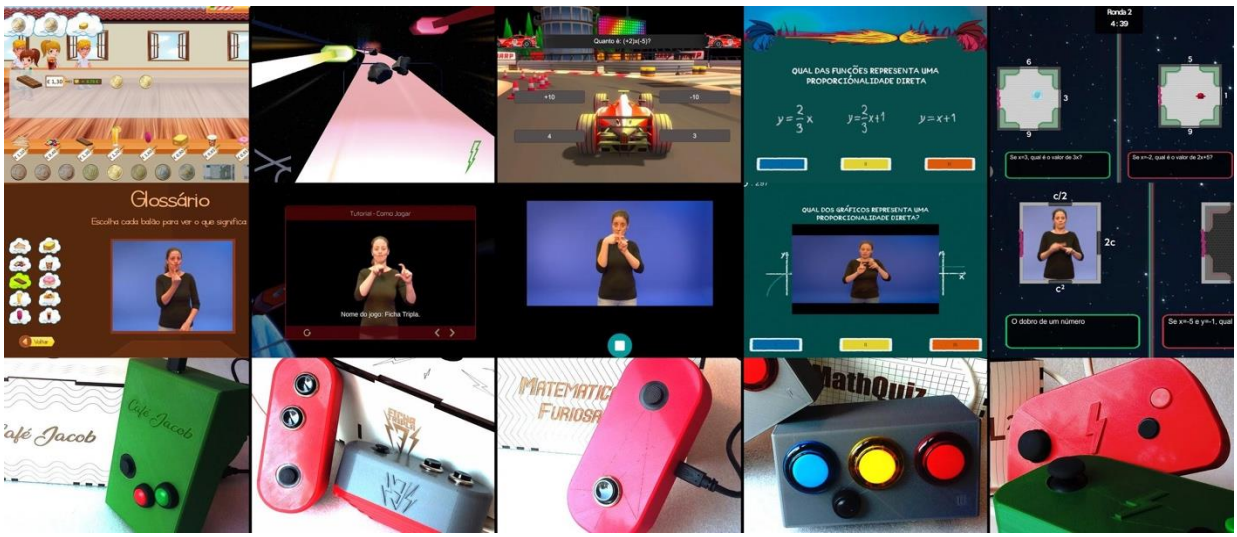

Figure 3: Phase 3 — *Café Jacob, Ficha Tripla, Matemática Furiosa,* Math Quiz *e Portal*[2]

3. Particularities and constraints for deaf people in the videogames development

The inclusion of tangible interfaces in the project frames one of its most innovative aspects. These types of interfaces enhance deaf students' emotional relationship with the videogames, eliciting curiosity and willingness to experiment. Moreover, the development of personalized controllers for each game optimizes students' interaction with it. Although these affirmations are not exclusive to deaf children, in our sample was evident an aesthetic interest in the interfaces and a willing to test. Such observations highlight the relevance of studying what a tangible interfaces-based approach brings to this population's performance and affective relation with videogames.

On the other hand, the inclusion of videos in Portuguese Sign Language (LGP) is a very relevant aspect, specifically to deaf children. LGP is an official language in Portugal and it is present in all the communication supports targeting deaf people, being also mandatory in deaf people's educational process. Considering these videogames target audience, the LGP videos have a mandatory institutional character, as well as they ensure an effective communication with deaf students in their own native language.

Such as tangible interfaces, LGP videos also evolved during the project. While we advance in the education cycle targeted as the games' audience, the complexity of the math content to be integrated also increases. Thus, in the 3rd cycle games the need to include video glossaries with math concepts' explanations emerged – a time consuming process since it involves the need to align the underlying concepts between the math teacher, the LGP interpreter and the deaf LGP teacher.

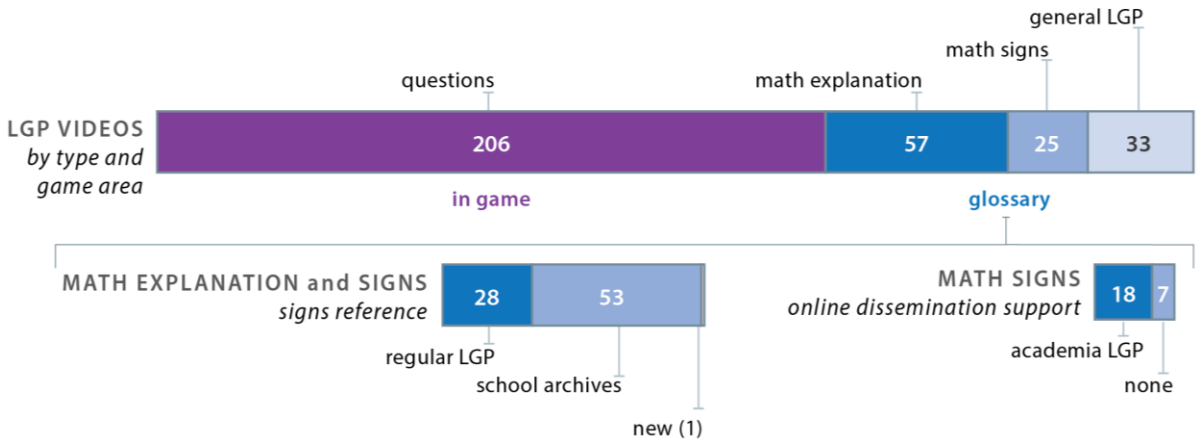

Figure 4. LGP videos classification (phases 1 to 4)

The glossaries represent an important part of the video resources. As documented in Fig. 4 (and including the video games of phase 4 still in validation) 321 videos in LGP have been made so far, including in-game questions and glossaries.

Considering the math explanations and signs of the glossaries, it's clear an LGP deficit on math related signs. If 28 only use regular LGP signs, 53 are taken from the signs repository of the project partner school, which were created over several years by the school staff. Despite this excellent resource, one more sign has been crated from scratch. Considering the math signs and its online dissemination supports, in 25 signs, seven don't have an online reference. These data suggest that there is a process of development of signs at school level that escapes official validation processes and have dissemination issues.

Regarding the formal issues of the videos, special attention should be paid to avoid any type of visual interference that disturbs the LGP message. Like the need to minimize shadows or any kind of strange irregularity on the background's surface.

Deaf children's specificities in visual acuity also influenced the development of the graphic interface and the games' informative elements, such as points and time. Although the concentration of game's informative components and the avoidance of their animation are widespread good practices applied to videogames usability in general, it was evident, after testing, that such distracting factors are much more relevant for deaf children, than for their hearing peers. Considering this type of insights, in the interface creation the students payed attention to avoid information dispersion and excessive animation.

4. Classroom application methodology

The developed videogames have been integrated into the classroom dynamics through a mathematics incentive project, which allocates 45 additional weekly minutes to the students' schedule. There are not computers for each student, so the videogames are played in pairs. This dynamic has a simultaneous reflection, promoted by the teacher, where the possible and right answers are discussed and explained, framing not only a game-based but also a critical pedagogical strategy. In some occasions, the videogames are also used in the regular weekly classes to perform consolidation exercises in a playful manner. In both modalities, the videogames mainly aim to consolidate, motivate and foster math communication among students.

Some constraints in the inclusion of the videogames in the classroom dynamics are posed by other educational dynamics that must be promoted during the mathematics incentive project time, framed in the school's tight schedule.

5. Conclusions and future work

An emerging and obvious conclusion is the possibility to produce feasible and useful pedagogical tools for support math teaching to deaf children, through a close and interdisciplinary collaboration between deaf students, teachers, academics and students of a bachelor's videogame degree. Once videogames are validated, they will be available in the *Educaçãoacessível.pt* online repository, free of charge, to support the learning process for other schools. This dissemination process facilitates the access of those pedagogical tools to students, teachers, and families that do not dominate LGP. The sign glossaries that were integrated into some of the games will be a valuable asset too, as they will allow the expansion of those signs beyond the project partner school.

Also relevant is the methodology of implementation in the classroom applied in this study, in pairs and accompanied by teacher-guided reflection, since it promotes the math communication in LGP and contributes to develop math reasoning. About the learning gains, math teachers reported that the videogame allows to vary the teaching strategies and to establish useful bridges with the traditional class content. Was also noticed that it´s playful nature encourages the informal learning and benefits the learning process.

Although the relevance of these benefits, we are aware that is required a systematic, multidisciplinary and broader research to describe and quantify learning gains. Thus, the present project is at the genesis of a larger and funded action-research project, aiming to produce a new set of games based on the accumulated expertise, and to study and document the impact of such pedagogical tools on deaf children's math learning process (more information at *https://gbl4deaf.ulusofona.pt*). Despite this new approach, the in-class videogame production is still active, with phase 4 waiting for validation and 5 being under development.

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