Music learning in preschool with mobile devices

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Abstract
Mobile and game-based learning are novel approaches characterised by the use of mobile devices and enabling learning anywhere and at any time. In this paper, we share an experience-based design and a pilot study to introduce music learning in preschool education. SAMI is a mobile application consisting of four games which main objectives are ear training, sound discrimination and music composition. The pilot study carried out in a real-life setting with third-year kindergarten children provides empirical data about music learning outcomes and compares an experimental group of children using SAMI with a control group which follows the traditional Montessori bells method. Our study results reveal a number of key findings for the design of preschool mobile games and the potential of using mobile technologies for music learning in early childhood.

Keywords
Children; Music education; Tablet; E-learning; Elementary school

1. Introduction

E-learning and the enabling learning technologies aim at making learning experiences in all types of settings more effective, efficient, attractive and accessible for learners (Koper and Van Es 2003). Technology-enhanced learning and mobile devices applied to the teaching-learning process have contributed to the rise of the mobile learning research field (O'Malley et al. 2005; Kukulska-Hulme 2005), and enabled the exploration of innovative educational scenarios based on access everywhere and at any time. Easy and affordable access to mobile devices and applications has favored the incorporation of mobile learning both into the classroom (Martin and Ertzberger 2013) as well as into informal and non-formal learning settings (Plowman et al. 2012). The motivation, interest and engagement aroused by mobile technologies at all educational levels, have enabled students to develop skills and abilities (Sotiriou and Bogner 2008; Martín-Gutiérrez et al. 2010; Liu, Tan, and Chu 2009; Klopfer 2008) that would not have been possible without the use of technology (Arvanitis et al. 2009).

At the same time, research literature (Bauer, Reese, and McAllister 2003; Savage 2007; Wise, Greenwood, and Davis 2011; Riley 2013), suggests that the didactics of music may greatly benefit from the use of the new learning and mobile technologies. Music learning is also an effective way to achieve broader educational benefits, as it goes hand in hand with other developmental learning processes. Recent advances in brain research have enhanced our understanding regarding the way in which active engagement in music influences the development of fundamental processes involved in learning, such as perceptual and language skills, literacy, numeracy, spatial reasoning, general attainment, creativity, social and physical performance (Hallam 2010).

The significance of early music education points to the importance of having children engage in musical experiences. Learning music in early childhood (Gordon and Browne 2013) is linked to experimentation, creativity and cognitive development. The basis of music listening, singing, playing, and improvisation is commonly incorporated in educational programmes and curricula in order to provide all-round quality education (Hargreaves, Marshall, and North 2003; Gimbert and Cristol 2004). One of the most direct effects (but not the only one) of early childhood music education is the acceleration of cognitive development in the domain of music-specific capabilities (Purwins et al. 2008).

A number of authors describe a methodology aimed at optimising the process of music teaching-learning. Several approaches suggest a gradual process based upon experiential knowledge, which in turn leads to learning the dimensions and combination of tones, rhythm, melody and harmony. Z. Kodály and E. Jaques-Dalcroze emphasise participatory knowledge-building and generation of musical imagery. Other classical approaches, such as those of Comenius, Rousseau, Froebel and Montessori, underline the impact of music on the child as a source of energy, emotions, play and creativity (Jorquera-Jaramillo 2004). Modern theories insist on tapping into children's spontaneity and curiosity to guide and promote music learning through play (Hallam 2010).

One particular area that has received increasing attention is game-based learning. It offers considerable potential for facilitating both informal and formal learning, as well as attracting digital-native generations of young learners (Arnab et al. 2012). Game-based learning remarks on the potential value of learning through play in education and skills training (M. Romero et al. 2012). Recent review studies have provided a deeper understanding on how games can support instruction (Wouters and van Oostendorp 2013) and learning outcomes (Akl et al. 2010). Games and mobile learning combine different types of channels and interaction. Music can be characterised by heterogeneous multimedia contents (Baratè, Bergomi, and Ludovico 2013). The use of computer graphics, colours and animations (Mitroo, Herman, and Badler 1979) can contribute to an increasing perception of music and identity construction through digital game play. Touch-based interaction can be used to train motor skills and spatial learning abilities. New information interfaces for musical expression (Parra-Damborenea 2014) provide learners with easily accessible music making experiences and enable collaborative music learning (Zhou, Duh, and Billinghurst 2008), allowing users to play together, see each other's gestures and more readily, understand the relationship between each player's actions and the sounds produced (Blaine and Fels 2003).

The incorporation of digital resources is reshaping the landscape of education. Music learning is changing very rapidly in many countries, as a result of a fast social and technological shift (Hargreaves, Marshall, and North 2003; Riley 2013). This shift has been addressed by the European Framework Programme (http://cordis.europa.eu/fp7/ict/telearn-digicult/telearn-projects-fp7_en.html). In the context of early childhood music education, MIRROR (Reflective Learning at Work) proposes a framework to promote specific cognitive abilities in the field of musical improvisation, both in formal and informal learning contexts.

1.1 Motivation and research questions

The effectiveness of using new technologies as teaching tools has been largely attributed to their potential to engage learners (Couse and Chen 2010). Technologies have been applied to the domain of music learning in a variety of ways and for a number of different purposes, including teaching concepts of music theory, or facilitating musical expression through ad-hoc hardware and software (Baratè, Bergomi, and Ludovico 2013; Zhou, Duh, and Billinghurst 2008; Burns 2006; Webster 2007). The emergence of mobile learning for early childhood music education (Annex 1) provides a large and exciting set of software applications. These apps provide digital resources for music learning, composition and improvisation with different musical instruments. However, one of the remaining challenges of mobile learning is determining what learning value students gain from it (Falloon 2013). In formal education, enabling mobile use and integrating mobile learning within the curriculum, makes it necessary to have specific and adapted educational apps to support teachers in their daily work; at all educational levels and for every student (Rose and Meyer 2002; National Council for Accreditation of Teacher Education 2008; International Society for Technology in Education (ISTE) 2014; Parikh 2012).

In Wu's meta-analysis (Wu et al. 2012), it is revealed that the use of mobile devices for learning is most common in higher education followed by elementary schools. In the case of early and preschool education, the variety of computer and mobile-based activities in the classroom at this age level, is narrower compared to primary and secondary students (Hinostroza, Labbe, and Matamala 2013). Moreover, it is particularly difficult to integrate children as users of this design process (Molin-Juustila et al. 2015). Children go to school for most of their days; there are existing power structures, biases, and assumptions among adults and children to get beyond. And children, especially young ones, find it difficult to verbalise their thoughts (Druin 2002). For all of these reasons, the development and testing of educational applications for preschool ages is cumbersome and the child's role in the design of new technology has historically been minimised.

Despite the significance of early music education as a driver for creativity, as well as cognitive and social development in children (Hallam 2010), and similarly to the situation in other countries (Savage 2007; McGregor 2013), music education is not part of any required curriculum for preschool children in Spain. Usually in kindergarten, music learning is based on children's songs, tapping a foot in time to a piece of music, clapping, dancing, etc. In this work, we report the results of an educational research project entitled "SAMI: Music learning in early childhood education with mobile devices", which has enabled the introduction of early music learning in a formal educational setting through the use of mobile technologies, and with the support of regional educational authorities (Research & Innovation Project. Principality of Asturias, 2013). SAMI (SAMI: Software para el Aprendizaje de la Música en Educación Infantil. Intellectual Property Registry 05/2014/128. Principality of Asturias, 2014) is a software for tablet computers made up of four games. It is a combination of a classical approach (impact of music on children as a source of play and creativity) and a learning-based approach (learning the dimensions and combinations of tones and harmony). It has been designed with and for children, taking into account inputs, indications and reflections made by children, teachers and experts in preschool education, who work with children on a daily basis.

Thus, the purpose of this study is to answer two research questions:

1. Is it possible to assist in musical note learning and auditory discrimination in early childhood formal education through mobile devices?
2. What is the impact of technology on music education for preschoolers?

We have first studied technological efficiency to help children to learn the pitch of musical notes using auditory and visual guidance. Then, we have examined effectiveness in keeping children motivated and interested in the musical discrimination learning activity. Finally, we have shown how children use technology and how tablets enable music learning in preschool education by means of interaction mini-games. To answer these questions, our research methodology is based on the comparison between a control group and an experimental group. The control group uses the traditional Montessori bells method (Figure 6) while the experimental group uses SAMI technology (Figure 1).

2. SAMI: Music learning for children using tablet-computers

Research in early childhood education indicates the benefits of using information technologies with preschool children (3-5 years old) in order to train different skills (Clements and Sarama 2003; Haugland 1999; Swaminathan and Wright 2003; Vernadakis et al. 2005). Traditional learning activities in preschool, such as drawing and writing (Couse and Chen 2010), may be actively supported by the use of tablets, which provide an adequate interaction and raise children's motivation, interest and engagement.

In (Egenfeldt-Nielsen 2006), the authors point out that the efforts to enhance the effectiveness of educational games are highly influenced by the particular learning context and by how teachers adopt a game to accommodate different needs and learning goals. SAMI is a mobile-based music learning game for preschoolers (3 to 5 years old), and the name of its mascot (see Figure 1). A multidisciplinary group made up of kindergarten teachers, experts in music and in the use of new technologies in the classroom, together with IT experts specialised in mobile software is involved in the development and deployment of SAMI. This way, both teachers and children take part in the design of the application interface, deciding and testing the position and size of the buttons for starting, changing game and level, success markers, sound and other auditory, visual and interaction details paramount for strengthening children's motivation and interest. The main purposes pursued are: to teach children how to identify the pitch of musical notes while playing; to introduce music to preschoolers in an interactive and friendly way using mobile devices; to integrate the innovative use of mobile technologies in the tasks carried out by educational institutions and to study the influence of new technologies on music learning.

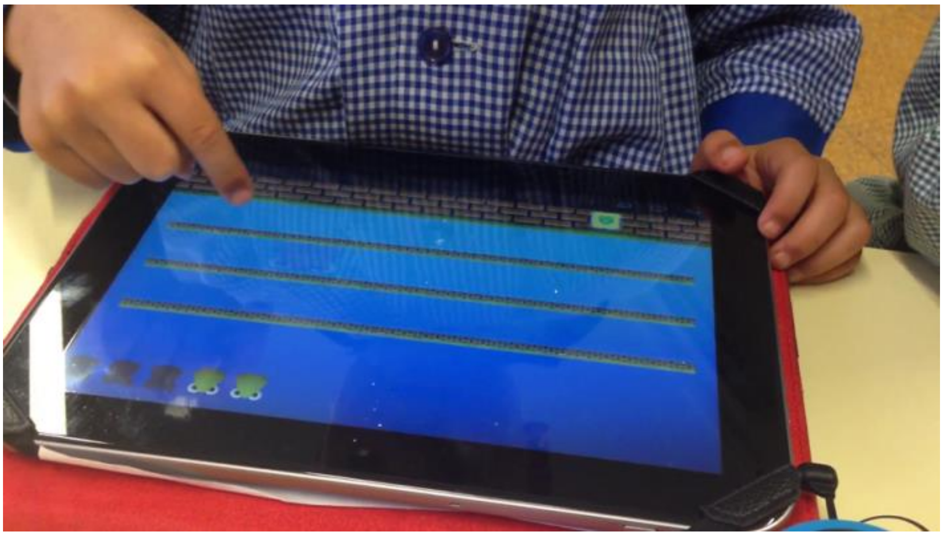

Figure 1. Children interacting with SAMI

2.1 Contents and competences

In the Spanish case, musical learning is not compulsory for 3 to 5 years old children in order to attend formal education. Rules do not specifically define the competences to be acquired during this educational stage as it only takes into account objectives based on the skills to be dealt with. Teachers understand "basic competences" as the implemented ability to integrate knowledge, skills and abilities to solve problems and situations in different contexts. Thus, when working with musical notes, teachers deal with:

1. Digital competence because we use mobile devices (tablets) and games (SAMI).
2. Mathematical competence because musical composition facilitates the creation and assimilation of mathematical patterns.
3. Cultural, creativity and artistic competence because SAMI gives children their first contact with music and the elements which are a part of it and, the most important feature, because they elaborate and share small compositions.
4. Social competence. Affinity for music, shared with peers and adults.

Music is a cross-sectional content which includes the main areas of knowledge of children´s education. This project specifically works within the field of music and the elements it has: seven musical notes and their sound discrimination, melody composition and visual memory as well as motor skill games related to music learning.

2.*2 Game design: SAMI*

The design of the 4 games used in SAMI takes the classical Montessori method as reference for the use of different colours, tuned according to the notes in the major diatonic scale. The four games carried out by children are designed to facilitate learning and encourage children's thinking and creativity. Children interact with SAMI, the mascot, in all four games, to carry out different activities:

- Game 1, "The notes with SAMI": The aim of this game is to begin educating their ear for music by suggesting children the following challenge: with a note specified at the beginning of each exercise, they should be able to find it out modifying another note until both sounds coincide. With this exercise, we want children to recognise the sounds identified with the different notes. We have used the seven standard notes "C" to "B", although it is more difficult to distinguish between "E" and "F", and "B" and "C", as there is only one semitone between those notes.
  In this game, interaction is based on a SAMI which appears in the middle of the screen with a different colour for each note and the name written on its "belly" (Figure 2). Each time you press big SAMI, a note will be played which must be recognised on the side bar where small SAMI moves vertically (up and down) producing different sounds and changing colour according to the sound. There are two levels in this game. The first level is the introduction, and each note is related to a colour. Children may identify colours with notes. In the second level, this relationship disappears. The target note must be found only according to the sound, thus showing sound discrimination.

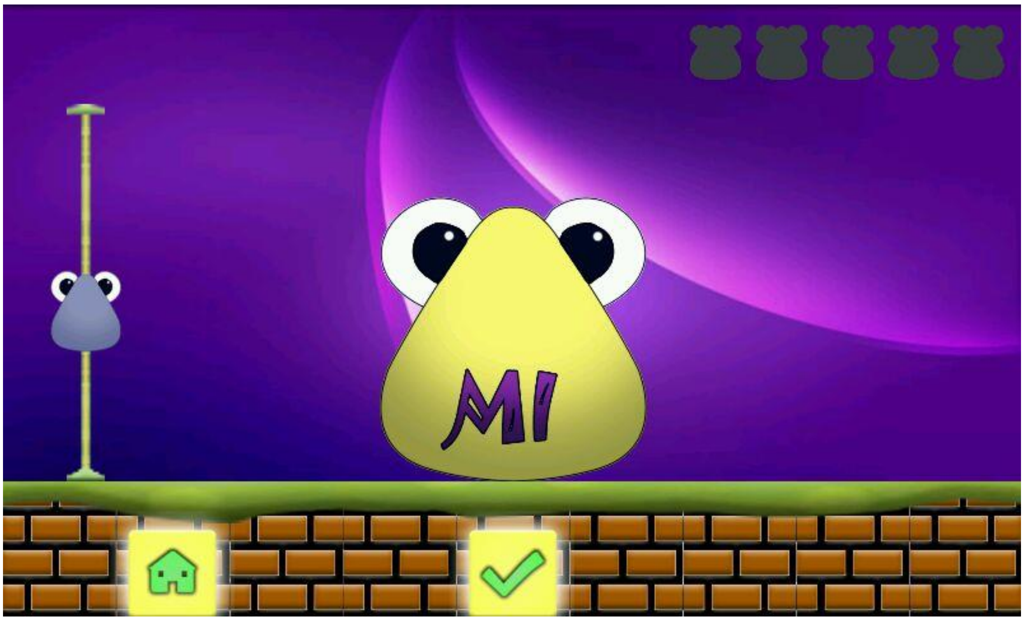

Figure 2. Game 1: "The notes with SAMI"

- Game 2, "SAMI says": The second game is a memory exercise in which there is a sequence of SAMIs. Children should repeat it in the same order (Figure 3). As levels are completed, more SAMIs appear, creating a sequence of 3, 4 and finally, 5 notes. The relationship of this exercise to music learning lies in the sounds that SAMIs produce as they are of a major chord. The possibility to choose major chords is based on the fact that these are lively sounds and they are used in all the lullabies or children's songs.

Figure 3. Game 2: "SAMI says"

The game has three levels. In the first level, there is a sequence of three SAMIs, which are the tonic chord, the third major chord and the dominant of a major chord. In the second level, a fourth SAMI –the subdominant note of the major chord– is introduced into the sequence, thus increasing its level of difficulty while maintaining harmony. In the last level, a fifth SAMI –the octave of the given chord– is used, making it the most difficult level.

- Game 3, "Catch SAMI": The goal in this game is developing fine-motor skills, required to play any instrument. Moreover, the underlying musical concept dealt with in this third game is the staff. The game shows three lines as background in the exercise and SAMIs appear in their corresponding places according to the note they represent (Figure 4). They appear during a short period of time and then, disappear. Children must press on them before they disappear. The aim is for children to understand that if the note is higher on the staff, a high-pitched sound will be heard loudly. It will be just the opposite for the lower notes.

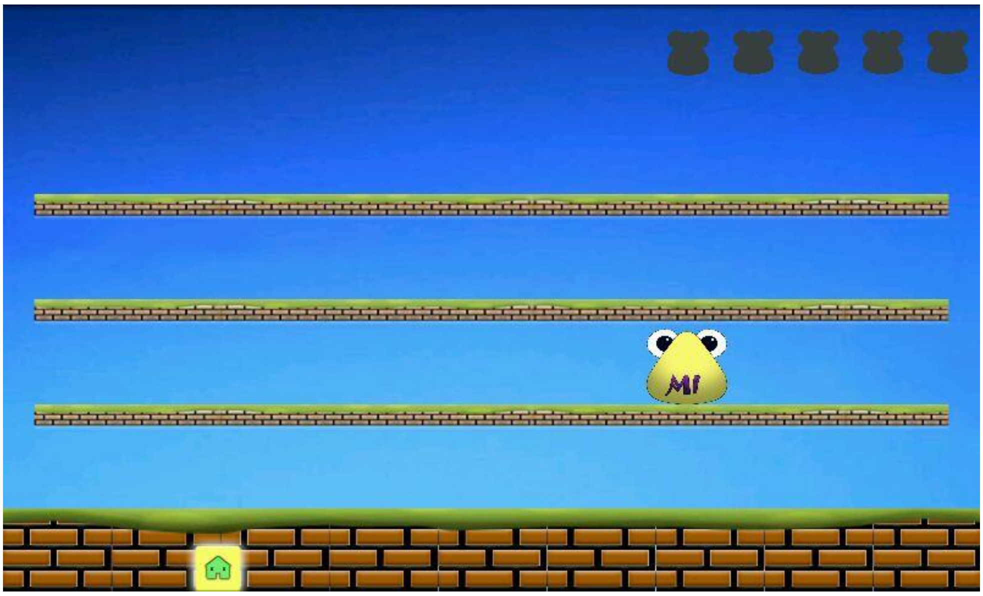

Figure 4. Game 3: "Catch SAMI"

- Game 4, "Compose with SAMI": The last game combines all the concepts of the previous activities so that children may create a free musical composition (Figure 5). The game shows 16 SAMIs which, when dragged and moved vertically, modify the musical note in the staff lines. Children use the same procedure as in the first exercise to modify the note. They implement the concept of harmony since, in the second exercise, they work with major chords. And they work with the staff concept of the third exercise because the higher a SAMI is placed, the higher the sound will be heard and vice versa. There are no levels of difficulty and the only purpose of this game is to encourage children's creativity with a simple tool with which they may prepare their first compositions.

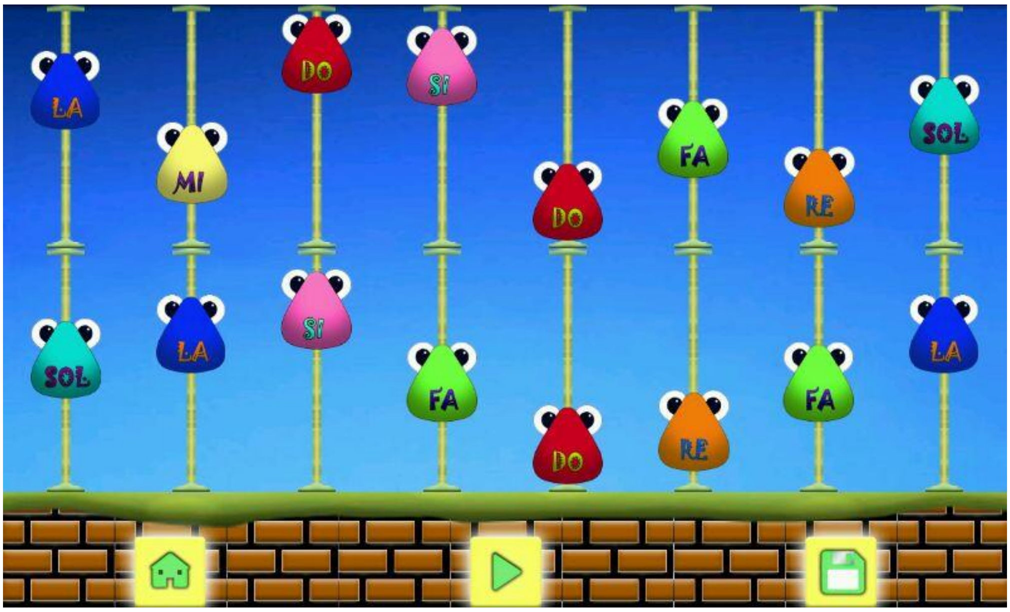

Figure 5. Game 4: "Compose with SAMI"

Each time children overtake a level in each of the first three games, a reward appears. Besides, if any of the tasks of the games is not correctly achieved, SAMI will indicate children they have not done it properly by making a different sound. And they shall try again.

3. Method

This study uses a mixed research method. We collect both quantitative and qualitative data to assess our research goals. Each child constitutes analysis unit. In the experimental group, we use tablets to quantitatively collect, for each child, the number of right and wrong answers from Game 1 "The notes with SAMI", in different sessions. These data are stored in interaction files (logs) together with the actions carried out by each child and in each game level. In the control group (Montessori bells), an assistant present during the class helps assessing the children's performance level during games by direct observation.

Such data give us the possibility to carry out a statistical analysis to assess the impact of technology, to know if it is possible to assist in musical note teaching-learning and to identify auditory discrimination using SAMI. T-test of independent samples and Levene's test analyses are run to observe if there are differences between the groups. In addition, to determine statistical significance, we estimate Cohen's d and effect-size r values. To interpret the effect size, we use the traditional criteria established in 1988 by Cohen (Cohen 1988). Also, we have obtained the corresponding frequency distributions for the experimental group in order to determine the number of children who have completed each level and test if the content sequencing between levels is adequate. Statistical analysis is carried out with R software (R Development Core Team 2012), 2.15 version. Quantitative data are collected in meetings held with teachers and students in which, by means of their experiences with the Montessori bells and the SAMI application, we could learn more about the process of using a game-based app on a tablet-computer in a preschool setting.

3.1 Subjects

The experimental group is made up of 43 third-year kindergarten children (mean = 5.6 years old), enrolled in 1 classroom which is taking part in this study (Table 1). The control group has 43 children on the same educational level as the experimental group, and who are about 4.7 years old and enrolled in 1 classroom which is taking part in this study (Table 2). All children, from a middle and low social background, attend a public school in northwest Spain. The school is equipped with new technologies; there are computers connected to the Internet and a projector in all the classrooms. There is also a dedicated new-technology classroom and, since 2013, there are 9 Android tablets available. All the children had used tablets in their previous school year with different educational applications. They had also come into contact with music informally in the past, i. e. music on the radio, TV and in extra-curricular activities at school. Parents were asked for permission in order to carry out the activity and 100% of them gave their consent.

Table 1. Demographic information for the experimental group

Age Group	N	Gender	
		M	F
5 years old	17	10	7
6 years old	26	11	15

Table 2. Demographic information for the control group

Age Group	N	Gender	
		M	F
4 years old	12	5	7
5 years old	31	17	14

3.2 Procedure

Experimental Group. Children divided into groups of 5 were invited to use a tablet in a quiet room outside the classroom with child-sized tables and chairs. They were already familiar with this room and used it frequently with teachers for small-group tasks. Children used our mobile application, SAMI, over 5 sessions in their weekly 2-hour long "new technologies" lesson, in the second quarter of the 2014-2015 school year.

Data collection was carried out in 4 phases which are summarised below:

Phase 1. Introductory and warm-up sessions. During the first session, the purpose is for children to get familiar with SAMI, the mascot. They have to observe how it moves and sings to each note. For this purpose, children begin with Game 2: "SAMI says" and then, Game 3: "Catch SAMI". Their teacher begins working on contents and competences with Game 4: "Compose music with SAMI". They sing the musical scale and they continue with the task using the tablet. Each student has to compose a musical piece by moving SAMIs along the intonation line and then, they hear it by pressing the play button. If they do not like it, they may modify it, listen to it again and finally save it to share it afterwards.

Once children have become familiar with SAMI, they proceed to Game 1: "Notes with SAMI", which focuses on learning aims. In level 1 of this game, each note is associated with a colour. There is a scoreboard which is completed as children give the right answer or else, a different sound will be played if their answer is wrong. This scoreboard is a good guidance for children self-assessment regarding this task. When 5 right answers are given, the child gets a reward.

Phase 2. In level 2, sound discrimination is necessary because the note-colour association is removed. In this level, the development of sound discrimination can be observed as well as different behaviours used by some children. Children play in level 2 on different days during 4 class sessions.

Phase 3: Interviews with children. We conducted interviews with children in the same room where they had played with SAMI. For such interviews, we used a semi-structured format asking them which was their favourite game, the one they liked the least and their perception of learning (Annex 2). To ensure that children's event trace memory of SAMI had decayed but that some aspects of the game events remained, we conducted these delayed memory recall interviews 3-to-4 weeks after stage 2 had finished. To guarantee inside validity, children did not have any other contact with SAMI at school for one month. In order to encourage children to say what they remembered, we asked them to play with SAMI again and to tell us how they played with Game 1: "The notes with SAMI" and Game 4: "Compose with SAMI". We wrote down everything they told us and for each question included in the assessment page (Annex 2) we asked them to circle their choices with a marker.

Phase 4: Interview with the teacher. We interviewed the teacher for 2 hours following a semi-structured interview format. We asked her about her opinion regarding the knowledge acquired by children from the games and about the children's interest towards SAMI. Besides, they also replied questions about tablet use and options for their class.

Control Group. Children were divided into groups of 20 and asked to play and perform music activities individually. We followed the traditional Montessori method for music learning, using seven coloured bells, where each bell/colour represents a different note in a musical scale (Figure 6). Children had already had some non-formal contact with the bells during the previous school year. Observations were carried out in their usual classroom, in a setting that was familiar to them over their weekly 2-hour long technology lesson, for a term of 5 weeks in the first quarter of the 2015-2016 school year.

Observations and data collection were carried out in 4 phases summarised below:

Phase 1. Exploration. The purpose of the first session is to allow children to familiarise themselves again with the Montessori bells. Their teacher plays all seven different notes with the bells and invites children to make musical compositions with various bells. Their teacher names the note being played and immediately asks children to play the corresponding bell. Their teacher then proposes discriminating particular notes. In this first stage, children use note/colour association to guess the sound associated to a bell.

Phase 2. In phase 2, their teacher plays a musical note but children do not see the bells. When children are asked to play the same note, they must necessarily discriminate the sound. Their teacher makes sure children receive a positive feedback at all times, whether they succeed or fail to play a note. If they succeed with 10 notes, there is a reward: playing with soap bubbles. If they fail any given note, their teacher will encourage them to continue trying until they succeed in producing such musical note. As in the experimental group, children directly touch the bell they consider is the correct one and in case of doubt, they are allowed to try again.

Phase 3: Interviews with children. In this case, we interviewed children and studied their views about using the coloured bells to learn musical notes. We used the same methodology and format as in the control group. To conduct the interviews, we returned 2 weeks later to their ordinary classroom. In order to guarantee its validity, during these two weeks after the test was already finished, bells had not been used. We encouraged their participation by allowing them to make compositions and play to guess the right note. We then asked them if they consider that the game with the bells is difficult or not and why, if they like it or not and why and if they like to be observed while playing.

Phase 4. Interview with the teacher. The same procedure as explained for the experimental studies was used for the control group. We interviewed the teacher during 2 hours using a semi-structured interview format. In this case, we asked her about the use of the Montessori bells and encouraged her to share details of her experience and provide educational insights and views about phases 1 and 2. At the same time, we asked her specifically about the interest and motivation different games aroused in children.

Figure 6: A girl from the control group playing with the bells

4. Results

4.1 Musical Note Learning and Auditory Discrimination

Experimental Group. Children's interactions with SAMI are recorded in log files. Based on the actions carried out by children with the games, we review the right and wrong answers for each of them. In the following section, we will focus on the results obtained for Game 1: "The notes with Sami". This game allows us to analyse results for sound discrimination when children learn 7 musical notes.

Table 3: Descriptive statistics of Game 1: "The notes with SAMI" for the experimental group

		Mean ($\overline{x}$)	Median	Standard Deviation (σ)	N (Sample Size)	Max.	Min.
Level 1	Right	4.89	5	0.68	35	5	1
	Wrong	1	0	1.7		8	0
Level 2	Right	9.88	10	0.76	43	10	5
	Wrong	3.33	2	3.93		15	0

The statistical methodology used is based on a descriptive analysis of the number of right and wrong answers for each level, yielding results such as mean, median or standard deviation (Table 3). In level 1, we have 35 valid cases, as there is a 25.53% rate of lost cases at this level. Attendance reports show children absent from this class when they are ill as being unable to complete the session. In level 2 of Game 1, we have 43 valid cases, as there is a 0.0% rate of lost cases at this level.

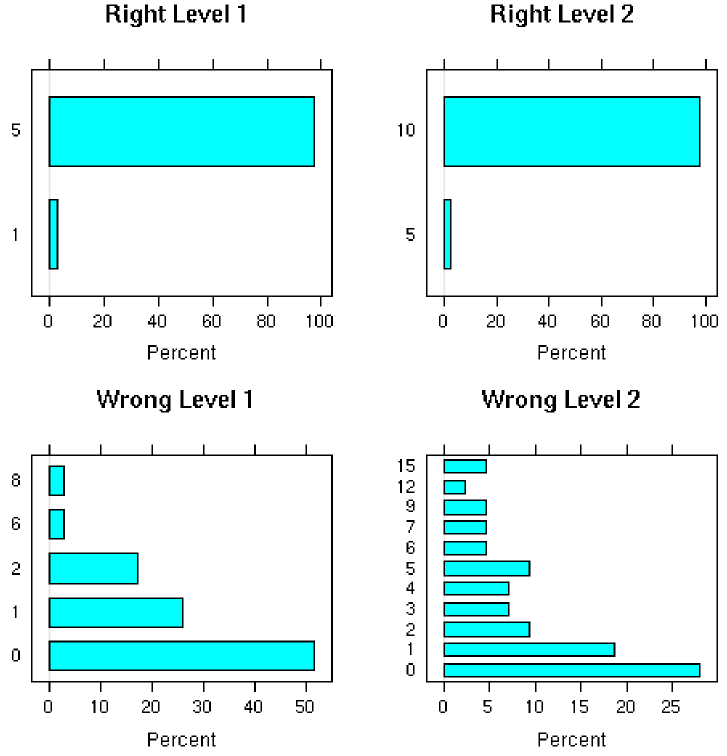

Figure 7. Frequency percentages (right and wrong answers) in Game 1: “The notes with SAMI”

Frequency distribution determines that the number of children who have completed level 1 and level 2 of Game 1, “The notes with SAMI”, is about 100% (Figure 7). Friedman’s test (p-value < .01) shows a significant difference when comparing the marks of the first and the third from the last session of level 2 for each child. Although there are methods that enable post-hoc tests (similar to Kruskal-Wallis’s post-hoc test), the power is such that obtaining significance is highly unlikely. The best strategy is to create a boxplot with the data (Gardener 2012). Figure 8 shows that the lowest marks in the first session are lower than those obtained in the last session, as their values are higher. In both sessions, there are children who get the highest mark, i.e. 10. In the first session, distribution is symmetrically done; in the last session, this effect is not observed. In the last session, average marks reach higher levels. They are near the maximum mark of 10 and there are more children with average marks.

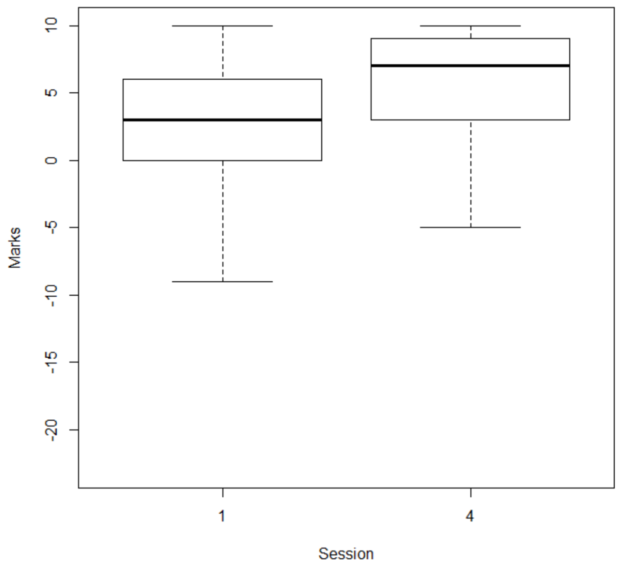

Figure 8. Boxplot comparing marks between the first and the third from the last sessions of level 2 for the experimental group.

Control group. An assistant uses a spreadsheet to mark the right and wrong answers given by each child trying to discriminate the sounds with the bells in each session. In the following section we focus on the results obtained for the game in phase 2 during which the child cannot see the bells and, therefore, cannot make the note-colour association. This game allows us to analyse results for sound discrimination when children learn 7 musical notes.

As in the case of the experimental group, we have carried out a descriptive analysis of the number of right and wrong answers, supplying summary results as mean, average or standard deviation (Table 4). For phase 2, we have 41 valid cases, and two lost cases.

Attendance reports specify that both children were ill and they could not complete the sessions.

Finally, Friedman's test (p-value =0.01) shows significant differences regarding the marks in the first and the last session of phase 2 for each child. The related boxplot (Figure 9) shows a difference in the marks regarding the first and the last sessions, as the marks in the last session are higher than those in the first one.

Table 4: Descriptive statistics for the control group

		Mean ($\bar{x}$)	Median	Standard Deviation (σ)	N (Sample Size)	Max.	Min.
Level 2	Right	9.5	10	2.13	43	10	10
	Wrong	17.86	16	10.44		44	2

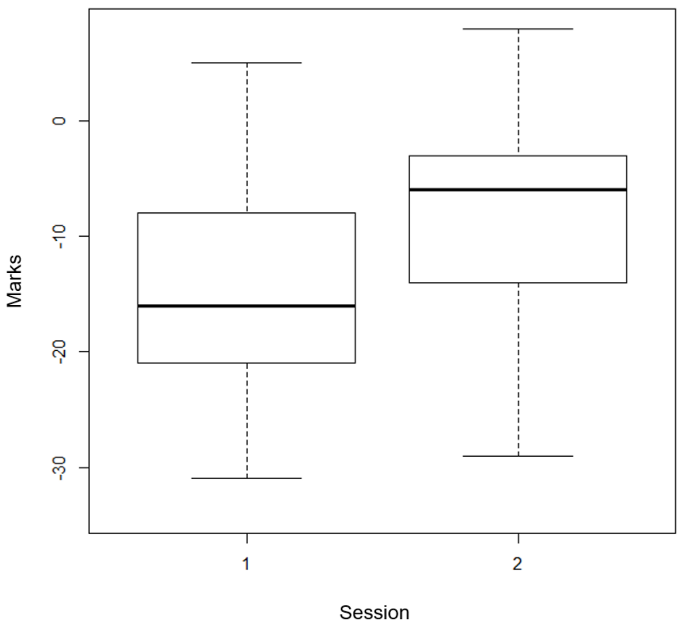

Figure 9. Boxplot comparing marks between the first and last sessions of phase 2 for the control group.

Control Group vs Experimental Group. Comparison between the control group and the experimental group is based on tests for comparing means and variances. The t-test for independent samples (p-value< .001) shows that the average marks for both samples are different. Levene test for the variance comparison (p-value< .001) demonstrates that there are some variations in the marks of the control group and those of the experimental group. The effect size calculated for the marks and the one obtained by Cohens, d value (= 1.9) and effect-size r (= 0.7), show that it is a long effect. In order to express the different marks between the control group and the experimental group in a clearer way, we have created a boxplot with the marks of both groups in the last session (Figure 10).

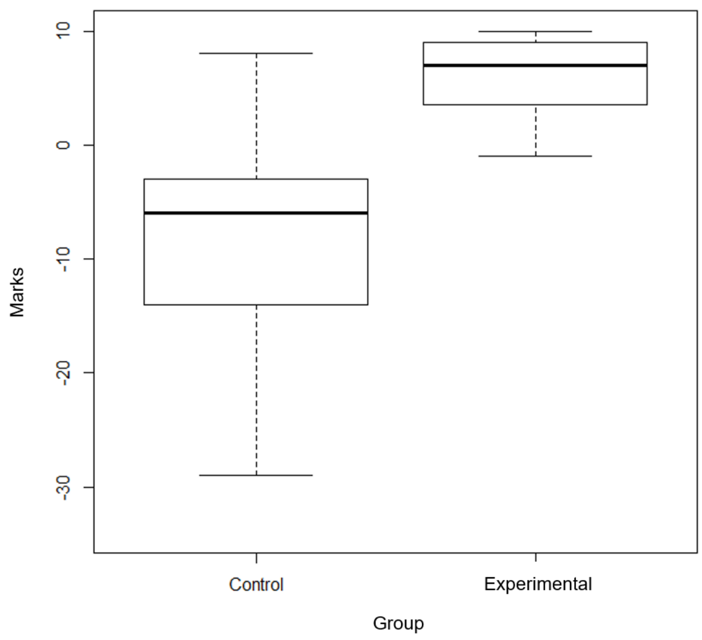

Figure 10: Boxplot comparing the marks obtained in the last session by the control and experimental groups

4.2 Children's interest and motivation

Experimental Group. The analysis of the interviews with children (Figures 11 and 12) shows that the majority of the children prefer Game 4: "Compose with SAMI", where they may compose a melody freely, save the composition to share it with others, play said composition and even change it if they do not like it. The game they like the most and the most interesting one for them is the one which encourages their creativity, as shown in this video: https://youtu.be/R7Y27eDdGNg. The games they like the least are Game 2: "SAMI says" and Game 3: "Catch SAMI". As for Game 2 –repeating a sequence of notes, which is more and more difficult each time– they think that "sometimes it is very difficult to win". And talking about Game 3, children think that "sometimes I catch it and sometimes I do not", "it goes too quickly", "it is highly boring and it is always the same" and "you have to touch it and it takes you too much time to get the reward".

In the interview with their teacher, she gave us qualitative descriptions about the evident interest and the feasibility of using the tablet as a tool in an early education setting. In addition, she realised that children were highly interested in using this new technology. With reference to the games offered by SAMI, among the different opinions expressed by teacher, we would like to distinguish the following ones: "I really like the SAMI app, especially Game 4 in which children may express musically promoting creativity and sharing musical ideas". "Game 1 has been quite a difficult challenge but surprisingly, they have all liked it. It is obvious that children do not like easy things".

When we asked her if children were excited because it was a new activity outside the ordinary classroom, their teacher replied the following:

“Children wanted to play with SAMI. They stroke the mascot and they asked to attend the classes: “Can I go now? Can I go now?” Nevertheless, children know that when they use computers or tablets, the activity will always take place in a classroom different from the ordinary one. Besides, these children are accustomed to using educational apps, because in the past, we used them in class. Therefore, I do not believe that the fact of being a new activity has influenced on the interest they have towards SAMI”.

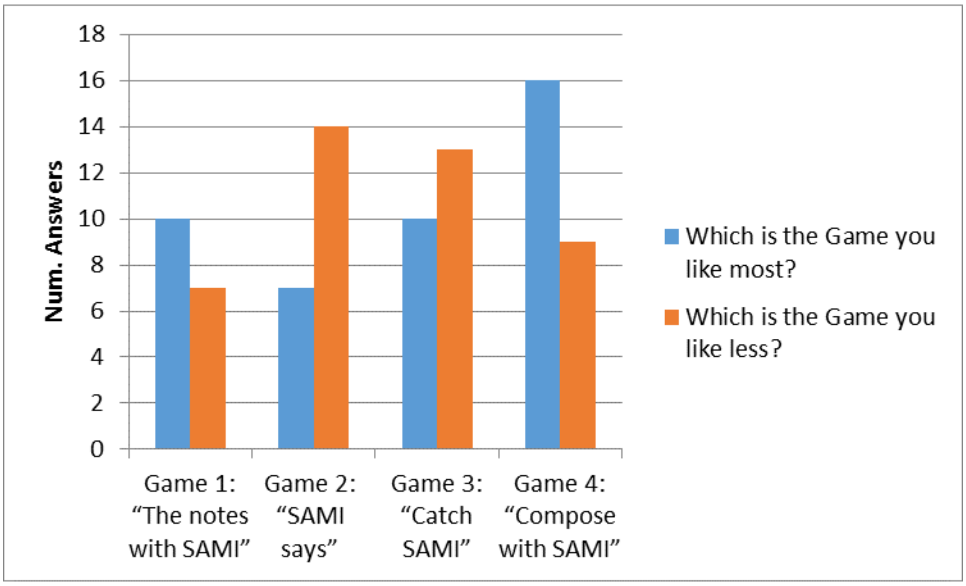

Figure 11. Children perceived learning benefits (I)

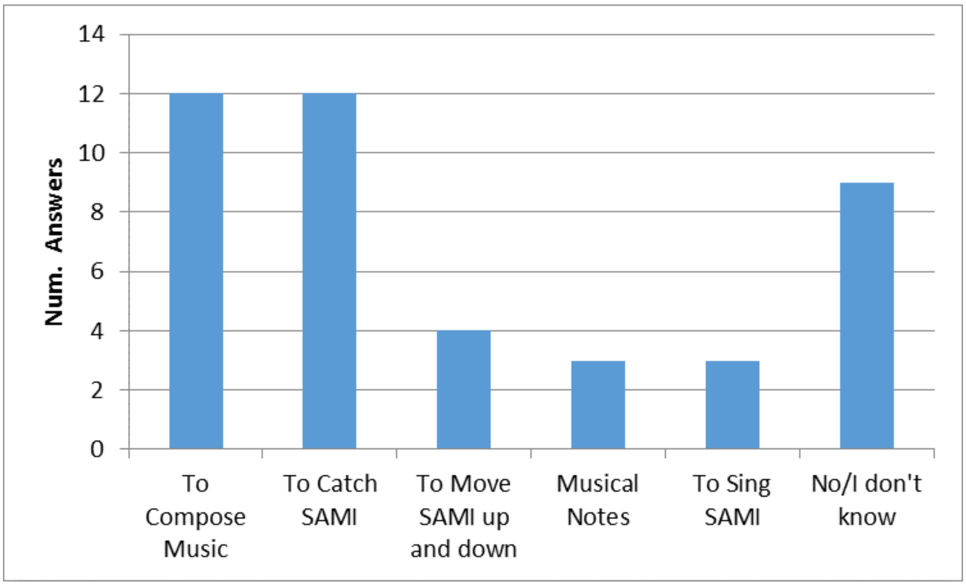

Figure 12. Children perceived learning benefits (II)

Control Group. Analysis of the interviews with children (Figure 13) shows that all children enjoy the bell game, 82% do not find the game difficult and that they all like to be observed while playing. The interview and the survey have been done with 91.5% of the children. In the interviews with children, they told us the reasons for their replies in the survey. Thus, we know that they like the game because it is easy, enjoyable, they always have some correct notes and because they may blow soap bubbles. They like the bells, as a game element, because they have colours, they make noise and they are fully heard. They like to be observed while playing, especially by their teacher because thus, "they do not get lost", because "she is nice" and because as a reward she lets them play with bubbles.

In the interview with the teacher, she gave us qualitative descriptions about the interest of using bells with different colours in early educational settings. Their teacher realizes that the game with bells is not easy. Children are both motivated and interested in playing and they ask her to choose them to play. She believes that such interest and motivation are, partially, due to the prize of "playing with bubbles at the end". When we ask her if it is because it is something new, she thinks that this is not the reason because "children had already used bells during the previous school year to make compositions". She believes that the procedure for data collection "is highly complicated for being carried out by only one teacher; the best alternative is that one teacher carries out the procedure and another auxiliary teacher writes down the comments". Besides, it is necessary for this game to have one person indicating which one is the correct note and therefore, "autonomous learning is not possible".

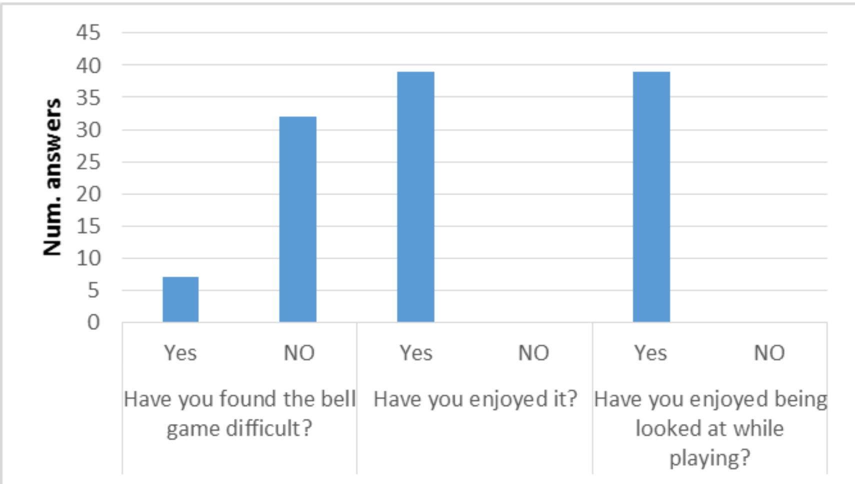

Figure 13. Results of the interview with children

5. Discussion and result interpretation

The results of the Friedman test for both groups indicate a progression in the scores along sessions. This progression is significant, for the experimental group between the first and the next to last session, and for the control group, from the first until the last session. The analysis of means and variances between the control and experimental groups yields a significant difference in marks, showing a large effect size. This result points out a significant effect on children using SAMI technology in comparison with those using the traditional coloured bells learning method. Surveys and interviews with children show evidence on the positive effect of technology on children's motivation and interest in the experimental group. These results are in line with previous findings and teachers' perceptions, i.e. in Couse and Chen (2010) the authors have found a high level of interest of preschoolers using tablets for daily educational activities like drawing.

In relation to the learning of musical notes, in Baratè, Bergomi and Ludovico (2013), the authors state that serious games can be applied to music education for a number of different purposes. In their study, Baraté and colleagues consider that a fundamental task of the serious game consists in preparing users to recognise notes in any key, which is "one of the most boring aims a student of music has to reach in any basic level music course". The results of our investigation are consistent with these observations; learning games fosters effective learning of musical notes, and we give a step forward, highlighting also the importance of learning games for children's creativity. Through the survey and interview with their teacher, we have observed how SAMI's game 4: "Compose with SAMI", encourages and enables creativity, allowing children to create and share their free music compositions. Educational apps can also encourage and enable children's creativity in other areas, as asserted in a study that assesses an app for the development of children's story-telling (Jerry Alan Fails, Druin, and Guha 2010).

The relevance of content design and appliance with which children can interact when they perform a task with a mobile device has been reflected in a number of studies in the field of Human Computer Interaction (HCI) (J.A. Fails, Druin, and Guha 2014; Falloon 2013). In the particular case of content design for auditory discrimination, the results of this study reinforce the importance of including in the activity sequencing tasks with a progressive level of difficulty. Both for the control and the experimental group, the preliminary stage –in which children learn the note-colour association– allows reaching the next stage with a similar knowledge. In the experimental group, the descriptive statistics in Table 3 and the frequency analysis of the game (Figure. 7) show a very high number of correct answers and students have only a few wrong answers. This statistical analysis allows us to state that the first stage of note-colour association is adequate and suitable to introduce the pitch of musical notes. In level 2 of the game, we have observed how students have also completed the level (obtained 10 points), but they have made more mistakes in the process if compared to level 1. This is a rather logical fact because, in the second level, students have no note-colour association and they need to make a correct sound discrimination of 10 musical notes to complete it. Another highlight of the results for content design is the requirement for introducing motivating elements, such as a reward, i.e. for the experimental group, on-screen scoreboards and confetti, or a character such as SAMI. Having a character is in line with previous findings stating that the emotional attachment of humans towards meaningful characters or mascots can be used to motivate children to learn in a digital classroom environment (Lauricella, Gola, and Calvert 2011; Chen et al. 2007) . In our study, teachers have mentioned during interviews that children stroke SAMI. In the control group, interviews and surveys have shown us that the reward, i.e. making soap bubbles, produces an extrinsic motivation for the child. Children consider that their teacher gives them some support during the game, apart from always receiving a positive feedback, as she encourages them to finish the game and gives them a prize at the end –blowing soap bubbles.

Regarding the devices used, one of the bases of Montessori method (Montessori 1912) says that students learn concepts from working with materials, rather than by direct instruction. For the children in the control group, Montessori bells are a direct interaction element which produces noise and may be properly heard. This is the reason why they like them. In the case of SAMI technology, the lateral intonation bar where children place the notes is based on the Kodály Method (Jacobi 2011). This vertical intonation line gives children the possibility to relate the deepest notes to the lowest positions in the bar, and the highest notes to the highest positions. This is not possible when the bells are on a table, as such distribution follows the Western reading pattern, from left to right, and it follows the position of the notes on a piano or metallophone. The association of the height in the intonation line with the high or deep sound level yields, as a result, better marks in the experimental group than in the control group (Figure 10). Children from the experimental group carry out fewer attempts to give the correct note while in the control group they have to make more attempts and, therefore, more mistakes before they find the correct note.

Finally, the use of the mobile SAMI technology is a benefit for autonomous learning, which is not possible with the traditional bell method. The bell game demands the teacher's attention towards children while playing, in order to tell them if they have chosen the correct note or not. Surveys in the control group show that children like to be observed while playing and they feel neither pressure nor distress.

5.1 Study limitations

In this study we present and describe the results of music learning in preschool through the use of our mobile app, SAMI, specifically designed for this purpose. We also investigate the effectiveness in instruction by comparing the results of a control group (n=43) that follows a traditional Montessori method and an experimental group (n=43) that uses SAMI. A few limitations of this study deserve consideration. While our findings are consistent with previous studies on the use of mobile technologies in education (See section 1), they also point to the need of further research to determine the influence of educational and contextual factors in the results. The use of classification algorithms (C. Romero et al. 2008), such as regression models based on age, gender, psychological and educational factors, could contribute to reveal relevant aspects about how children interact with technology. At the same time the identification of cognitive, emotional and behavioural responses could help to improve the design of educational apps and enhance the appeal of technology. The appeal of technology has proven its relevance in previous studies (Yu et al. 2012; Wake 2012) and it can be considered a variable within the study of interest and motivational aspects of mobile learning.

6. Conclusions and future work

The focus of this paper contributes to supporting musical education as a school curriculum area that seems to be overlooked in most innovations for teaching and learning. "SAMI: Music learning in early childhood education with mobile devices" is a pioneer project that has enabled the introduction of music learning in preschool and has been awarded a prize by the Council of Education of the Principality of Asturias in Spain. This work shows that technology can provide conditions for music learning that, otherwise, would be very difficult to create for instance, by allowing individual interaction and autonomous learning on mobile devices, and providing audio materials for sound discrimination and tone identification.

This study explored the viability of mobile devices, in particular tablets, for music learning in early childhood education. SAMI is an educational game that facilitates development of sound discrimination as well as identification of sounds and notes in an octave of the musical scale. SAMI has been used with pre-schoolers in a real learning context. Children felt comfortable playing with the games offered by SAMI, and they improvised musical compositions they then shared with their classmates.

The comparison between a control group and an experimental group has given us significant results regarding the effect of technologies on children. Interviews show the motivation and interest elements present in the use of SAMI technology. Statistical analysis of data collected for both groups gives us the possibility to recognise some of the necessary items for a suitable design in kindergarten mobile learning. In an educational app, the contents, navigation and elements with which children interact need to be adapted to the specific subject of study. Content browsing should be based on learning sequences and widgets ought to be user-friendly, as it is the case with the lateral intonation bar where children place the notes. This design also facilitates young children's understanding of the relationship between the "height" of a note and the sound tone. The interfaces with which children interact must include colours and elements that stimulate children's creativity and extrinsic motivation –such as meaningful characters or mascots–, scoreboards and on-screen rewards –such as smiley faces and confetti as it happens on SAMI– or tangible rewards –like playing with soap bubbles in the case of the control group. In addition, the different behaviour profiles found show the need to adapt the learning syllabus to children's needs and characteristics.

The results from this study contribute to the design and evaluation of mobile games for children in formal, informal and non-formal settings. Further studies in different educational contexts and an increased sample size would be necessary to verify these findings and allow to extrapolate and generalise the results. Additionally, we suggest the following lines for future work: A suitable learning design in the applications of mobile learning must be accompanied by a multidisciplinary team with experience in pedagogy and technology, which can take a coordinated approach for developing an educational syllabus adapted to children's specific characteristics and needs. Automated log analysis in educational apps can facilitate capturing children's interaction, real-time interpretation and intervention. In this context, the use of learning analytics in mobile learning applications may lead to the identification of opportunities and improvements in teaching and learning processes.

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ANNEX 1: Music Learning Apps

Bubble Music; Identifying musical instruments by sight and sound, learning the sounds of musical notes, and writing music.

Dubstep Drum Pads; App for composing beats and music with the fingers.

Fun with notes; Learning the musical notes, sounds, positions on the staff and on the keyboard.

Kids Make Music Lite; Making music compositions with different instruments.

Kids games piano; App focused on recognising different keys of the piano

Kids Piano; Playing and singing popular melodies with a piano.

Little musical loops; Creating small musical loops using a guitar or piano and change the tempo.

Melodyline; App for creating melodies.

Music Tales-Kids Learn Notes; This app works with the pitch, musical notes and knowledge about musical instruments.

Note teacher; App designed to help learning musical notes

Note Trainer Learn Piano; App aimed at recognising musical notes.

Piano Lessons; Learning how to play piano

Prelude Composer; Making music compositions.

Sound Toy mix; A visual music composer

Vibrafun; It shows how to play several popular songs on the vibraphone, marimba or xylophone. In addition it is possible to record, save and load recordings.

Xylophone for children; Learning and recording songs using different musical instruments: xylophone, wind, strings, choirs, etc.

Xylophone Master; Songwriting with xylophone.

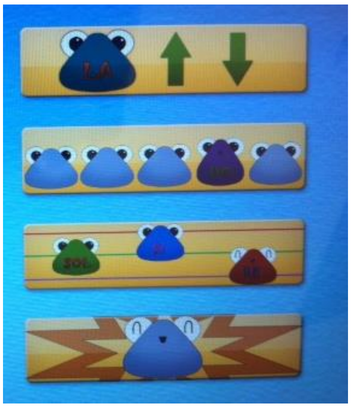
123Kids Fun Music; Learning the sound of instruments such as xylophones, drums, guitars, trumpets, flutes, bells, etc.

ANNEX 2: Children's questionnaire

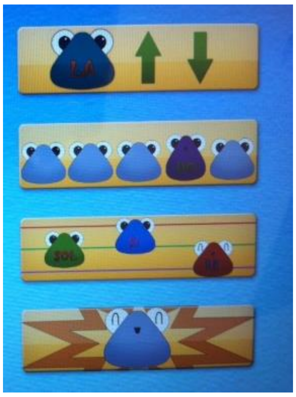
NAME:

COURSE:

Which is the game you like the most?



Which is the game you like the least?



Have you learnt anything?

TO COMPOSE MUSIC

TO CATCH SAMI
TO MOVE SAMI UP AND DOWN
MUSICAL NOTES
TO SING WITH SAMI
NO/I DON'T KNOW

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