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Mobile learning technology based on iOS devices to support students with special education needs

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ABSTRACT

Students with special education have difficulties to develop cognitive abilities and acquire new knowledge. They could also need to improve their behavior, communication and relationships with their environment. The development of customizable and adaptable applications tailored to them provides many benefits as it helps mold the learning process to different cognitive, sensorial or mobility impairments. We have devised a mobile platform (based on iPad and iPod touch devices), called *Picaa* and designed to cover the main phases of the learning process: preparation, use and evaluation. It includes four kinds of educational activities (Exploration, Association, Puzzle and Sorting), which can be personalized by educators at content and user interface levels through a design mainly centered on student requirements, whose user profiles can also be adapted. We have performed a pre-experimental study about the use of *Picaa* by 39 students with special education needs from Spain, including an evaluation based on pre/post testing. The use of the learning platform *Picaa* is associated with positive effects in the development of learning skills for children who have special educational needs, observing that the basic skills (language, math, environmental awareness, autonomy and social) have been improved. Besides, in many cases they have the opportunity to perform activities that previously were not accessible to them, because of the interface and contents of the activities have been adapted specifically to them. The study also suggests that the repertoire of types of activities provided is suitable for learning purposes with students with impairments. Finally, the use of electronic devices and multimedia contents increases their interest in learning and attention.

1. Introduction

Students with special education needs exhibit difficulties in learning due to cognitive, physical and sensorial disabilities. They are characterized by their heterogeneity. One of the main objectives in the classroom must be to improve the behavior of such students and their relationships with their environment. But at the same time they must learn to perform daily activities autonomously, improve their communication, develop cognitive abilities and acquire new knowledge.

Regarding communication, users need communication strategies that allow them to convey emotions and feelings, and request objects or activities. To do this, alternative communication systems based on interaction with pictograms or pictures are typically used (Mirenda, 2003).

In terms of cognitive disability, the main difficulties of these students are perception, memorization and attention (Barkley, Cross, & Major, 2005). Learning activities can help to improve these aspects. Activities that are used in special education are the same as those

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used in early elementary school level, or a variation of them. Adaptation of learning activities is necessary in this context because the students often have many different syndromes and pathologies (autism, Asperger's syndrome, Down syndrome, etc.), and varying abilities and skills. Their work rhythm and learning needs are also different. Therefore, individualization in the learning process is necessary.

It is essential to help people with special education needs to achieve greater autonomy so that they can independently perform day-to-day activities. Dependency generates high social and economic costs, and at the same time it generates self-neglect, disinterest and isolation of the individual. Technical aids and software adaptations enable people with special education needs to move, travel, undertake activities, have fun and learn without having to depend on other people.

This is all more so the case in an educational environment, where activities should encourage students to develop skills and acquire knowledge that will be useful during their entire life.

In this scenario, the development of customizable and adaptable applications tailored to users with special education needs brings many benefits as it helps mold the learning process to different cognitive, sensorial or mobility impairments. Therefore, the design of this kind of application must take into account non-functional requirements (Chung & do Prado Leite, 2009), such as:

- Usability/accessibility, designing easy-to-use applications, ensuring that users can interact with them and understanding both the tasks to be accomplished, and also the response of the system. Special emphasis needs to be placed on students' cognitive and sensorial functional diversity and on promoting approaches to intuitive interaction such as touch or voice. Moreover, at this point is important to note that students will not be the only users of the system so it must also be designed to take into account the therapists' and/or educators' preferences and difficulties in the use of ICT.
- Flexibility/adaptability, allowing educators to customize and adapt application contents according to both user and educational contexts. However, the customization options should not have been chosen at random, but must be the result of an in-depth analysis of the diverse characteristics and needs of students.
- Mobility, mobile devices have become a very useful support in constructing learning applications because they provide freedom of movement between different locations within the school (classroom, dining room or playground) or outside (house, street, park, etc.). Users can always take out the application to be used when they need it.

Based on these requirements and our experience developing software for people with special needs (Fernández, Roldán, et al., 2009; Paredes, Pino, Rodríguez-Fórtiz, González, & Rodríguez, 2006), we have devised a platform to design educational activities for these kinds of users. The objective is to create exercises which can be personalized at content and user interface levels through a design mainly centered on user requirements, and easily understood by users – not only students but also teachers.

Furthermore, because the system can be used in multiple contexts during the learning process, we opted for a fully mobile platform based on iOS (iPod touch, iPad and iPhone) devices.

The present paper is structured as follows: in Section 2 the theoretical framework and related work are shown. Section 3 describes the features of the platform proposed. Section 4 and 5 show the method and results of a research study on the use of the platform in real environments. Section 6 shows the discussion about the outcomes of study and the main benefits of the proposal. Finally, conclusions and future work are presented in Section 7.

2. Background and related work

2.1. Theoretical background

Students with special education needs can be defined as "those who, because of a disability, require special education and related services to achieve their fullest potential" (Hasselbring & Williams, 2000). Students' disabilities range from speech and language impairments to mental retardation, and more than half have a specific learning disability due to a psychological disorder.

Specific learning disability is defined as "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations" (Specific learning disability, 1997).

Students have special educational needs when they have more difficulty than the rest of their classmates in accessing specific learning in the curriculum that corresponds to their age. With individualized instruction it is possible to make adjustments, to reflect the capabilities, needs, concerns and previous training of students and respect their personal workspace. Therefore, it is necessary to carry out a curriculum adaptation.

Curriculum adaptations are contextualized educational strategies to facilitate the teaching and learning process in students with special educational needs, making modifications to the normal curriculum (Ainscow et al., 2006).

Technology is useful for creating new ways of learning and teaching (Bertini & Kimani, 2003) and gives such students opportunities to engage in basic drill and practice, simulations, exploratory, or communication activities that are matched to their individual needs and abilities (Edwards, Blackhurst, & Koorland, 1995).

The potential benefits of computer-based instruction are grounded in basic learning theory and are the same for all students, including both those with and without mild disabilities. The use of technology can enhance a student's acquisition of skills and content knowledge when the computer is used to deliver well-designed and well-managed instruction (Woodward & Rieth, 1997) by means of curriculum adaptations.

Students with learning disabilities often demonstrate higher-level performance and attention to detail when working on multimedia projects than they normally exhibit (Hasselbring & Williams, 2000). Computers and computing devices help to capture the attention of students with special needs and get them to focus on the tasks to be performed – typically problematic in the education of these students.

Moreover, mobile devices can offer disabled people different kinds of help (Upadhyay, 2006): aids for carrying out functions in everyday activities become a means to communicate, to support them in the learning process and to use as an assistant (alerting to dangers or acting as a guide).

In this context, *mobile learning* (Dillenbourg, 1999) is a booming paradigm based on mobile device supported learning that provides autonomy and ubiquity and facilitates interactions between users thanks to the devices' connectivity.

Brown et al. (Brown et al., 2011) and Gentry et al. (Gentry, Wallace, Kvarfordt, & Lynch, 2010) show that the use of mobile devices helps people with intellectual disabilities to increase their quality of life and independence. The first one also presents a location-based service developed taking into account the participation of final users and trainers in an iterative design, and tested by them. This allows more effective assessment of its benefits.

2.2. Related work

During the last few years, our research group has been working on applications for mobile devices for users with special needs, in particular the Sc@ut Project (Rodríguez-Fórtiz et al., 2009). This project consists of a platform to create adapted, augmentative and alternative communication (AAC) systems for people with communication problems (Fig. 1). In this context, AAC systems can be extremely powerful tools enabling students with severe communication disorders to participate in instructional activities alongside their non-disabled peers, being widely used in the educational and social environment.

Sc@ut has been used successfully for the last four years by more than a hundred special education students and many professionals from education. We have observed (Fernández, Roldán, et al., 2009; Fernández, Rodríguez-Fórtiz, & Noguera, 2009) that their main benefits are: increasing the intention to communicate, understanding language, reducing disruptive behaviors and improving the integration with the social environment.

Use of Sc@ut with mobile devices represented our first approach to *mobile learning* since communication is one of the first facets to develop at school. Educators can change content and interaction, adapting them to the educational context, and the application can be used as a support in learning process.

Professionals who were using the Sc@ut system suggested a new application of this approach to us, aimed at providing guided learning through educational activities.

Then, we began to study the existing technological alternatives dedicated to education or to therapy for students with special educational needs. In some cases the technologies shown have been designed for general education and adapted by special education professionals due to lack of specific tools.

In this context, several interactive environments such as learning and teaching tools have been developed, for example:

- VTech (Vtech) has commercialized multiple products that combine entertaining electronic formats and engaging content that help children learn. However, these products are not targeted at children with special educational needs.
- Clic (Clic) is an environment that allows the creation of individual activities, but it only runs on desktop computers.
- Hot Potatoes (Hot Potatoes) is a suite to create interactive multiple-choice, short-answer, jumbled-sentence, crossword, matching/ordering and gap-fill exercises for the World Wide Web.

These applications have the problem that they are not tailored to students with special educational needs. Other applications try to address this issue:

- In (Schelhowe & Zare, 2009) a mobile application is presented, designed for people with special needs from a mild to severe level of mental ability. It is focused on fostering learning process directly within the context of use, with a flexible learning speed and a fixed structure. A server is used to feed the client's mobile with learning materials that are adapted to the student profile. A customization and decision engine is used to meet this objective. User profiles are provided by the application but they are not configurable. The teacher does not intervene in their creation and they cannot be modified.
- Some learning applications have been developed for the iPhone OS system. IWriteWords (iWriteWords) teaches children handwriting while playing an entertaining game; other example is Proloquo2Go (Proloquo), a product that provides a communication solution for

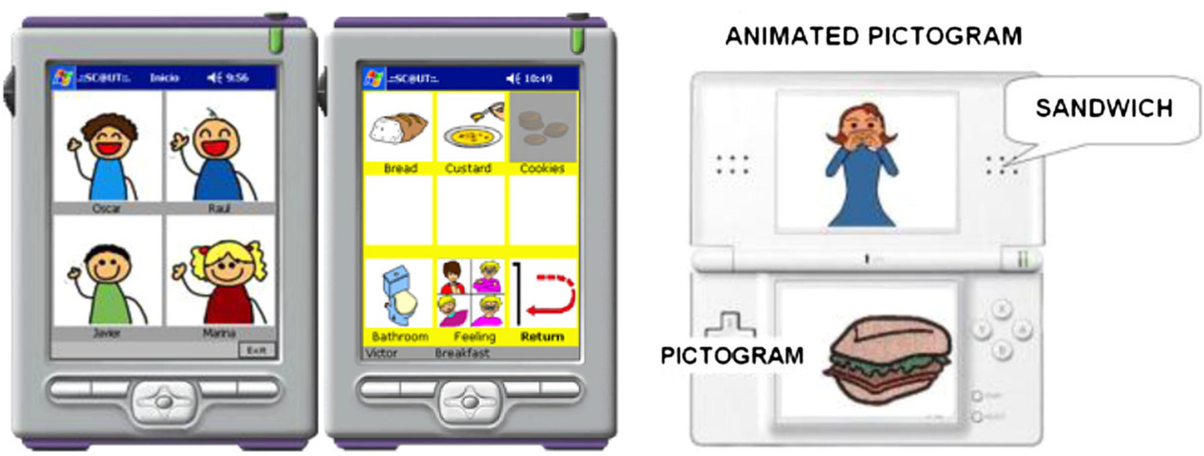

Fig. 1. Sc@ut communicators for PocketPC and NintendoDS.

people who have speaking difficulties. These applications are designed for individual use only and they are not configurable in the sense of customization based on the user's cognitive level or preferences.

However, none of these systems proposes an adaptive approach that takes into account professional directives in an educational context and user-specific needs, and nor do they provide mobility capabilities.

3. Picaa: mobile learning platform

Our proposal, *Picaa*, is a platform to design educational activities for users with education special needs. Its aim is helping in the design of learning activities, which can be personalized by teachers at content and user interface levels. In this section we will analyze the learning process to determine the characteristics of users and activities. Then we will expose the main features of the platform and finally how to treat personalization and adaptation.

3.1. Learning process analysis

In order to reach the proposed objectives, the first step is to analyze how instruction should be defined for a student with special educational needs.

To achieve curriculum adaptations, educators must define a learning plan consisting of personalized classroom activities. These activities are designed to be sufficiently flexible to adapt to the characteristics of each user, to their interests and learning needs, integrating personal data from their own inner world, and respecting their own work rate. The activities must be flexible and can be modified during a learning session.

Taking into account the educational objectives for each user during the curriculum adaptation, the educator's work is focused on two dimensions: the *User Dimension* and the *Learning Dimension* (Fig. 2). Via these, the educator determines the characteristics of users and activities with input from:

- Professional interviews with users and families.
- Models obtained from the observation of users' interactions.
- The knowledge of the therapists.

3.1.1. User dimension

The educator is responsible for identifying the user's profile considering their particular characteristics (Rights and Dignity of Persons with Disabilities). Table 1 shows which technological or curricular adaptations are necessary for different kinds of users with limitations (at sensorial, mobility or cognitive impairment levels).

3.1.2. Learning dimension

Activities must be designed to cover a set of learning objectives such as: memory (hearing, visual, short-term, work…), hand-eye coordination, communication, vocabulary, attention, perception, cause–effect relationships, interpretation, priority, examination of assumptions, language (reading, writing, oral, syntax, semantics and pragmatics), calculations or strategies for the resolution of problems.

To achieve these learning objectives different kinds of activities can be used, for example: puzzles, associations between elements, series, memory or exploration (navigation across templates with elements).

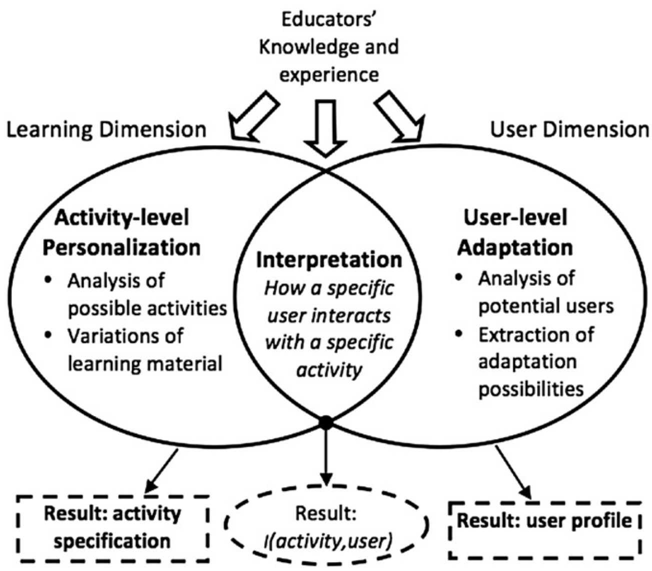

Fig. 2. Analysis process to obtain user profiles and activity specifications.

Table 1
User impairments and possible adaptations.

User limitations	Adaptations
Visual	Colors, size, contrast, magnification. Do not use color as information Conversion of graphical information to text and use of voice synthesis User interface components accessible by means of mouse, keyboard or tactile device
Hearing	Alert sounds coded as text or graphic Adapted vocabulary Use of subtitles and language of gestures
Mobility	Adapted input and output devices Alternative selection of components (alt-keys, voice as input, scrolling…) Time of scrolling, time for user selection, pace of the application
Cognitive	Simple interface without distracting elements Priority use of graphics

Thus, in the learning process of students with special educational needs multiple approaches/methodologies can be applied, but most agree on several requirements:

- Allow changes to the content quickly and easily, without the need for long or complicated operations.
- The need to capture the attention of the student, who often has serious problems focusing on a particular stimulus.
- The use of an agenda: the students learn to carry out the activities that take place during the day and to organize their time.
- Freedom to choose and edit the pictures or pictograms to be used when creating activities. Students with disorders such as autism have trouble processing complex images, so professionals tend to use simple and schematic pictures. It is common for educators or therapists to make use of a particular pictogram catalog with a student. In fact, the use of templates of pictograms is widespread in the treatment and learning of this kind of users.
- The importance of sound, especially the spoken language. Students with impairments often have communication difficulties at both vocabulary and comprehension levels so sounds are also used to give reinforcement to the user about his actions. These sounds could be also recorded or synthesized using a text-to-speech (TTS) engine.
- Promotion of proactive interactions. These students tend not to take the initiative, and to have little personal motivation to communicate.
- Work on the association of ideas, building relationships between concepts, sorting sequences of steps. In this sense, the cause and effect paradigm is widely used.
- Enable content exchange between different professionals, so they can share resources and ideas, or divide work.
- Make it easy to use. One of the biggest challenges when introducing technology in the classroom is that professionals may see it as something complicated that is going to bring more problems than advantages. In this regard it is necessary to devote much of the design process to achieving a usable and intuitive system.

3.2. Features

In line with the requirements described in the previous section, we have designed a platform called *Picaa* (Interactive and Cooperative Platform to Support Learning) (Fernández, Rodríguez-Fórtiz, et al., 2009) that aims to bring flexibility and adaptability to the education of children with special educational needs. The more innovative features of the platform are that:

- It is a multi-user system.
- It is a mobile platform, following an approach where activities run on entertainment mobile devices such as Apple's iPod touch, iPhone or iPad that tend to be more attractive to users. Moreover, mobility offers the opportunity of new alternatives for interaction with physical objects, while the accelerometer built in to mobile devices enables the system to react to their movements and rotations, thus permitting innovative interactions.
- It is designed to cover the main phases of the learning process: preparation, use and evaluation.
- It has the capability of user adaptation and content customization, as previously mentioned.

3.2.1. Activities

Picaa activities can be of four different kinds, covering the main learning objectives previously described:

- Exploration: templates of multimedia items that let students learn concepts through the navigation of a hypermedia system (Fig. 3a, b). Elements can be arranged so that users must navigate through a hypermedia system to create sentences or learn concepts. It is also possible to assign timings or multimedia reinforcement to each item.
- Association: the student must indicate relationships between elements that belong to several sets (Fig. 3c).
- Puzzle: a fragmented image must be rebuilt from multiple pieces (Fig. 3d). The number and shape of pieces can be configured in the range of 2–25 pieces. The image can also be customized.
- Sorting: a list of elements must be ordered in a sequence (Fig. 3e).

3.2.2. Mobile platform

After analyzing the needs of students, teachers and parents we came to the conclusion that the best option was to design a fully mobile platform, where everything takes place in the same device, without using computers.

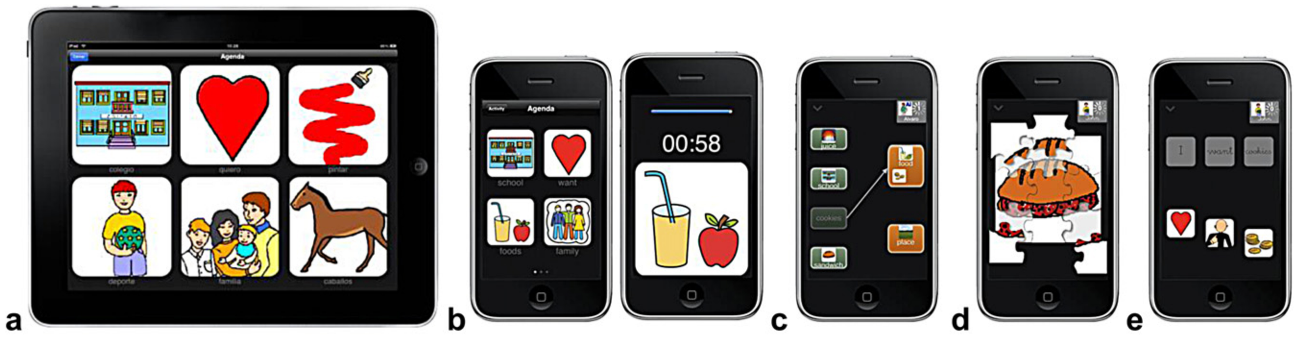

Fig. 3. Examples of *Picaa* activities.

Apple's iPhone OS family, comprised of iPod touch, iPhone and iPad, were the chosen devices for implementing the application. Their main features are:

- Touch screen: the iPhone is the first fully finger-based (rather than stylus-based), multi-touch device. It offers high-quality responsiveness thanks to the incorporation of a capacitive touch-screen and can detect interactions by means of gestures. In general, children love to touch things – is a natural interaction that requires no learning. On the other hand, many students do not have the skills necessary to work with a pencil or stylus, making this device ideal for people with cognitive disabilities.
- Mobility and design: they provide the necessary portability. In addition, their minimalist design (with just one button at the front) makes them easier for users to work with. Furthermore, using integrated GPS and digital compass (only iPhone device) it would be possible to identify the spatial position and orientation, and thus make decisions in light of this contextual information. Mobility allows users to perform activities anywhere and any time.
- Interaction through motion: a built-in accelerometer detects movement when a user rotates the device from portrait to landscape and changes the display accordingly. Rotations or shakes can also be interpreted as a user input, so activities could also be developed that involve moving the device.
- Accessibility: devices feature high contrast function, zoom and a gesture-based screen reader.
- Connectivity: Peer-to-peer connectivity using Bonjour Services (Apple Bonjour) allows applications to create an ad-hoc Bluetooth or Wi-Fi network, a feature that proves very useful in supporting group work.
- Ease of acquisition: It is important to assess the difficulty that educators and parents encounter in sourcing the devices. IPod touch and iPad are consumer devices that can be bought at any shopping mall or shop without having to set up a contract with a telecommunications company. Moreover, their enormous success in the marketplace facilitates continuity over time for this family of devices, something difficult to achieve in the ever-changing world of hardware.

Meanwhile, iPad tablet allows the use of the *Picaa* application with other groups of users for which the iPod touch-screen was too small. In addition, this device offers more possibilities thanks to its bigger screen size (9.7 inches), which leaves more room for user interface elements and allows showing larger items easier to see and touch.

3.2.3. Platform architecture

Our aim was to integrate, within one single application, features that allow teachers and students to intervene in the learning process from the same application. To achieve this, the system includes two modalities depending on the user's role:

- Educators have access to all application modules, including capabilities of activities personalization or user profiles adaptation.
- Students only interact with those activities that educators have designed for them.

The modules of the platform are related to the process followed by educators to create both the activities themselves and also the support for students undertaking them, together with subsequent evaluation. They are (see Fig. 4):

- *Activity designer* module. Educators create activity specifications by means of templates.
- *User profile designer* module. Educators establish what users will use the device for, and define their preferences.
- *Activities engine.* In light of both these specifications, the application generates an activity running ready to be used by the students or tested by the educator.
- The *evaluation* module is dedicated to collecting usage information to facilitate the process of improving the system and adjusting the student's learning process.

3.3. Personalization and adaptation

The most important features are related to the edition of activities and user profile configuration, as detailed below.

3.3.1. Activity designer

During the preparation phase of the learning process, the teacher accesses this module to prepare the activities to be performed by the users.

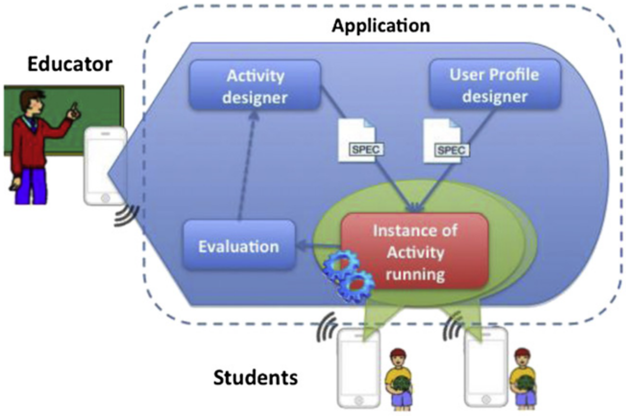

Fig. 4. *Picaa* modular system architecture.

Picaa application enables educators to create and manage a collection of activities (Fig. 5a, b) and by means of templates, they can select a type of exercise and determine some of its features: the number of components or concepts to be taught, screen composition, screen position (rotation or not), multimedia used to represent the components, difficulty level (goals of the exercise, working out the punctuation), reinforcements and help to the users. Additionally, some rules to be considered during use can be defined such as, for instance, the order to be followed when selecting components.

For each element that makes up the activity, the editor can set the text, select an image (taking a picture from the library on the device or captured by the camera if the device includes this) or assign a sound, which can be transferred from a computer, recorded on the spot, or synthesized through a web service available in both English and Spanish languages.

The activities may also be shared through an export/import mechanism, transferring them by email or by connecting the device to the iTunes software on a computer (Windows or Mac). This provides a simple but powerful system of resource sharing among professionals.

3.3.2. User profile designer

Educators must complete a template (see Fig. 5c) to determine what specific adaptations are necessary for each user during the learning preparation phase. As a result of this process, a user profile is generated.

The sample template in Table 1 shows an example that includes questions relating to accessibility, regarding colors, size, contrast and magnification of pictures to be used in the exercises and whether the use of subtitles is necessary. Educators may also choose the best interaction mode from several types available taking into account user mobility, cognitive level and sensorial capabilities. Educators decide, using the template, the characteristics that they consider ideal for the user.

If when the activities are tried out they do not fit user needs, the educator can use the template to perform changes in the user profile, thereby adapting the exercise to the correct profile.

Educators must also set the calendar of activities for each user and define the timetable for each day of the week (Fig. 5d).

4. Methods

4.1. Research design

The overall purpose of the pre-experimental study is to evaluate the use of mobile learning platform *Picaa* with students who have specific support needs in different areas of their development. This is intended to verify the following hypotheses:

H1. *The use of the learning platform Picaa promotes the development of learning skills for children who have special educational needs.*

H2. *The repertoire of types of activities provided is suitable for learning purposes with children with special education needs.*

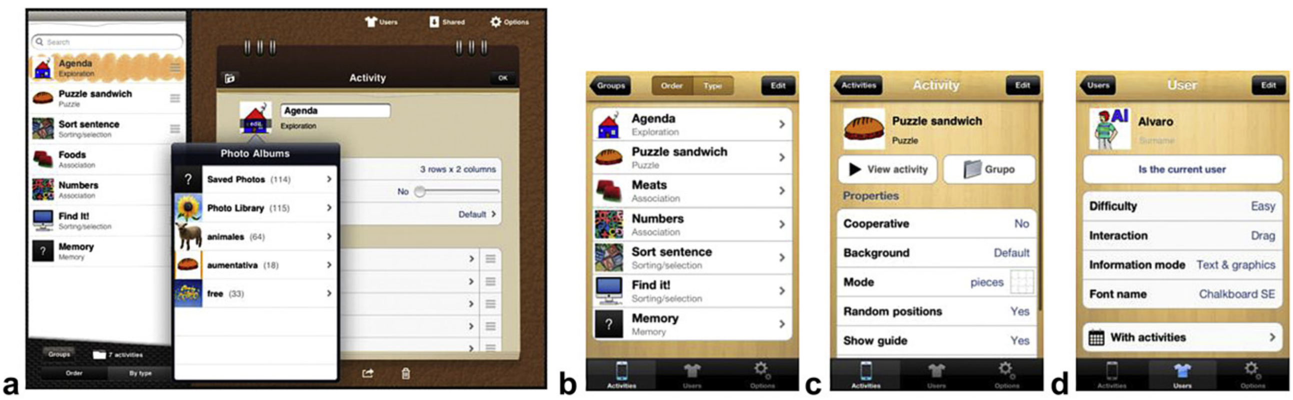

Fig. 5. Collection of activities and an example of activity specification on iPad (left), iPhone/iPod touch (middle) and user profile (right).

The objective is to measure the skills developed by students through a pre-test and post-test scheme, and also collect comments and observations on behavioral aspects during the use of the platform.

The study duration was 6 months, of which 4 were for working sessions (an average of 40–50) with *Picaa*. Working sessions were introduced in the usual planning of each student so that the tool *Picaa* was used instead of some other material. The first month was dedicated to present the tool to the teachers and the last was for the collection of materials and exchange of experiences among participants.

The research design did not include a control group, the classic experimental design strategy (Winner, 1971) that however raises some methodological difficulties in the field of Special Education. For several decades various authors have pointed out difficulties associated with the variability of the population, sample selection problems, how to form homogeneous groups or to obtain representative samples (Bryk & Weisberg, 1977; Cronbach & Snow, 1979; McReynolds & Kearns, 1982; Schindele, 1985). There are also political and ethical issues involving control groups in this type of research (McReynolds & Kearns, 1982; Schindele, 1985), among other reasons because few parents are willing to their children being deprived of one aid potentially beneficial for them.

The above issues led to consider the need for a pre-experimental design with a pre-test and post-test scheme, in order to obtain some measures of change after the intervention, although not void of problems of validity. Despite these drawbacks this type of design was chosen for the following reasons:

- Because of the difficulty of finding a control group that had similar characteristics to those in the experimental sample used.
- This study aimed to generate a set of ideas that allowed testing them later in other more systematic designs of type quasi-experimental, and with more homogeneous population groups.

4.2. Participants

The subjects of this study consisted of 39 students with special education needs from special and elementary schools in Spain. These students belong to 14 different schools (regular or special education) and they were arranged in reduced groups (maximum 6 students). Sampling was not probabilistic, causal, for accessibility (frequently used in educational research).

The use of the tool was conducted with a larger number of students, around 50, but finally we obtained records and measures of 39 of them, 34 in the case of skills tests.

4.3. Materials

During the study period each school has used 1 or 2 iOS devices (ratio of 2 students per device), a total of 20 devices between iPad (higher proportion) and iPod touch. Also a user guide of the platform and some sample activities was provided to educators.

4.4. Instruments

Two measurement instruments have been used for the study:

- A questionnaire assessing skills at different levels (language, math, environmental awareness, autonomy and social). The teacher of each student conducted this evaluation before and after use of *Picaa.* Due to the wide functional diversity of students with special education needs, in this field there is no a standard test to assess the skills and knowledge of students. For this reason, we designed a questionnaire adapted with the aim to measure students' abilities based on a set of skills. The five basic skills that the Spanish educational system provides for the development of all students were chosen and a total of 51 items to evaluate were defined. For each skill there will be a score derived from the sum of the scores of the items that compose it.
- An evaluation questionnaire on the use of activities by each student, indicating the frequency of use, the suitability of the activity, the acquisitions and student motivation when working. It had a total of 15 items.

All items of both questionnaires had 4 levels Likert scales, rated from 1 (low end) to 4 (high end). A four-level Likert scale was chosen, where the neutral choice has been removed, to prevent the surveyed are inclined to group the evidence in the central category, thereby missing the capacity of discrimination of the items (McMillan & Schumacher, 2006).

In addition, educators completed an observational registry of sessions to collect aspects as used type of activity, purpose, duration of the session, etc.

4.4.1. Instruments reliability

Analysis of the measurement instruments showed that the data from the current administration were internally consistent with a Cronbach's α of: 1) .87 in the case of language skill, 2) .91 for the maths skill, 3) .92 for the environmental awareness skill, 4) .80 for the autonomy skill and 5) .92 for the social skill. Respecting the block of items about the activities, the Cronbach's alpha was .87. All these values exceed the minimum recommended by literature (Peterson, 1994).

The reliability could have been estimated in different ways (stability, equivalence, internal consistency, the agreement). We chose to calculate the reliability through internal consistency because it is the most common type of reliability that can be estimated from a single delivery in the form of test. And specifically, we used Cronbach's alpha because it is the most appropriate type of reliability for research study in which questionnaires have a possible range of responses for each item (McMillan & Schumacher, 2006).

4.5. Procedure

Before the study, teachers were instructed in the use of the *Picaa* platform through classroom courses. Then, when the study began educators completed a personal record and also the initial assessment of skills for each student.

During the completion of study, its development was monitored through regular visits to schools and through an e-learning platform based on Moodle. A record of sessions of use was also conducted.

At the end of the study, teachers conducted a final evaluation of student skills (with identical items to those of the initial evaluation). They also completed the questionnaire on activities.

5. Results

5.1. Descriptive statistics

Seventy-one percent of participants were male and 28% were female. The mean age of the sample was 11.8 with a standard deviation of 4.2. The age of participants ranged from 4 to 20, although over 82% were between 6 and 15 years old.

Students have diverse disorders such as Autism (Autistic Spectrum Disorder, ASD), Down syndrome, Fragile-X syndrome (FXS), Attention-Deficit Hyperactivity Disorder (ADHD) with mental retardation or Pervasive Developmental Disorder (PDD). Table 2 shows student's distribution by diagnosis and gender. Forty-six percent of participants were diagnosed with Autistic Spectrum Disorder.

5.2. Skills evaluation results

Of the entire sample, both initial and final skills questionnaires were completed for $n = 34$ participants. We check that the data was normally distributed by means of a Shapiro–Wilk test and values obtained did not result in rejection of the hypothesis that the data are from a normally distributed population.

After comparing the results for the five basic skills we observe that there was an increase in scores for each one:

- Language skills were up 5.76% on average.
- Math skills were increased 5.56% on average.
- Environmental awareness skills, a mean of 7.59%.
- Autonomy skills were increased 7.26% on average.
- Social skills were up 4.23% on average.

In order to verify that this increase was not due to chance, we performed a Wilcoxon signed-rank test for related data based on next hypothesis:

Experimental hypothesis: the improvement of skill level of students is statistically significant.

Null hypothesis: the observed increase is due to chance.

Results of Wilcoxon test revealed statistically significant differences in all the skills considered ($p < 0.05$). Therefore we can reject the null hypothesis and assert that the increase in skill level is significant.

To complement, sign test was also performed and results concluded that the compared variables (skills before and after) differ significantly ($p < 0.05$).

Once known that there was significant differences between the results of pre-test and post-test, we carried out comparative analysis separating the population by two factors: 1) gender and 2) diagnosis. Then a Mann–Whitney test and a Kruskal–Wallis test were performed and as result we obtained that there were no significant differences between the degree of improvement by gender or isolating the sample of students with ASD (for this case were taken into account only two groups by statistical issues, autism and the rest of disorders, and the aim was to test that the usefulness of the tool was not limited only to students with autism).

5.3. Activities usage

With regard to the use of activities by session, the *association* and *puzzle* activities were the most used. It should be noted that the four types of activities were used by the 89.7% the students. Table 3 shows the percentage of user by type of activity.

All types of activities were useful to work the 5 basic skills. By way of example, it should be noted some of the uses performed by educators:

Table 2
Distribution of participants by diagnosis and gender.

Diagnosis	Male	Female	Total
ASD	13	5	18
PDD	1	0	1
FXS	1	0	1
ADHD	2	0	2
Down syndrome	2	1	3
Others	9	5	14

Others set includes students without a clear diagnosis but with mental retardation or cognitive special needs.

Table 3
Percentage of use of activities by session.

Activity type	Never	Sometimes	Frequently	Always
Association	0.0%	9.7%	51.6%	38.7%
Exploration	3.4%	27.6%	58.6%	10.4%
Puzzle	6.4%	22.6%	29.1%	41.9%
Sorting	3.2%	25.8%	41.9%	29.1%

- *Association* activities were used to work the language skill by creating pre-reading activities as joining letters with syllables, syllables with words or words with pictograms. They were also used for math skills, e.g., by joining numbers with pictures representing a set with the same number of objects.
- *Exploration* activities were designed for use as alternative communication system (working language skill) such as time planning agenda (working autonomy skill) or address book (social skill).
- *Puzzle* activities were used as reinforcement for work on concepts such as transport, meals (environment awareness skill) or family members (social skill).
- *Sorting* activities were employed to teach about how to perform common tasks like washing the face (autonomy) or categorize objects by size as transport (environment awareness) or order numbered sets (math).

6. Discussion

6.1. Supervised study

The study was planned with the aim of responding to the following research hypotheses:

H1. *The use of the learning platform Picaa promotes the development of learning skills for children who have special educational needs.*

H2. *The repertoire of types of activities provided is suitable for learning purposes with children with special education needs.*

Based on the results shown in Section 4.2 we can see that the use of the *Picaa* platform has shown beneficial in their application with students with special educational needs, as intended in hypothesis *H1*.

Analyses are positive for the five skills tested (classified as basic in the Spanish education system), indicating that the platform is versatile and useful for widespread use in education.

As a limitation, it is important to note that the study sample was neither randomized nor statistically representative of the special education needs students collective as a whole. Moreover, it is a pre-experimental design without control group, as previously justified.

There also are some limitations that can be derived from a pre-experimental design, because of the potential threats that may occur derived from uncontrolled covariates. Otherwise, the analysis of covariance is an alternative discouraged when it is not an experimental design in the strict sense (Hinkel, Wiersma, & Jurs, 1994; Kirk, 1995). Moreover, Hunter and Schmidt (Hunter & Schmidt, 1990) claiming the possibilities of this simple pre-experimental design (pre-test/treatment/post-test, without a control group), noting that it is the researcher who must consider whether these potential threats actually exist (they almost never occur, according to Hunter and Schmidt).

In order to compensate these drawbacks, the results have been obtained from the application of technology with a very heterogeneous sample (a broad range of ages, different types of disabilities, different phases of the educational process, multiple geographic locations and professionals performing the implementation, etc.). This fact may be a reason to show that the difference between the results of pre-test and post-test are due more to the intervention with the Picaa application, common to all cases, than to other possible independent variables that could act as covariates and that would be different with each subject.

Therefore the results, while promising, should be applied cautiously for other factions of the special education needs population.

Additionally, the results of comparative analysis by gender or diagnosis is indicative of the development done has advantages for individuals with special education needs analyzed regardless of gender or diagnosis (isolating ASD), which gives greater universality to the platform.

In addition, these students were from multiple schools (14) distributed throughout the Spanish territory (they were from Andalusia, Murcia, Madrid, Galicia and Valencia), extending the generality of the study.

About the purpose for which the tool was used, in general, the platform was used to support or complement various exercises in the classroom and daily activities. Many professionals used it to promote reading and some of them to promote writing. Its use for anticipating circumstances, such as in the augmentative communication system or agenda, was also noteworthy. Other uses were: as Bits of Intelligence, working with numbers (Math), generalization exercises, dialog/conversation, or prewriting.

With regard to the hypothesis *H2*, four types of activities were used by high percentage of the students, almost all, and with high frequency, showing that the choice of repertoire was appropriate and correct for the intended purpose.

Activities have been used for several educational skills (math, social area, science, language, etc.). Also various types of activities have been used to work on a same subject or content, planned by means of the user's agenda.

Finally, a descriptive analysis of the results of questionnaires and observational registry of sessions along with personal interviews with educators reveal the following benefits/results for students:

- The use of electronic devices and multimedia contents increases their interest in learning.
- The students can learn any time and anywhere because of the mobility of the devices.

Table 4
Apple reports on downloads and updates of application.

Country	Total downloads	Total updates
USA	2139	6157
Spain	1736	4431
China	418	136
Mexico	287	449
Saudi Arabia	227	93
Canada	154	234
UK	125	117
Australia	114	309
Others	1665	1808

Data for the period Nov. 07, 2011 to May. 06, 2012. (*) Other countries include: Chile, Argentina, Netherlands, Hong Kong, Japan, Czech Republic and others not specified in the reports.

- Students with impairments have the opportunity to perform activities that previously were not accessible to them, because of the interface and contents of the activities have been adapted specifically to them, and multimedia resources are often the only material that users with sensorial impairments can perceive.
- Training sessions can be delivered to help the students become familiar with the application and use of mobile devices.

6.2. Worldwide use

Since the final version of *Picaa* was published in the summer of 2010 via the online applications store App Store, the use of the tool has been extended throughout the world (*Picaa* application is distributed free and with support in English, Spanish and Arabic). Although we cannot provide data on actual usage, Apple reports indicate a total of around 17,000 downloads worldwide, with half of these accounted for by the USA and a quarter by Spain. Table 4 outlines the download and update statistics for the last six months.

Feedback that comes in email format from different countries such as the USA, Argentina or Chile shows that the platform is enjoying good acceptance, largely due to its versatility.

7. Conclusions

The use of mobile technologies and multimedia increases the interest of students, helping them to learn while they are entertained. In the case of students with impairments, learning exercises must be individualized in order to meet their special educational needs. In this context, educators usually intervene during the learning process as qualified experts in order to foster the development of their students' capabilities. Educators must prepare the exercises to be carried out, personalize them, and supervise and guide students whilst they undertake them.

With the objective of facilitating the use of the technology in class, we have designed a single application which runs on mobile devices and which is firstly used by the educators to create and modify exercises as they see fit, and then, by the students to learn while carrying out such exercises. The mobility functionality of the devices means that exercises can be done any time and anywhere, thus promoting the participation of the stakeholders in the learning process and the socialization of the students. We have selected a specific device family well known for its ease of use and offering the accessibility and support to communication and mobility required by this group of users and their educators.

A system comprised of several modules has been proposed in order to separate concerns and follow different phases in the design and use of the application.

We are participating in a national project, collaborating with several Special Education schools. Professionals from the schools set out their requirements for us to address in our specifications, design and prototypes. Prototypes allowed functional and non-functional requirements to be specified, completed and validated.

We conclude that *Picaa* is an excellent tool for supporting special educational needs adaptations as it:

- Can help develop basic skills, including activities to work on perception, attention, memory, reading and writing, motor skills and reasoning.
- Enables adjustments to be made in the work environment to fit the profile of each student and their interaction, for instance: format of content to be accessible (image, text, sound), interaction with the content (requiring more or less fine motor skill), or screen size.
- Can be used in different curriculum areas as activities can be specified and customized to focus on different content as required in each area.
- Supports communication in the classroom by incorporating an AAC system.
- Is adaptable to several methodologies and learning styles, as it provides generic activities that can then be further tailored into sub-activities.
- Sets the sequence and timing of learning to incorporate a calendar of events for each day. Moreover, its portability allows learning to happen at any time, anywhere, not only in school, so that participants can transfer the learning process to a family setting or to other support groups.

We are currently working on the collaborative extension of the platform in order to address better social skills development, a major deficit area in the case of students with special educational needs.

Appendix A. Students skills survey questionnaires

Evaluation Questionnaire for Students

Language skills				
Express their **agreement** or **disagreement** with the issues presented below, scoring them for it with **1, 2, 3 or 4**. Considering that **1 indicates the lower end**, while the **4** refers to the **highest end**.	**Assessment**			
1. Use nonverbal resources (gestures, glances…) to facilitate his/her communication.	1	2	3	4
2. Use an Augmentative and Alternative Communication System to communicate with his/her environment.	1	2	3	4
3. The student expresses through oral language needs and moods.	1	2	3	4
4. The student communicates information in response to issues previously raised.	1	2	3	4
5. The student explains in organized way information concerning any fact, experiences, etc., in any of the usual contexts in which he/she operates.	1	2	3	4
6. The student understands and executes simple commands.	1	2	3	4
7. The student verbally interacts with different people (children or adults) in the school environment.	1	2	3	4
8. The student uses a vocabulary appropriate to his/her chronological age.	1	2	3	4
9. The student reads and understands words.	1	2	3	4
10. The student reads and understands simple phrases.	1	2	3	4
11. The student understands the written information that appears in different parts of his/her environment.	1	2	3	4
12. The student is able to write simple texts with simple sentences.	1	2	3	4
13. The student uses writing to respond to situations of everyday life and his/her learning.	1	2	3	4
14. The student expresses interest and enjoyment in participating in oral communication situations.	1	2	3	4
Other aspects of interest to note regarding Language skills:				

Math skills				
Express their **agreement** or **disagreement** with the issues presented below, scoring them for it with **1, 2, 3 or 4**. Considering that **1 indicates the lower end**, while the **4** refers to the **highest end**.	**Assessment**			
1. The student classifies different types of activities in response to the place where they are developed.	1	2	3	4
2. The student orders series of objects by color, shape or size.	1	2	3	4
3. The student relates in different ways (by comparison, correspondence or seriating) the activities in daily life.	1	2	3	4
4. The student knows the numbers from 0 to 10 and identifies the amount they represent.	1	2	3	4
5. The student knows the numbers from 10 to 100 and identifies the amount they represent.	1	2	3	4
6. The student groups amounts and performs simple sums (which results in less than 10).	1	2	3	4
7. The student recognizes simple geometric shapes (circle, square, triangle).	1	2	3	4
8. The student solves simple problem situations of everyday life.	1	2	3	4
9. The student knows the days of the week and relates them to specific activities.	1	2	3	4
10. The student associates some hours of the clock with regular activities that take place at that time (wake up, eat, sleep…).	1	2	3	4
11. The student recognizes the money as an exchange to acquire objects.	1	2	3	4
12. The student identifies the value of some coin/bill.	1	2	3	4
13. The student is oriented in space following simple commands.	1	2	3	4
14. The student handles a basic vocabulary related to concepts of space, time, size or position.	1	2	3	4
Other aspects of interest to note regarding Math skills:				

Environment awareness skills				
Express their **agreement** or **disagreement** with the issues presented below, scoring them for it with **1, 2, 3 or 4**. Considering that **1 indicates the lower end**, while the **4** refers to the **highest end**.	**Assessment**			
1. The student recognizes objects belonging to different domestic contexts (kitchen, bathroom, bedroom…) and identifies their use.	1	2	3	4
2. The student recognizes objects belonging to the school environment (classroom, playground…) and identifies their use.	1	2	3	4
3. The student recognizes usual places and identifies the activities that take place in them.	1	2	3	4
4. The student identifies his/her products commonly consumed.	1	2	3	4
5. The student relates consumer products with the store where they are purchased.	1	2	3	4
6. The student recognizes different types of transport.	1	2	3	4
7. The student describes the usefulness of different transport.	1	2	3	4
8. The student identifies commonly consumed foods and indicates his/her preferences.	1	2	3	4
Other aspects of interest to note regarding Environment awareness skills:				

Autonomy skills				
Express their **agreement** or **disagreement** with the issues presented below, scoring them for it with **1, 2, 3 or 4**. Considering that **1 indicates the lower end**, while the **4** refers to the **highest end**.	**Assessment**			
1. The student recognizes his physical image identifying the different component parts of his/her body.	1	2	3	4
2. The student identifies the most significant features of his/her own body.	1	2	3	4
3. The student recognizes some changes that happen to his/her body as the time passes.	1	2	3	4
4. The student points out his/her interests and he/she prioritizes them.	1	2	3	4
5. The student identifies his emotions and feelings and relates to the causes that produce them.	1	2	3	4
6. The student is independent in performing basic activities of daily life (food, clothing, travel, toilet).	1	2	3	4
7. The student expresses his/her own initiative to carry out some tasks.	1	2	3	4
Other aspects of interest to note regarding Autonomy skills:				

Social skills				
Express their **agreement** or **disagreement** with the issues presented below, scoring them for it with **1, 2, 3 or 4**. Considering that **1 indicates the lower end**, while the **4** refers to the **highest end**.	**Assessment**			
1. The student recognizes people from different contexts (school, family…) and identifies their source.	1	2	3	4
2. The student identifies what is his/her relationship with different people.	1	2	3	4
3. The student maintains a spontaneously and fluently relationship with the rest of his/her classmates.	1	2	3	4
4. The student maintains a spontaneously and fluently relationship with most of the professionals who care for him/her at school.	1	2	3	4
5. The student maintains a spontaneously and fluently relationship with people living in his/her family unit.	1	2	3	4
6. The student is able to distinguish strange people of the already known.	1	2	3	4
7. The student distinguishes the role of professionals working in some social and cultural services of their immediate environment.	1	2	3	4
8. The student recognizes and applies rules of citizen coexistence (relating to movement on the streets, the garbage disposal…).	1	2	3	4
Other aspects of interest to note regarding Social skills:				

Appendix B. Activities usage survey questionnaires.

Activities Questionnaire

ACTIVITIES used	Frequency of use			
	Never	Sometimes	Frequently	Always
1. Association	①	②	③	④
2. Exploration	①	②	③	④
3. Puzzle	①	②	③	④
4. Sorting	①	②	③	④

Activities				
Actions taken by the user	Assessment			
1. The student is able to select a stage/space in which to place the action (home, school, park, food, places…).	1	2	3	4
2. The student identifies actions/objects by their name/sign.	1	2	3	4
3. The student is able to distribute different elements from a number less than or equal to given sets.	1	2	3	4
4. The student is able to discriminate useful elements to solve the task.	1	2	3	4
5. The student is able to sort items previously disordered following the correct sequence.	1	2	3	4
Acquisitions				
I It encourages communication and social interaction.	1	2	3	4
II The student learns and uses new concepts (vocabulary/signs).	1	2	3	4
III The student is able to maintain a rhythm of action-pause-action during task performance (favoring the development of waiting times).	1	2	3	4
IV It promotes the development of discrimination (visual/auditory).	1	2	3	4
V The student anticipates actions or changes of space from images or sounds.	1	2	3	4
Motivation and development				
a) The student manipulates the tool autonomously.	1	2	3	4
b) Sound reinforcement fosters motivation of the user while using the tool.	1	2	3	4
c) The student expresses his/her preferences regarding the selection of activities.	1	2	3	4
d) Failures during the development of the activity do not adversely affect its resolution.	1	2	3	4
e) The student participates actively in the development of activities.	1	2	3	4
Other points to note:				

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