Gremlings in my Mirror: An Inclusive AR-Enriched Videogame for Logical Math Skills Learning

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Abstract—Implications on a simultaneous application of Augmented Reality (AR) and Digital Game Based Learning (DGBL) to inclusive learning have yet to be observed. We designed an AR enriched videogame for Logical Math Skills Learning. Then we tested the game with a set of 20 students with diverse learning needs. Our experiment showed that the performance on the game is similar for kids with different needs. The results and feedback from teaching staff suggest that AR and DGBL allow the integration of children with special needs in the learning process.

Keywords— AR, Digital Game Based Learning, ADHD, Videogame, Augmented Reality, Inclusive Learning, Mathematics, Learning, Gremlings in my Mirror

I. INTRODUCTION

Digital Game Based Learning [1] has started to be applied in instruction and curriculums around the globe. This educational paradigm proposes games as useful tools for learning and training. It can have greater advantages in many learning scenarios with digital natives [1]. It is being considered as a main tool to be soon adopted by schools as the Horizon Report 2012 claims [2].

Augmented Reality [3] is being introduced as an open, massively-used technology, especially by mobile users around the world [4]. In particular, Simple AR has been proposed for use in learning by the Horizon Report 2010 [5]. Nonetheless, there are still some obstacles to overcome and enablers to exploit in order to a widespread adoption of DGBL and AR.

In our opinion, Digital Games and AR are technologies can address the principles of the Universal Design for Learning [6]. In this paper, we show Gremlings in my mirror: an Inclusive AR enriched videogame for the learning of basic logical mathematical skills.

We considered Attention Deficit Hyperactivity Disorder (ADHD) implications for learning in our user-center design. We observed ADHD as it is considered particularly special in kids because of the lack of the right executive functions that control attention and hyperactivity [7]. Note that we have taken into account special requirements of ADHD for the game design; however, we consider that addressing the special needs of this population benefits all students as well. This is because approaches like this aim to design inclusive learning environments that not only appeal to certain population sub-group, but it helps to support every student’s learning by providing multiple media formats and tools [8].

In section 2, we present some of the work and expert-input related to the subject (AR, DGBL and ADHD). In section 3, we show the design and development of the videogame. Finally, in section 4, we show highlights of an observation scenario we carried on using the videogame with 20 children with different ages and needs.

II. RELATED WORK

An Augmented Reality (AR) system overlays computer presented material over the real world [3]. From a hardware perspective, some classifications of AR systems have been proposed including Hand-held, Headworn and Spatial devices with Projective, Video and Optical See-through displays [3], [9], [10]. From a software perspective we explored the most relevant and useful API’s and frameworks in the market to create AR-based games, including ARToolkit, UnityAR, Vuforia, NyARToolkit, ARToolkit for Unity and FLARToolkit. Since we had experience with the Unity3D game engine, our choices narrowed to UnityAR and NyARToolkit. After some tests, we chose NyARToolkit since it seemed very stable and easy to use when integrated with Unity3D (Utilities, C# language scripts, simple API etc.).

AR has been labeled as a good tool for learning since it has strong potential to provide both powerful and contextual “in situ” learning experiences [5], it allows experimental learning without displacing the learner [11], and it fosters participation of the observer [12].

We found some previous experiences on the application of AR to learning, specially some efforts applied to ADHD, like [13] where authors show the usage of AR courseware for ADHD students using cloud-computing and [14], a study that showed the use of AR in the classroom with a software using conventional assets.

Regarding Digital Game Based Learning (DGBL), we used Prensky’s work [1], [15]–[17] to orient the game with the DGBL philosophy of learning by doing and fun as the greatest motivator. Later, we applied Gee’s properties in our Game Design as described in [18], [19]. Gee claims that a good learning game: Allows the player to take advantage of the game; Offers microcontrol mechanics; Offers Experiences to the learner for good learning; Uses modeling; Allows the player to enact their own trajectory.

According to [20] ADHD comes from a dysfunction on the “executive functions”. These are functions of the mental apparatus that control functions like: Inhibition Control, Working Memory, Planning, Cognitive Flexibility and Fluency. We interviewed Dr. Ferrán Viñas, psychologist and UdG’s professor who explained the most common techniques for intervention on ADHD kids, including:
Operant Conditioning: Changing of behavior by the use of reinforcement [21]; Token Economy: Providing reinforcers such as points associated to a desired behavior [22]; and Self-Instructions: A set of steps the therapist uses to allow the kid to guide his own behavior [23].

III. OUR PROPOSAL

Here we show how we built the prototype for and AR-enriched inclusive videogame for Mathematics learning for kids, including a set of Game Design Principles. Our prototype is classified as a Spatial Video-Displayed game [3], [10].

For the game design, we asked for advice on math pedagogy. We consulted professor Maria Antonia Canals[24], [25], UdG’s professor emeritus and former elementary Mathematics teacher. She helped us to understand what a kid should have to effectively understand and apply Mathematics and basic logical skills. She told us math should come as a result of a self-reflection process next to the interaction with an object of learning.

The Game Design principles we proposed for designing Inclusive AR games are as follows:

- **Comply with Gee’s properties:** The game should comply with James Paul Gee’s properties [19].
- **Comply with Universal Design for Learning principles:** Offer to children visual and auditory ways to acquire information. Offer different pathways and opportunities for interaction.
- **Learner-Centered Interaction:** The game should be centered on the player, according to their background and context and should be aware of their actions. The game should let the player microcontrol [19], and also, should let a time for reflection on the learning [1].
- **Fun/Appealing:** The game should be as fun for the kid, as possible [1]. Consider what they like.
- **Augmented:** Especially if augmentation represents something important for the learning or if it allows a better control within the game.
- **Consider Executive Functions:** Like lack of attention, problems in retention, and delay [20].
- **Avoid Frustration:** A highly usable, interesting gameplay and appropriate satisfaction should be offered within the game.
- **Reward by Token Economy:** The game allows the kid to exchange tokens (coins, points, stars) into new items, prizes or scenes.
- **Self-Learning:** Allow Autonomy. Allow reflection and problem-solution. Step-wise and repetitive-mechanics games are recommended for self-instructions.
- **Induce operant conditioning:** Reward desired actions and learning.

Guided by these principles, we designed two mini-games: one for fostering pairing and one for ordering (called It’s Raining Gremlings and The Gremlution, respectively) both included inside one game called Gremlings in my Mirror.

We used previously defined markers for interaction as shown in Fig. 1.

Over the platforms used, we built an AR Interaction Framework in order to ease the development of this game and future ones. Using the framework we developed a set of common objects specific to this game and over them we built the Gremlings in my Mirror executable. The web version of the game is available at http://bcds.udg.edu/Gremlings/. We also constructed a standalone version of the game with a system to record player’s milestones which we used to carry-on the observation scenario we describe next.

IV. OBSERVATION SCENARIO

We allowed 20 students from a school (which integrates special-needs children) to play the game freely. The school’s psychologists and professors helped, but they were instructed to not offer instructions when not needed. The group consisted of 20 children with the following characteristics: 3 with ADHD, 1 with Autism, 7 with Mental Retardation, 1 with Asperger, 1 with Microcephaly, 1 with Down syndrome and 2 with Deafness.

We offered the game to the students and provided each one with a printed AR-marker and let the game record the timestamp when they reached an important milestone within the game.

To observe and compare the students’ performance, we divided the group in two: Kids with and without special needs. We averaged the timestamps to compare both. As this was a one-shot study our observations are preliminary. That said, we were able to see that kids with special needs took slightly more time than the others and that their performance is similar.

The students were not familiar with the interaction method (the AR marker). Thus, in the beginning they tried to use the mouse or the keyboard. Nonetheless, the students were not undermined by that. Once they were able to use the game, they got acquainted with it. This situation evidences that designers have to take special considerations on User Experience and User Interface design for a successful interaction, gameplay and finally, learning.

To obtain a qualitative view of the results, we interviewed the headmaster of the school and asked for her thoughts and opinions about the whole experience.

When asked about the implications and importance for logical-mathematical skills, she said: ‘The motivation to use the game the kid shows helps them foster their thinking in general. Kids like ours, like ADHD, for example, have a
hard time in mathematics. But it was very surprising how they achieved the game’s objective and that they did it in a very short time."

About children motivation: “I totally think they enjoyed the experience because I saw the kids joyful. Most of them did not even want to leave the game”

About AR: “Technology is nowadays our right-hand. I think that kind of technology allows the kids to recognize themselves which is one of the more important features of the game. Also, by seeing themselves [reflected] in the game they feel they are the protagonists in the game which is very important.”

About the autonomy in learning: “It is hard to define that. On one hand, the game allows the kid to make decisions which is a part of autonomy. On the other hand, since the game (and all games) has a closed set of goals and rules which can be counterproductive for the kid’s autonomy.

When asked about the inclusiveness of the game: “I think the game is applicable to most contexts; in fact, we had a very diverse group with kids with different needs and the game showed good results.”

V. CONCLUSIONS & FUTURE WORK

We have presented “Gremlings in my Mirror” as an inclusive learning Digital Games and as an empirical study on the use of digital games enriched with AR applied from an inclusive vision. We have also proposed a set of Game Design principles for AR Learning Digital Games for all students. Our proposal is based in documental and empirical research on which we base the game design principles for AR Learning Digital Games and considering some features of ADHD syndrome for supporting user-center design. Our observation scenario experience suggests that the Digital Games achieves the inclusion of all children into the learning process. All students achieved the goals of the game and felt strongly motivated in the learning process which is convenient for children with special needs.

As a future work, our Game Design Principles are yet to be tested in other environments. Also, those principles have yet to be fine-tuned and proven in other experiences to validate their implications. We think some other observations on AR and DGBL have yet to be observed using the game, thus we plan to carry-on an experience to measure enjoyment, engagement and motivation in participant children.

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