Diogo Cunha e Silva

Contributos para o Desenvolvimento de Aplicações para Crianças com Problemas de Comunicação e Integração

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia de Computadores e Telemática, realizada sob a orientação científica do Doutor António Teixeira, Professor associado do Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro, e do Doutor Samuel Silva, Professor Doutorado (Nível 2) do Instituto de Engenharia Electrónica e Telemática de Aveiro

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Resumo

A comunicação, para expressar as nossas necessidades e ideias, é uma peça fundamental do nosso dia a dia, permitindo a nossa interação com os outros e contribuindo para estabelecer laços sociais. Quando essa capacidade é afetada, seja por questões contextuais (por exemplo, ambiente ruidoso) ou condições intrínsecas (por exemplo, dificuldades de articulação de fala), ela cria um cenário desafiante tanto para os indivíduos como para os que os rodeiam. As crianças diagnosticadas com Perturbação do Espetro do Autismo (PEA) são um exemplo notável de uma audiência que enfrenta esses desafios, devido às suas frequentes dificuldades para comunicar e interagir socialmente com os outros. Neste contexto, os seus desafios não afetam apenas a sua capacidade de integração com a família e os amigos, podendo, também, influenciar o seu desempenho na escola, um ambiente importante para o seu desenvolvimento.

Nos últimos anos, têm sido feitos esforços para propor soluções tecnológicas que contribuam para apoiar essas crianças na sua comunicação, mas a maior parte do trabalho na literatura concentra-se principalmente no uso, pela criança, de apoios que não abordam verdadeiramente a integração.

Considerando esse contexto, argumentamos que esses desafios precisam de ser abordados considerando as necessidades e motivações das crianças com PEA, mas também tendo em mente as motivações das pessoas ao seu redor, ajudando pais, professores e amigos a participarem na integração.

Aproveitando os trabalhos anteriores sobre a caracterização das necessidades e motivações das crianças com PEA, as suas famílias e professores, o trabalho realizado explora diferentes cenários relacionados à comunicação, na escola e em casa, e propõe um conjunto de requisitos que devem ser considerados para os servir.

Considerando esses requisitos e adotando uma abordagem de projeto iterativa, centrada no utilizador, uma primeira aplicação de prova de conceito é proposta. AMICA, Adaptive Multimodal Integrated Communication for All, é uma aplicação multi-plataforma, multi-utilizador e multimodal que visa ilustrar como algumas questões que afetam as crianças com PEA e aqueles que as rodeiam podem ser abordadas para tentar facilitar as suas vidas.

No estado atual, a AMICA já engloba o suporte a vários recursos de comunicação adaptados para atender a criança, a família, os amigos e os professores, proporcionando-lhes um espaço de interação.

A natureza modular multi-plataforma do trabalho realizado permite que AMICA seja uma base para mais pesquisas sobre diferentes formas multimodais de comunicação para crianças com PEA (por exemplo, olhar ou pictogramas), mas, também, permitindo a participação de diferentes utilizadores, promove primeiros estudos sobre a natureza dinâmica de tal comunicação.

Abstract

Communication, to express our needs and ideas, is a fundamental piece of our daily lives, enabling our interaction with others and contributing to establish social bonds. When this ability is affected, whether by contextual issues (e.g., noisy environment) or intrinsic conditions (e.g., speech articulation difficulties) it creates a challenging scenario for both the individuals and those surrounding them. Children diagnosed with Austism Spectrum Disorders (ASD) are a notable example of an audience facing these challenges given their frequent difficulties to communicate and socially interact with others. In this context, their challenges not only affect their ability to integrate with family and friends, but can also influence how they perform at school, an important environment for their development.

In recent years, efforts have been made to propose technological solutions that contribute to support these children in their communication, but most of the work in the literature mainly focuses on the child entailing a support that does not truly addresses integration.

Considering this context, we argue that these challenges need to be addressed considering the needs and motivations of children with ASD, but also keeping in mind the motivations of those around them, helping parents, teachers and friends to take part in the integration.

Profiting from previous work on the characterization of the needs and motivations of children with ASD, their families, and teachers, the work carried out explores different communication-related scenarios, at school and at home, and proposes a set of requirements that should be considered to serve them. Considering these requirements, and adopting an iterative user-centered design approach, a first proof-of-concept application is proposed. AMICA, Adaptive Multimodal Integrated Communication for All, is a multi-platform, multi-user and multimodal application that aims to illustrate how some issues that affect children with ASD and those surrounding them can be addressed in order to their lives easier.

At its current stage, AMICA already encompasses support for several communication features adapted to serve the child, family, friends, and teachers providing them a space for interaction.

The modular multi-platform nature of the work carried out enables AMICA as a testbed for further research on different multimodal ways of communication for children with ASD (e.g., gaze or pictograms), but, also, by allowing the participation of different users, it fosters first studies on the dynamic nature of such communication.

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List of Acronyms

AAC   Augmentative and Alternative Communication

AMICA Adaptive Multimodal Integrated Communication for All

ASD   Autism Spectrum Disorders

PECS   Picture Exchange Communication System

PDD-NOS Pervasive Developmental Disorder-Not Otherwise Specified

PSSUQ Post-Study System Usability Questionnaire

SEN   Special Educational Needs

SGD   Speech Generating Devices

SUS   System Usability Scale

VOCA   Voice Output Communication Aids

CHAPTER 1

Introduction

"For people without disabilities, technology makes things easier. For people with disabilities, technology makes things possible." [1]

Communication, to express our needs and ideas, is a fundamental piece of our daily lives, enabling our interaction with others and contributing to establish social bonds. Human-human communication is a complex, multidimensional process that is sometimes hard to accomplish, whether due to a challenging context (e.g., language barriers or a noisy environment) or to specific characteristics of the person including, for instance, difficulties in speech articulation, eye contact, and social interaction. These barriers to expressing themselves and understanding their peers might exacerbate their difficulties in effectively participating in everyday activities, for instance, at school, potentially hindering their ability to acquire important knowledge and skills. Therefore, while a relevant issue for all ages, communication difficulties assume particular importance at early ages.

1.1 Motivation

Children with communication problems, a notable example being children with Autism Spectrum Disorders (ASD), face challenging scenarios in their daily lives.

When it comes to their relation with people, namely their family, friends and teachers, they show difficulty in sharing emotions and initiating or responding to social interactions, difficulty in maintaining eye contact and understanding the use of gestures and difficulty in adjusting behavior to different social contexts, among others.

Some of the most used applications that assist communication focus on non-verbal children, serving as intermediary in a conversation by converting symbols-to-speech and having sentences read out loud by the device. As useful as these applications may be for direct conversations, they do not address other issues of communication like the ones represented above. Namely, displaying and understanding emotions, maintaining eye contact, understanding gestures and

adapting behavior to social context. Furthermore, they do not address issues like extreme distress with changes to routines and repetitive behaviors.

From a technological perspective, mobile technology is well established in people's lives, mainly, in the form of smartphones and tablets. Inherently to these devices there are different forms of interaction, the most used being touch. However, there are multiple forms of human-computer interaction, some of them being decades old and yet only now are starting to be popularized. For example, with the introduction of virtual assistants, people started using speech. However, this technology dates as far back as 1960's to the IBM Shoebox [2]. With the introduction of Kinect[3], people started using gestures to interact with computer systems, even though gesture recognition started being used in 1970's with the creation of the Sayre Glove [4].

Devices are progressively getting smaller and that allows technology to find new ways to enter peoples lives. From desktop computers, to laptops, to smartphones, to wearables. All these developments have potential to improve technologies targeting ASD, assisting people in their daily activities and connecting them to others.

Previous work from our group [5] has enabled the characterization of the needs and motivations of children with ASD along with their family and teachers, resulting in valuable information to understand their context, also when it comes to communication. A first effort to materialize this work was performed by presenting a first prototype application "Tell Your Day"[6], to further support the refinement and elicitation of new requirements and providing positive inputs for a continued effort in this area. This dissertation aims to continue to explore the work developed by Diogo Vieira in the context of multimodality. Furthermore, we feel that it is important to explore the development of applications for diverse groups of users, not just children with communication problems, going beyond existing approaches.

Ultimately, different forms of communication should be comprehensive and include children with difficulties, rather than excluding them.

1.2 Challenges

Everyday, children with ASD and those surrounding them, face challenges related to the condition. These challenges manifest everywhere the children go, whether at home, at school or even outside. ASD is not a condition with a single characteristic but rather a wide spectrum of characteristics that can affect different children in different ways, ranging from problems inherent to them, to problems in their communication and social interaction with others.

At school, by law, children with ASD need to share at least a part of their time in regular education classes. This poses problems not only in integrating these children with the other students, but also in assisting teachers educating all of their students equally.

At home, families also face challenges helping their children in their daily activities and in their overall growth.

When it comes to applications, while there have been significant efforts to assist in communication, there is still a major gap when it comes to the children's interaction with

others in the classroom and interaction between those surrounding the children. Applications do not solve issues like promoting communication with teachers and classmates and facilitating communication between teachers and parents. They should focus on a continuous effort of helping users with as many problems as possible without constraints such as only working on specific platforms and for specific users. Furthermore, they are based on the fundamental constraint that users need to use touch to control the application, thereby not providing support for other forms of interaction. Instead, given the diversity of users and characteristics, they should allow multiple forms of interaction so the users can choose the ones that best suit them.

1.3 Objectives

Considering the challenges mentioned in the previous section, our overall objective is to evolve the work previously developed for children with ASD. This includes extending the study of children with ASD and those surrounding them by understanding their interests and defining requirements to extend the work on applications for them. More concretely, this will result in the development of a proof of concept in the form of a context-aware, multi-platform, multimodal application. This will allow the application to adapt to different users and roles and work in the devices they already have. Furthermore, it will serve as a basis for further development targeting ASD users in school and familiar context.

To achieve this overall goal, our work envisages to address the following more concrete objectives:

- Evolve previous work on the characterization of the needs and motivations of children with ASD and their families and teachers, particularly targeting communication-related contexts, conducing to a more specific and refined set of requirements;
- Propose a first proof-of-concept system, encompassing the requirements elicited above, and specifically addressing and adapting to the different kinds of users;
- Contribute to support a more continued effort in this line of research, by the team, by proposing a technological solution that can serve multiple scenarios and work as a testbed for future ideas.

Ultimately, the two main objectives are providing children with ASD more ways to communicate with others as well as helping parents and teachers better interact with their children, their students and with each other.

1.4 Dissertation Overview

The remainder of this document presents the work carried out to address the objectives detailed above and is organized as follows:

- **Chapter 2 - Background and Related Work**
  Consists in an introduction to the background of our work, namely the fields of Autism

Spectrum Disorders, Multimodal Interaction, Iterative User-centered Design and finally, the technologies used to develop the system examples of existing applications for ASD.

- **Chapter 3 - Personas, Scenarios, Requirements**

  Consists in the first part of our work, i.e, understanding the users by studying Personas, creating Scenarios to describe the actions of the Personas in order to achieve certain goals and finally, inferring Requirements for the system.

- **Chapter 4 - Development of a Proof of Concept**

  Consists in the second part of our work, i.e, the development of a proof of concept system to achieve the objectives we established.

- **Chapter 5 - Conclusions**

  Consists in a final summary of our work, an overall analyses discussing its outcome and finally, proposes some work that can be done in the future to make the system more complete and, therefore, more capable of fulfilling the objectives.

Background and Related Work

Taking into account the objectives of this dissertation, two main areas are going to be in focus: Autism Spectrum Disorders and Multimodal Interaction, specifically in the way that multimodal applications can be used to assist children with ASD and the people around them to interact with each other. Children with ASD and those that interact with them are going to be the focus group of the work developed in this dissertation.

Multimodal Interaction represents an important alternative to common user interfaces and is especially relevant when the focus group is composed of children that have special needs given that it provides systems with different forms of interaction to best suit them. To assess requirements, User Centered Design is the method that best suits our work, given that a knowledge of the users and their needs is paramount. To achieve a system that is the groundwork to address all the users' needs we will be focusing on technologies that allow the creation of a multi-platform, multi-user system.

Therefore, in the following sections, we will detail the areas mentioned above. In the end of the chapter we will focus on related work, specifically existing applications for children with ASD.

2.1 Autism Spectrum Disorders

Formerly, Autism Spectrum Disorders (ASD) were divided into several different disorders, the three main ones being Autism, Asperger's Syndrome and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS)[7]. Because each diagnosis is different, as every person is unique and has their own combination of characteristics, with the release of the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders [8], in 2013, these disorders stopped being differentiated and where grouped into a single definition, Autism Spectrum Disorders. Therefore, ASD is the name given to a set of neurological anomalies that, among others, result in lack of social interaction skills and autonomy and repetitive behaviors. Usually, ASD

is diagnosed early in the child's development, between two and three years of age, as these symptoms are noticeable even in early ages.

2.1.1 Main Characteristics of ASD

Symptoms for ASD are revealed from twelve to eighteen months of age or in some cases, even earlier. [9] In these early ages, it is difficult for parents to notice symptoms. Parents are not prepared to distinguish signs of the condition from issues with their children's development, thinking only of the possibility when they notice that children do not start speaking as early as they should. Therefore, not all symptoms can be noticed at early ages. A child can show what would be a symptom of ASD while it being completely unrelated.

Common characteristics of children with ASD are as follows.

Problems with social interaction such as difficulty in maintaining eye contact, understanding the use of gestures and sharing emotions, difficulty in adapting to social contexts, for example, being loud in libraries and disliking close contact with other people, such as hugs or kisses. Engaging in repetitive behavior, such as always playing with the same toys. Problems in communication such as choosing to be silent even though they can talk, being unable to understand when someone is calling them by name and having difficult in expressing emotions when speaking. Inherent problems such as showing extreme distress when facing changes.

Some of these characteristics are not as noticeable in adolescence or in adulthood, having been attenuated. Some noticeable characteristics are little to no friends, prefer staying at home, difficulty in finding and maintaining jobs and little autonomy.

As stated before, ASD is a spectrum, meaning that there is not a single number of identifiable symptoms. The number of symptoms and their gravity vary from person to person.

2.2 Augmentative and Alternative Communication

One of the problems that affect children with ASD is the difficulty or the inability to speak. According to the University of Boston [10], thirty percent of them are "minimally verbal" or "nonverbal", while generic difficulties in communication affect a much wider percentage.

Augmentative and Alternative Communication is the term used to describe a variety of communication methods that can be used to enhance speech or to replace it. It aims to facilitate communication both of verbal and nonverbal people with ASD or other disabilities that affect speech.

According a publication by the Department of Human Services, Government of South Australia [11], Augmentative and Alternative Communication (AAC) can be divided in three main categories: Unaided AAC, Non-electronic AAC and Electronic AAC. Unaided AAC refers to methods of communication that do not require any external object. A typical method of unaided AAC is sign language [12] as it only requires the usage of certain parts of the body (for example hands and arms) to convey meaning. Non-electronic AAC refers to methods of communication that require external, non electronic, objects. This includes pictures, symbols and objects where text can be written, for example, the Picture Exchange Communication System [13]. Finally, Electronic AAC refers to methods of communication that utilize external, electronic, objects. This does not require devices designed solely to the purpose of assisting users via AAC [14], referred to as Speech Generating Devices (SGD) or Voice Output Communication Aids (VOCA). Typically this refers to applications running on computers, tablets or smartphones that convert a user input to a visual output on the screen such as images or expressions or an auditive output on the device's speakers such as text-to-speech.

Studies[15] show that the usage of Picture Exchange Communication System (PECS) have a positive effect on the communication of children with ASD. Initially PECS consisted on the usage of physical objects such as cards with pictures that users would arrange to properly convey an idea, called pictograms, the representation of physical objects to convey meaning. With the proliferation of mobile technologies it is now possible to have hundreds of pictograms in a single mobile application, placing the tools for communication directly in the hands of the users.

2.3 Teaching Students with Special Educational Needs

In Portugal, it was only with the establishment of the *Law Decree number 35/90* [16] in 1990 that school attendance became mandatory for all children and it was only in 1991 with the *Law Decree number 319/91* [17] that regular schools were responsible for teaching children with Special Educational Needs (SEN) [18]. Because of that, schools had to encompass in their boards teachers and auxiliary staff who had training teaching children with SEN. In 2008 with the establishment of the *Law Decree number 3/08*, students with SEN were included in regular teaching classes in addition to the special education classes that already existed.

Inclusion of students with SEN is still a controversial subject. Maria Cardoso studied the inclusion of students with special educational needs in regular teaching classes [19]. She focused on the grouping of schools on the municipality of Moita, in Setúbal and a sample of twelve teachers all of them regular education teachers with at least one student with SEN in their classes. According to her conclusions: *"Most of the teachers (...) present a similar vision, they agree with the inclusion of students with special educational needs in regular teaching classes, but they have some concerns (...). Their agreement depends on the existence in schools of essential resources to the attending of students with special educational needs, that allow them to answer the needs of their students who have different styles and learning rhythms."*

It is clear that the majority of teachers have concerns about the inclusion of students with special educational needs in their classes. However, in the end, they agree that with the proper tools, preparation and legislation, a shared classroom can bring benefits for all students especially in the development of social skills, tolerance, solidarity and respect for difference. They also agree that a case by case review is necessary and that not all students can be included in regular education classes.

Children with SEN require different degrees of support and some of them require such an amount of support that it does not allow a proper learning environment for the other students. If there are students with SEN in the regular education classes, an adaptation in the flow of the lessons is required. A compromise must be met where the tempo of classes is slow enough for the students with SEN to properly learn what is being taught, without jeopardizing the learning process of the other students at the same time.

2.4   Multimodal Interaction

"A multimodal HCI system is simply one that responds to inputs in more than one modality or communication channel" [20]. A communication channel is a particular way of human-computer interaction, using a combination of system features and one or multiple user senses [21]. A multimodal system may interpret a user command by the usage of a single modality or multiple modalities used simultaneously.

Input modalities refer to ways the user can interact with and send information to a particular system. As stated in "Multimodal interaction: A review" [21], some examples of input modalities are as shown on table 2.1.

Modality	Example
Visual	Face location Gaze Facial expression Lipreading Face-based identity Gesture (head/face, hands, body) Sign language
Auditory	Speech input Non-speech audio
Touch	Pressure Location and selection Gesture
Other sensors	Sensor-based motion capture

Table 2.1: Input modalities and examples as stated in [21].

Output modalities refer to ways the computer can give feedback to the user, through communication channels. Some examples as shown on table 2.2.

Modality	Device Capability	Channel Example
Visual	Display	Text Images/Video
Auditory	Speakers	Sound
Haptic	Vibration Motor	Vibration Feedback

Table 2.2: Output modalities and examples as stated in [21].

Multimodality allows users to interact with systems in a more natural way. As new technologies emerge, so do new input and output modalities. In the future, this modalities may be obsolete as humans may found themselves interacting with computers in completely different ways.

One of the first systems that implemented modality fusion was "Put That There" [22], a system that combined speech and gestures to create and move objects. A system that implements multiple modalities has a higher chance of reaching a wider number of users. Depending on their conditions, users may be impaired to use some of the modalities but may be able to use others. The usage of multiple modalities, however, is not always relevant and should not happen without purpose. A study of the users of the system is always important to assess which modalities are important for each system, based on its users.

2.4.1 Architectures and Frameworks

Multimodal applications in their core add a level of complexity that applications with single modalities, like touch, do not have, posing a challenge to designers and developers [23]. It is not limited to having more than one modality in the system but also to having a constantly growing amount of modalities that may at any time need to be implemented in the system.

To assist designers and developers, over the years, there have been multiple approaches on multimodal architectures, each with their own interpretation of how input modalities should be identified and processed.

Multimodal architectures are high level representations of multimodal interaction systems that show the different components of the systems.

Two noticeable approaches are Mudra and the W3C Multimodal Interaction Architecture.

Mudra Architecture

Mudra is a unified multimodal interaction framework for the processing of low-level data streams as well as high-level semantic inferences [24].
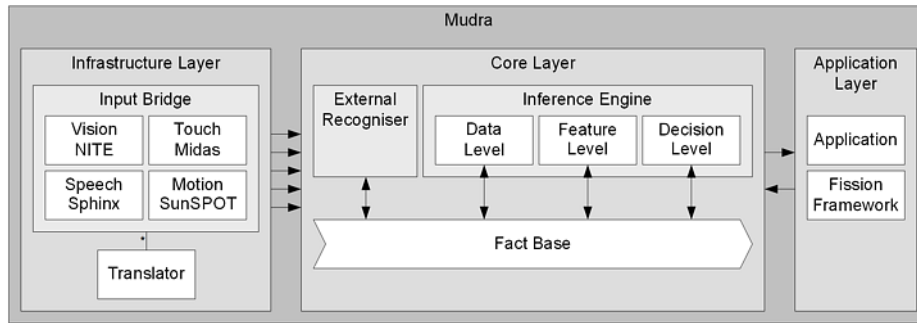
Figure 2.1: Mudra architecture illustrating the 3 layers.

Mudra proposes three layers: Infrastructure, Core and Application:

- The **Infrastructure Layer** is composed by the input modalities and a translator that converts the information given by the modalities into a uniform representation, facts.

- The **Core Layer** is composed by:

  - Fact Base, containing the facts originated in the infrastructure layer;

  - Inference Engine, Mudra's approach of fusion engine, that has three types of information processing:

    - Data-Level Processing, primarily used for noise filtering and recognition useful, for example, to get better results on gesture recognition;

    - Feature-Level Processing, used to improve recognition rates, for example, on a touch modality, to assert if multi-touch is being done with fingers from the same hand;

    - Decision-Level Processing, provides developers with access to events ranging from low to high level and allows external data-level, feature-level or decision-level fusion algorithms to be applied to any facts available in the fact base;

- The **Application Layer** provides handlers for end-user applications or fission frameworks.

W3C Architecture and Framework

The W3C proposes a Multimodal Architecture that defines a generic structure to allow the modules in a multimodal system to communicate with each other [25].
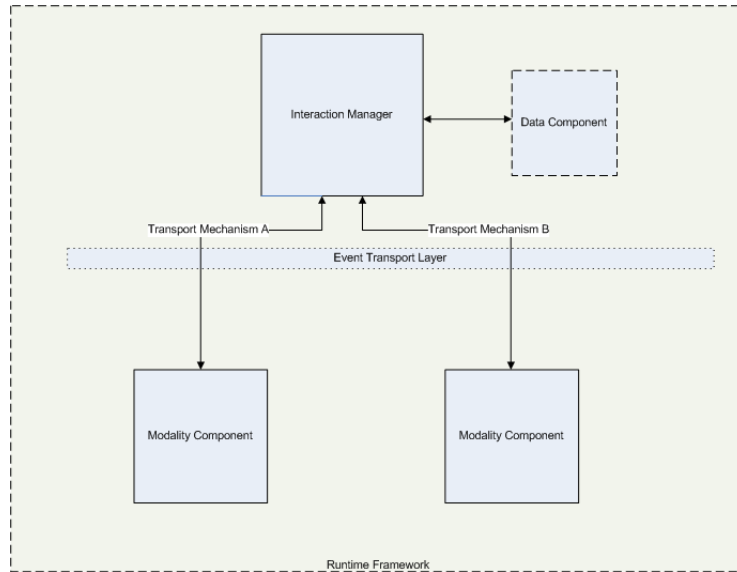
Figure 2.2: W3C multimodal interaction architecture illustrating the four main components.

It states four main components to its Multimodal Interaction Architecture:

- The **Interaction Manager (IM)** is a logical component responsible for connecting the components of the system and the multimodal Runtime Framework. Each system may configure its own Interaction Manager to satisfy its specific interaction requirements and may even require multiple Interaction Managers. It is an event handler and a communication bus to mediate connections between multiple Modality Components and between the Modality Components and the Data Component.

- The **Modality Components (MC)** implement the necessary features to interact using specific modalities. As such, multiple MC can be present in the same system. They are responsible for controlling the interaction with the user, both input and output. Even though many MC may be present in the same system, they do not share information with each other directly. To communicate with each other, they must mediate such connection with the IM.

- The **Data Component (DC)** is responsible for storing the application data. The only way to access the DC is to use the IM as mediator.

- The **Runtime Framework** refers to all the necessary services to run the multimodal system.

Based on the W3C recommendations a relevant effort of a multi-device multimodal interaction framework was created by Almeida et al. [26].
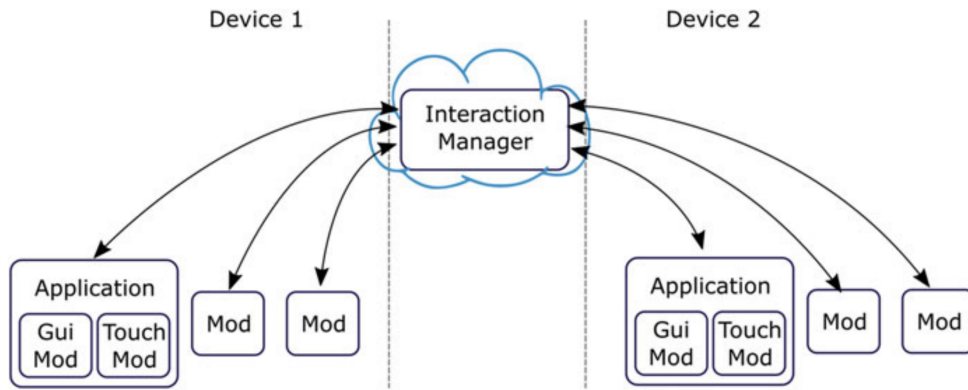
Figure 2.3: Overall architecture for multi-device MMI support using a single Interaction Manager located in the cloud

This approach proposes a single Interaction Manager located in the cloud, to which multiple devices can connect. To enable multiple clients in the IM, each modality registers with a unique identifier. This way, the IM will be able to identify, at any time, which modality, in which device, originated which request.

2.5 Iterative User-centred Design

"User-centered design (UCD) is a broad term to describe design processes in which end-users influence how a design takes shape." [27]

It is a type of design of a system in which the designers have clear understanding of the type of users, their needs and their environment when designing the system.
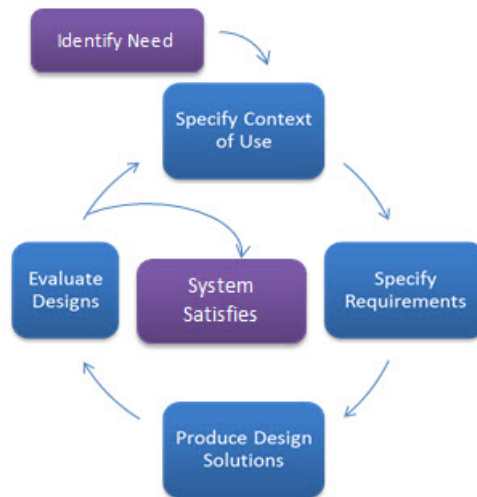
Figure 2.4: Iteration phases of the User-centered Design methodology. [28]

Generally, each iteration of user centered design process is composed of four different phases [29]:

- **Specify Context of Use**: Identify the users of the system, what they will use the system for and under what conditions.
- **Specify Requirements**: Identify the users' goals.
- **Produce Design Solutions**: Develop the system, possibly in different iterations, from concept to full system.
- **Evaluate Designs**: System evaluation, ideally, with actual users.

2.5.1 Personas, Scenarios, Goals

Personas, Scenarios, Goals is a User Centered Design approach that focuses on Persona to define scenarios and ultimately goals to drive the design of a system.

Personas

Personas are fictional representations of the target audience of a system. Based on proper research, before the development process begins, a group of fictional characters is created to help the developers understand the needs, motivations and goals of the users [30] [31].

If the Personas are not adequate to the system, then the developers may fail to adequately design it and include all the necessary features.

Scenarios

Scenarios are narratives that describe the actions of the Personas in order to achieve certain goals [32], [33].

Scenarios can describe how a system was intended to behave or how it behaves at a given moment.

Furthermore, they are useful to extract use cases and perform usability evaluations.

Goals

Goals define what the Personas want and their motivations to perform an action. When the Personas reach their goal, the scenario ends.

2.5.2 Methodology

As illustrated in picture 2.5, this method is composed of three main parts:

- **Requirement Acquisition**

    The acquisition of requirements assumes a study of the Personas starting by their identification, that is, who is going to use the application. After that, it is necessary to know the motivations of the Persona, that is, why would they use the system and what can the system help them with. That will allow the creation of scenarios and goals. Based on the scenarios and on the motivations of the Persona, the requirements can be extracted and sorted based on their importance. Because this process is iterative, not all requirements are selected at once. This will result on smaller versions of the system that can help the developer meet all the users' needs.

- **Development**

    Based on the requirements, the system can start being developed always having in mind who are the users and adapting to them if necessary.

- **Evaluation**

    After the development of the version of the system that focuses on the selected requirements, it is necessary to perform an evaluation with the users. The evaluation will vary based on the version of the system. Early versions will focus more on usability and design problems. They may have static content and may be evaluated with groups of users that are not the end users. The later versions will follow the usability and design of their predecessors and will focus on actual features with dynamic content to make sure the system is ready to be released. These later versions will ultimately be evaluated with the end users of the system.
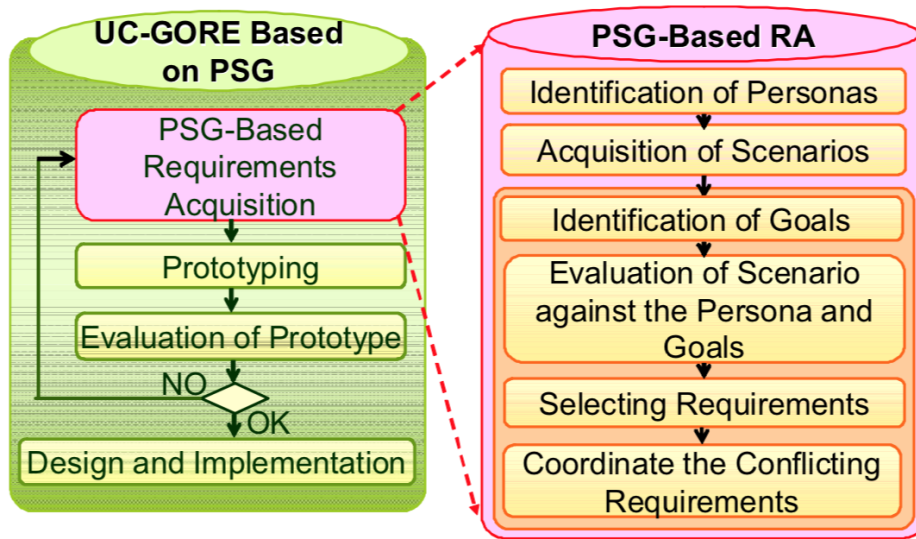
Figure 2.5: User-Centered Goal-Oriented Requirements Engineering based on Personas, Scenarios and Goals.[34]

2.5.3 Evaluations

Evaluations are very important in iterative development as they are the tools that allow the developers to get feedback from the users in every stage of the process. Depending on the stage of the prototype, different methods of evaluation may be used.

Heuristic Evaluation

Heuristic Evaluations [35] are evaluations performed by experienced users that aim to test the interface of a system against a set of pre-established heuristics.

While there are many usability heuristics a widely accepted set of heuristics are the Nielsen's Heuristics [36]. This heuristics are:

- **Visibility of system status**: The system should always keep users informed about what is going on, through appropriate feedback within reasonable time;
- **Match between system and the real world**: The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms;
- **User control and freedom**: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue;
- **Consistency and standards**: Users should not have to wonder whether different words, situations, or actions mean the same thing;
- **Error prevention**: Even better than good error messages is a careful design which prevents a problem from occurring in the first place;
- **Recognition rather than recall**: Minimize the user's memory load by making objects, actions, and options visible;

- **Flexibility and efficiency of use**: Accelerators - unseen by the novice user - may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users;
- **Aesthetic and minimalist design**: Dialogues should not contain information which is irrelevant or rarely needed;
- **Help users recognize, diagnose, and recover from errors**: Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution;
- **Help and documentation**: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation.

This type of evaluations, done with experienced users, allow for a quick way to make developers aware of potential usability problems before engaging in real user evaluations.

User Evaluation

User Evaluations do not require experienced users. They use more intuitive forms of evaluation meant to assess how well users perceive the system and how satisfied they are with it [37].

These evaluations presume direct contact between the evaluators and the representative of the system being evaluated either on a step-by-step basis or on an overall questionnaire after the evaluation.

Some common moderating techniques are [38]:
- **Concurrent Think Aloud (CTA)** Used to understand the user's thoughts on the system as they go through the test by having them think out loud.
- **Retrospective Think Aloud (RTA)** Used to understand the user's thoughts on the system by asking them to retrace their steps and asking them their thoughts on each part of the test.
- **Concurrent Probing (CP)** Used to understand the user's thoughts on the system by asking them questions based on their actions on each task (if they do or say something of interest).
- **Retrospective Probing (RP)** Used to understand the user's thoughts on the system by asking questions when they finish the test.

Usability Scales

After the test is completed, the user may be asked to answer a questionnaire using, for example, the System Usability Scale (SUS) [39], [40] or the Post-Study System Usability Questionnaire (PSSUQ) [41].

The SUS provides a simple, yet reliable tool for measuring the user experience after evaluating a system. It consists of 10 questions:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.

4. I think that I would need the support of a technical person to be able to use this system.

5. I found the various functions in this system were well integrated.

6. I thought there was too much inconsistency in this system.

7. I would imagine that most people would learn to use this system very quickly.

8. I found the system very cumbersome to use.

9. I felt very confident using the system.

10. I needed to learn a lot of things before I could get going with this system.

The users evaluate each question on a scale 1-5, 1 being "strongly disagree" and 5 being "strongly agree". All answers are, then, processed to obtain a final score 0-100.

Jeff Sauro [42] reviewed the existing research on SUS and analyzed data from over 5000 users across 500 different evaluations. He verified that the average score of all evaluations was 68, therefore, a SUS score above 68 is considered above average and a score below 68 is considered below average. He found that the best way to interpret a SUS score is converting it to a percentile rank and then associate each rank to a letter grade from F to A+ (A+ being the best). A product needs to score above an 80.3 to get an A (the top 10% of scores) and A is the point where users would consider recommending it to a friend.

Similarly to the SUS, the PSSUQ is also a post-evaluation usability questionnaire having, however, 19 questions instead of 10. The scale for each question is also different, ranging from 1 to 7, where 1 corresponds to "strongly agree" and 7 corresponds to "strongly disagree". It consists of the following questions:

1. Overall, I am satisfied with how easy it is to use this system.

2. I It was simples to use this system.

3. I could effectively complete the tasks and scenarios using this system.

4. I was able to complete the tasks and scenarios quickly using this system.

5. I was able to efficiently complete the tasks and scenarios using this system.

6. I felt comfortable using this system.

7. It was easy to learn to use this system.

8. I believe I could become productive quickly using this system.

9. The system gave error messages that clearly told me how to fix problems.

10. Whenever I made a mistake using the system, I could recover easily and quickly.

11. The information (such as on-line help, on-screen messages and other documentation) provided with this system was clear.

12. It was easy to find the information I needed.

13. The information provided for the system was easy to understand.

14. The information was effective in helping me complete the tasks and scenarios.

15. The organization of information on the system screens was clear.

16. The interface of this system was pleasant.

17. I liked using this interface of this system.

18. This system has all the functions and capabilities I expect it to have.

19. I Overall, I am satisfied with this system.

The final PSSUQ score is given by an average of the answers to each question. However, it is possible to divide the questions into sub categories and evaluate separately. The score for system usability is given by the average of the answers from question 1 to 8. The score for information quality is given by the average of the answers from question 9 to 15. Finally, the score for interface quality is given by the average of the answers from question 16 to 18.

2.6 Support Technologies

In this section we focus on the technologies used to develop the back-end of the system to support the application.

2.6.1 Spring Boot

Spring Boot is a project developed by Spring on top of the Spring [1] Framework for Java based applications. It aims to allow a developer to quick and easily deploy an application. It automatically configures the project based on the specifications the developer defines upon creation and its own defaults while allowing modifications at any time. The main purpose is to let the developer focus on the features of the application instead on what is necessary to make it run.

2.6.2 Java Web Containers

A Java web container is the component of a web server that interacts with Java applications. It is the software component that, running on a web server, is capable of deploying Java applications. The most popular Java web containers are Tomcat, WildFly/JBoss and Jetty [43].

Tomcat is a simple HTTP server and Java Servlet container. JBoss on the other hand is a full Java EE application server. This means that Tomcat is lighter and enough to run applications that do not need a full Java EE server such as applications built with Spring.

Similarly to Tomcat, Jetty is also a Java HTTP server and Java Servlet container. Even though Tomcat is the default web server on Spring Boot, Jetty is also supported.

2.6.3 Database Engines

A Database Engine is the software system that handles a database allowing data management operations to be executed. The most popular database engines are Oracle, MySQL, Microsoft SQL Server and PostgreSQL [44].

PostgreSQL

PostgreSQL is an lightweight open source object-relational database system that uses and extends SQL.

It supports a wide range of operations and runs on several platforms including Linux, macOS and Windows. It supports text, images, sounds, video and includes programming interfaces for languages including Java, C, C++ and Python.

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[1]https://spring.io/

2.7 Multi-Platform Development

In this section, in the effort of developing a multi-platform, multi-user application, we focus on the technologies that will be used to create it.

Our objective, with multi-platform development is to allow users to use the application in whichever device they own. This can be achieved using technologies that allow us to write once, deploy to many (platforms).

2.7.1 Apache Cordova

Cordova [45] is an open-source mobile development framework. It allows developers to create cross-platform applications written with standard web technologies such as HTML5 [46], CSS [47] and JavaScript [48]. Cordova inserts applications in wrappers specific for each platform and makes them able to access the device's hardware through a set of API's. accessible via a set of Cordova plugins.

Cordova is the core framework, however, there are several frameworks that augment it, the most popular ones being Adobe PhoneGap [49] and Ionic [50].

PhoneGap is the first distribution of Cordova. It provides desktop and mobile applications that allow for quick deployment and preview of the developed applications. As the core Cordova it uses HTML, CSS and JavaScript.

Ionic is a front-end UI framework that means to handle the UI interactions of the application. It comes with a set of UI elements much like the ones found on native SDK of Android and iOS. Similarly to Cordova, Ionic uses HTML, CSS and JavaScript but can work with AngularJS to for a lot of the core functionalities.
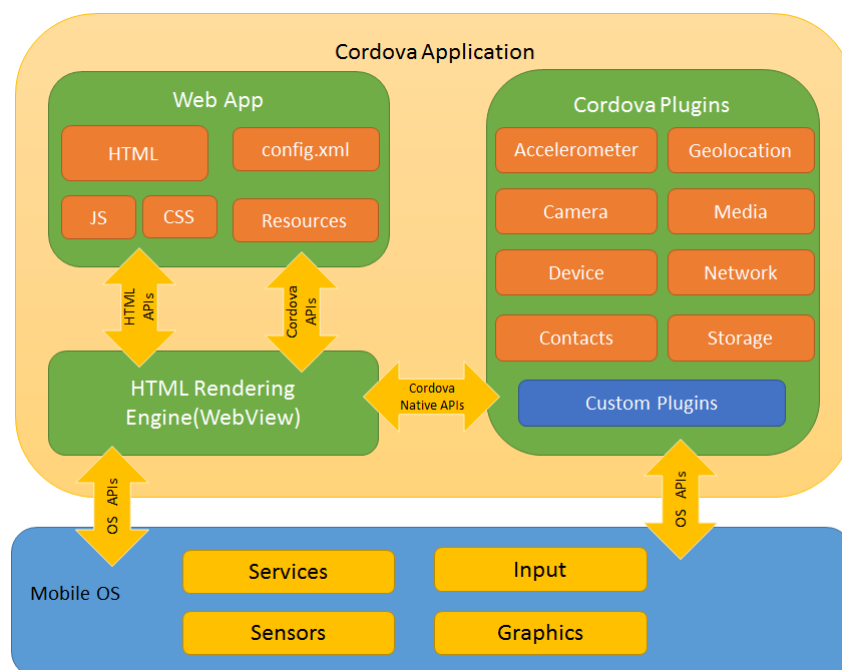
Figure 2.6: Overall Cordova application architecture.

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2.7.2 Multi-Device Communication

When thinking about applications running on the same context with multiple devices and multiple users, it is common to think that some form of interaction will happen between the users. For example, a meeting management application for writing minutes and taking notes that can be accessed and edited by all users present or even a gallery application that allows user to transfer pictures between devices.

In this type of applications, it is important to know which type of communication between instances of the application better suits the users and the context they are in. Taking both examples above, users using a meeting management application would most likely want their minutes to be saved and accessible by all members so, to fulfill this objective, perhaps the best way is to send all individual changes to a centralized server, then sync them with the global version and finally update the global version on the individual versions opened in all instances of the application. This would ensure the possibility of users on different locations, maybe at another branch of the company, accessing the minutes "in real time".
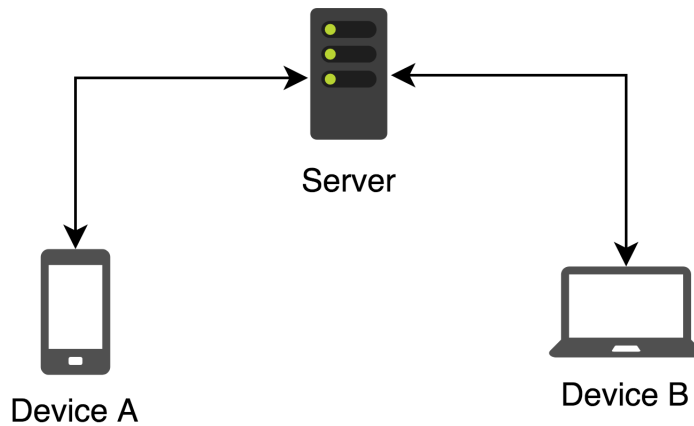
Figure 2.7: Device-to-Server communication illustration.

However, when using a gallery application to transfer photos, users are presumably near each other, so there is no need to use a server as intermediary in the transfer. Direct communication between devices would be much faster.
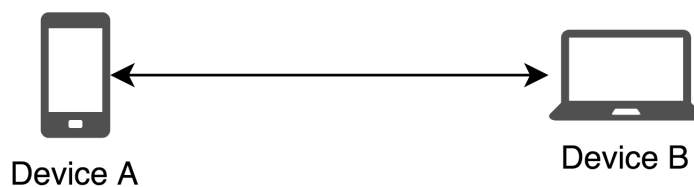
Figure 2.8: Device-to-Device communication illustration.

2.7.3 Indirect Data Transfer

In this context, indirect data transfer refers to the transfer of data from a sender through a mediator, typically a server, where data may or may not be stored and then transfered to or accessed by the receiver.

This type of transfer is generally done with client devices on a local network with access to the Internet and a server on a different location.

2.7.4 Direct Data Transfer

In this context, on the other hand, indirect data transfer refers to the transfer of data from between devices in relatively close proximity to each other.

This type of data transfer is not as generalized as the previous one. Since it does not require access to a network connected to the Internet, the form of communication depends mainly on the capabilities of the device, application and on the user. In the example above, photo transfer could be done in multiple ways, depending on the device, the most common being Bluetooth.

Bluetooth

Bluetooth [51] is a wireless technology standard for communications over small distances. It is commonly used on peripherals and IoT devices [52].

Data transfer speed over Bluetooth can be as high as 2Mbps.

Near Field Communication (NFC)

NFC is a wireless technology that enables connected devices to transfer data in a distance no larger than 10 centimeters with speeds as high as 424Kbps.

It is used mainly for contactless operations using smart cards or using smartphones simulating smart cards for example using Google Pay [53] or Apple Pay [54].

Comparison

While Bluetooth is widely available, with 100% of smartphones, tablets and laptops being Bluetooth enabled [55], NFC is not yet widely used especially not in laptops and even in mobile devices.

Therefore, even though, NFC is an interesting option as its use would promote close contact between devices and, by extent, users, Bluetooth is the logical option as it covers all devices and does not promote further fragmentation.

2.8 Applications for Children with ASD

There is a very large number of applications for children with ASD. Each application focuses on different aspects that will help children in their daily lives.

Autism Speaks [56] filters applications based on category, user age and target platform. They differentiate in 10 different categories: recreation, social skills, accessibility, behavioral intervention, communication, creative arts, educational, functional skills, language, math skills and organizer. Because there are several applications that target each category and platform, with some of them targeting multiple categories, the market is very fragmented.

The following applications represent significant efforts of applications for children with ASD.

Proloquo2Go

Proloquo2Go [57]–[59] is a symbol based AAC application for iOS devices that uses pictograms. It uses a method of symbol-to-speech where users select multiple symbols to create sentences.

Figure 2.9: Main page of the "Proloquo2Go" application.

Proloquo2Go is particularly useful for people with speech impairments that could not otherwise speak. However it is also very useful for people with communication problems like people with ASD that would prefer interacting with other trough the application.

The application comes pre-installed with Crescendo [60], a proprietary vocabulary of AssistiveWare, however, users can install different vocabularies if they chose to.

The main screen is composed of a grid of pictograms, each of them conveying a different meaning, sorted by type like pronouns, verbs, adjectives, etc. Users can select different pictograms to create sentences and then select the sentence on the top of the screen so they are converted to audio output.

Predictable

Similarly to Proloquo2Go, Predictable [61] is a also a speech synthesis application for iOS devices meant for people with speech impairments. However, Predictable uses text as the user input instead of symbols.

Figure 2.10: Main page of the "Predictable" application.

The user starts writing a sentence with the virtual keyboard and Predictable suggests common words to complete it. Users can also draw the words on the screen. If Predictable recognizes the word, the user can add it to the sentence. When the sentence is completed, the user can select the speak button so it is converted to speech. Alternatively, Predictable allows users to have their sentences spoken automatically so speech feels more natural.

CommBoards

CommBoards [62] is a highly customizable speech assistant for Android devices that uses symbols-to-speech. It allows users to create their own vocabulary, using custom images, names and voices.
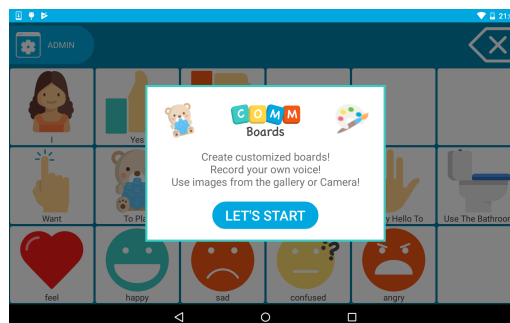
Figure 2.11: Main page of the "CommBoards" application with first start dialog.

i Get... My Schedules at School Social Skills Stories

i Get... My Schedules at School Social Skills Stories [63] is an iOS application that aims to help children with their day at school by providing personalized schedule entries for each day.
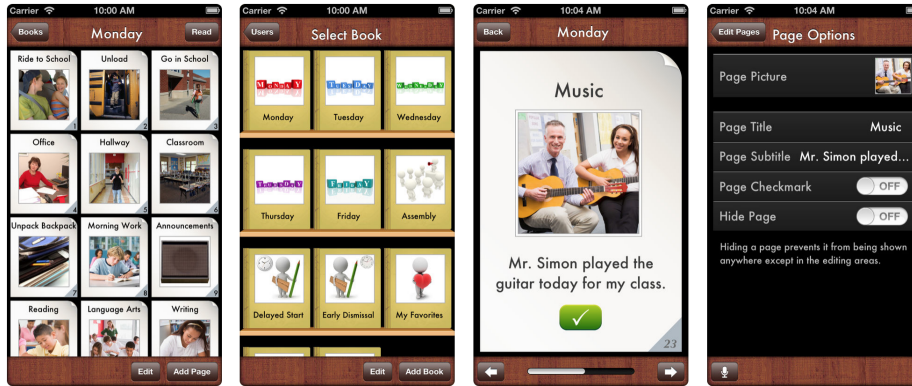
Figure 2.12: Multiple screenshots of the "i Get... My Schedules at Schools" application.

Conta o Teu Dia

"Conta o Teu Dia" [6] is a multimodal Windows application that has four main features: a camera to take photos, a gallery to view and edit photos or images, a quiz game to be played with a tutor, and a "diary", a minimalist way to access to Facebook.
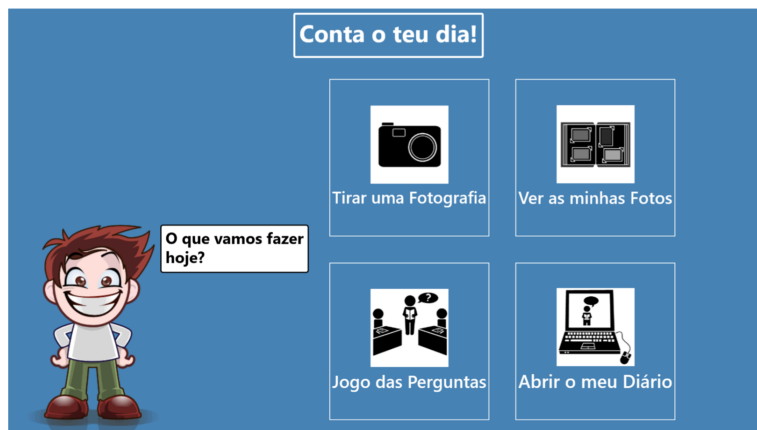
Figure 2.13: Main menu of the "Conta o Teu Dia" application.

Comparison

In this subsection we compare each of the applications above based on their input and output modalities as well as the platforms they support and the characteristic of the children with ASD that they aim to assist. This allows to have an better idea of the fragmentation of modalities, platforms and areas of action of the applications.

Application	Modalities		Platforms	Characteristic that Aims to Assist
	Input	Output		
Proloquo2Go	Touch	Audio, Symbols, Text	iOS	Communication Issues
Predictable	Touch	Audio, Text	iOS	Communication Issues
CommBoards	Touch, Speech, Image Capture	Audio, Symbols, Text	Android	Communication Issues
i Get... My Schedules at School Social Skills Stories	Touch	Text, Images	iOS	Need for Predictability
Conta o Teu Dia	Touch, Speech, Gaze, Image Capture	Audio, Images, Symbols, Text	Windows	Lack of Social Interaction Skills

Table 2.3: Application comparison focusing on input and output modalities as well as platforms and target characteristic of the children.

While all applications support more than one output modality, most of them only support one input modality, touch. Both "CommBoards" and "Conta o Teu Dia" support multiple input and output modalities, however they only support one platform, Android and Windows, respectively.

Platform separation is very noticeable in this types of applications with only one being supported by each one.

When it comes to characteristics that they aim to assist, none of them has more than one. Each of them focus on one issue and try to assist children with it.

2.9 Discussion

Applications for autism exist in every application store, on every platform. However, the large majority is not supported on a multi-platform level. Taking, for example, the list of applications made by the Autism Parenting Magazine [64], out of the two hundred and sixteen applications mentioned, only forty two support both Android and iOS operating systems. If we use that as a test group, we can infer that only less than twenty percent of the applications made for children with ASD are multi-platform.

Most of these applications aim to help children with problems they face every day, from communicating with others to keep track of routines, however they do not facilitate communication between those surrounding these children.

In the classroom, there are no applications that effectively assist teachers and students with SEN. In fact, the applications that exist promote separation between students. In one hand, applications for students with SEN are suited only for some problems and are not meant to be used by students without SEN. On the other hand, applications for students without SEN are not prepared for the problems that students with SEN have to face.

Applications like Proloquo2Go offer a significant effort in assisting with the communication of children with ASD, however, they are localized efforts that aim to assist in one problem instead of being more complex applications that aim to assist children in ever increasing aspects.

In sum, there is a clear need for applications that assist children with ASD both at home and at school and that do not promote separation between the people related to those children but rather provide means for them to communicate with one another.

Users, Scenarios and Requirements

This chapter will focus on introducing the necessary background for the development of the system, namely, understanding of the users by studying a set of Personas, creating scenarios and deriving use cases and, finally, creating functional and interaction requirements.

One of the objectives of this dissertation is to explore how it is possible to assist children with communication problems, their family and their teachers in their daily live interaction with one another. To do so, the focus group that was chosen was children with Autism Spectrum Disorders.

3.1 Personas

Having as support the Personas described in the dissertation of Ana Leal, "Contributos para o Desenvolvimento de Aplicações Destinadas a Crianças com Perturbação do Espectro do Autismo" [5], the considered Personas were Nuno Rocha, child with ASD, Laura Rocha, Nuno's mother and guardian (responsible for school matters), Beatriz Rocha, Nuno's sister and Sofia Rodrigues, Nuno's teacher.

Nuno is the Primary Persona. As the child with ASD him and the people he most interacts with will represent the target users of the system that we are trying to achieve.

In addition to these, the creation of a new Persona was thought important to fulfill the objectives of both Nuno and his teacher, Sofia. That Persona is Gabriel, Nuno's best friend. He represents children without communication problems.

3.1.1 Description

The Personas as described in Ana Leal's dissertation are the fundamental representation of what would be the people focused on by this dissertation.

To provide context, in this subsection we transcribe the Personas as they are described in the dissertation of Ana Leal. They will be used as base, however their motivations may not

be used exactly as described. The motivations that will be taken into consideration are the following.

Nuno Rocha

Nuno Rocha, born on February 20, 2005, is from Moita, municipality of Anadia, Aveiro district. He lives with his father, mother and a 13-year-old sister.

At 2 years of age he went to a developmental clinic at the District Hospital, due to his parents' suspicion that something was wrong with his development and was later referred to the autism clinic of the Pediatric Hospital of Coimbra. At 3 years of age, he was diagnosed with Autism Spectrum Disorder (level 2 severity), with associated cognitive deficits.

Currently attending the 4th grade at the Basic Education School of Anadia, benefiting from support in Especial Education Unit that provides him with structured teaching model (TEACCH) and the application of interdisciplinary intervention methodologies. In the school context, he also has Speech Therapy sessions.

He is a student with a specific individual curriculum (with changes in the common curriculum, which translates into the introduction, substitution and/or elimination of objectives and contents). Every day for two hours, he attends the regular classroom, with the purpose of working socialization. Functional areas (functional Portuguese, world knowledge, functional mathematics and Daily Live Activities) are taught in the unit.

At home, his favorite activities are to watch television and play computer games, so when asked about his professional or future preferences, he mentions that he would like to stay at home with his mother watching television and playing computer games.

Nuno has a good knowledge of the basic functions of the computer; however, he only uses that knowledge to play. Alone, he is not able to search information in different search engines, nor does he use social networks as a means of communication.

He demonstrates a good level of understanding of simple oral verbal material, namely, words and phrases related to your family and social daily life. On the other hand, he shows difficulties in understanding longer sentences (coordinated and subordinate complex sentences), without visual support and decontextualized.

The privileged form of communication is speech. [Produces predominantly short phrases, with simple syntactic structure of (subject + verb + object). At the level of reading, he recognizes all the letters of the alphabet, but still demonstrates difficulties in the mechanization of reading processes, making a sketchy reading, with some loss of meaning and hesitation]. He writes with orthographic correction but needs support in structuring small texts and responding to questionnaires. He also presents difficulties in the use of markers and morphosyntactic constituents, namely, omission of connecting words in the sentence (mainly, prepositions), difficulties in the agreement of articles defined in gender and in number and difficulties in verbal inflection, according to the personal pronoun used (example: I do).

He makes requests only within his area of interest, has difficulty answering questions when asked, sharing experiences of everyday life and starting and maintaining a conversation. He shows difficulties in maintaining eye contact, respecting shifts of interaction and adjusting

to the context and the interlocutor. In some situations, he continues to verbalize incoherent phrases and out of context (delayed echolalia).

In a school context, when he does not recognize his surroundings, he walks from one side to the other, not asking staff for help. [He is anxious whenever he changes his routine or when he is annoyed, showing inappropriate and sometimes aggressive behaviors like screaming, pinching and biting who is around].

He manifests deficits of attention/concentration, namely to remain attentive in a classroom context, easily discouraging if the proposed activity is not to his liking.

When it comes to activities of daily live (dressing, personal hygiene), he can usually complete tasks with autonomy, requiring, on time, supervision to follow the sequence of actions.

Motivation: Nuno wants to be as autonomous as the other children. He wants to be able to stay in regular education class with the other students and be friends with all of them. He wants to stop going to special education class, where he feels alone. He also wants to communicate more with his family, when he is at school, and with his friends, when he is at home. He wants to do that by sharing his school activities with his parents and chatting with his best friend, Gabriel.

Laura Rocha

Laura Rocha, born November 23, 1973, is a native of Moita, municipality of Anadia, Aveiro district. She is married to Miguel Rocha and has two children, a 13-year-old girl (Sofia Rocha) and a 10-year-old boy (Nuno Rocha), who is diagnosed with PEA.

She holds an academic degree corresponding to Master's, and her profession is architect. She recently set up a studio at home, so she could spend more time and provide extra support for her child outside school hours.

[When she received the news that her son had a diagnosis of ASD, Laura says she experienced moments of anguish, fear and disappointment over the lack of the idealized child. However, after the initial shock, she looked realistic and positive on her son's limitations].

Because her husband spends much of his time on business trips, she plays the role of primary caregiver and is responsible for the overall care of her children.

She is a very interested and committed mother in all matters related to the school of the children, continually accompanying their school's progress. Usually shares information and asks for help in answering questions about her son's day-to-day life.

Her favorite hobbies are reading, playing the piano and traveling. However, since Nuno was born, traveling is a rare occurrence as it is extremely disturbing, making him have aggressive behaviors and anxiety.

She does psychotherapy every fifteen days since her son had five years, saying that this kind of therapy helps her deal with the anxiety and stress that the demands of taking care of a child with ASD cause in her daily life.

She mentions that her main concerns are based on the uncertain future of her son, whether he will be able to attend university, whether he will be able to engage in a professional activity or simply whether he will be able to be autonomous.

Motivation: Laura wants to be able to follow Nuno's day and easily communicate with his teacher to follow his learning process.

Beatriz Rocha

Beatriz Rocha, born on August 30, 2001, is a native of Moita, municipality of Anadia, Aveiro district. She lives with her 10-year-old brother, mother and brother, who is diagnosed with PEA.

Currently attending the 8th grade at the school of 2nd and 3rd Cycle of Basic Education in Anadia. She is a committed student with exemplary behavior. Demonstrates a good command in the use of the functions of the computer, using them mainly, to be able to access the various social networks and to carry out several researches.

Her extracurricular activities are ballet and violin music. At home, she likes to watch television, read and help her mother with housework.

In spite of the special characteristics of the brother, she refers that she can establish a good relationship with him. When Nuno demonstrates destructive and noisy behavior, she tries to calm him, giving him time and showing him how to react. Furthermore, at school, during breaks, when other children make fun of him or mistreat him, she tries to protect him.

When she was younger, she sometimes felt jealous of him because he had most of their parents' attention. However, she now understands that her brother requires a lot of care from them, dealing well with the reduced attention they give her.

When asked about her professional preferences or about the future she mentions she would like to attend the university and obtain a degree in special education, so she can help children with the same diagnosis as her brother.

Motivation: Beatriz wants to have a more active role when it comes to taking care of Nuno. She wants to show him that she supports him by encouraging him in his activities.

Sofia Rodrigues

Sofia Rodrigues, born May 3, 1989, a native of the city of Aveiro, is single and lives with her parents.

In terms of academic training, she graduated in Basic Education and has a Master's degree of Pre-School Education and 1st Cycle Teaching. She also has training in "Detention of Child Abuse Treatment" and "Sign Language Level I".

At the moment, she teaches students on the 4th grade of the Basic Education School of Anadia. She 2 years of teaching experience; however, she has only one student with ASD integrated into her regular education class in the course of seven months. Since her class consists of approximately 20 students, she mentions that it is difficult to provide the

amount of attention that children with this condition require. In addition, the ASD student often challenges her authority, refusing to perform assignments, and demonstrating recurring opposing behaviors such as shouting, tearing, or sticking worksheets with the pencil. By his own will, he rarely looks to establish eye contact or interact with the teacher. This way, she plays a small role in Nuno's teaching as compared to the Special Education Teacher. In the future, she wants to learn more about this area of intervention.

Her main interests are literature, cinema and a painting. In her free time, she likes to practice swimming and do handwork. In the weekends, she likes to walk outdoors.

Motivation: Sofia wants to be able to interact better with Nuno and help him in his learning process. She wants to be able to do that without having to do things differently for Nuno and the other students.

Gabriel Pereira

Gabriel Pereira, born on March 1st, 2005, is from Moita, municipality of Anadia, Aveiro district. He lives with his father, mother and two younger twin sisters. He currently attends the 4th grade at Basic Education School of Anadia. He is a great student who likes all subjects. He has a good knowledge of computer and mobile devices, especially computer games. At home, he loves to text his friends, play computer games with them and play with his little sisters. His favorite extra curricular activities are playing computer games and rollerblading. In the future he wants to create computer games. At school, Gabriel is one of Nuno's classmates. They met in kindergarten and have been best friends ever since. However, recently they have not spend much time together because of Nuno's special education classes.

Motivation: Gabriel wants Nuno to spend more time with him in the regular education class.

Persona Identity Cards

Persona	Relation to Nuno	Characteristics
Nuno	-	**Age:** 10 **Gender:** Male **School Year:** 4th **Diagnosed Condition:** ASD with associated cognitive deficits. **Speech:** No specific speech impairments. Speaks mainly in simple, short sentences. **Writing:** Has some difficulties, prefers to use other methods when possible.
Laura	Mother; Primary Caregiver	**Age:** 41 **Gender:** Female **Profession:** Architect
Beatriz	Sister	**Age:** 13 **Gender:** Female **School Year:** 8th

Table 3.1: Brief Persona Description - Part 1

Persona	Relation to Nuno	Characteristics
Sofia	Regular Education Teacher	**Age:** 26 **Gender:** Female **Education:** Graduate in Basic Education and Masters Degree in Pre-School Education and 1st Cycle Teaching; Training in "Detection of Child Abuse Treatment" and "Sign Language Level 1".
Gabriel	Best Friend	**Age:** 10 **Gender:** Male **School Year:** 4th

Table 3.2: Brief Persona Description - Part 2

3.2 Scenarios

Now that the Personas are established, the next step is to define the scenarios. When creating them, two main locations will be taken into consideration: school and home.

When thinking about the interaction between Nuno and the other Personas, we will consider two main forms, direct messages and sharing memories.

3.2.1 Scenario 1 - Sofia

Scenario description:

Sofia informs parents about a field trip.

Sofia is in the teachers' room before classes. She just got confirmation of the field trip the teachers were planning for next month. She wants to make that information available to students and parents. To do so, she goes to her computer in the teacher's room and fills the information about the field trip, including the schedule for the day and gives that information to the relevant classes.

Sofia prepares an exercise for her students.

After that, Sofia goes to Nuno's portuguese class. There she wants students to answer an exercise. For the other students, she writes the exercise on the board and tells them to answer in their notebooks. For Nuno, she writes down the exercise on a paper and goes sit next to him. She tells him to read the exercise and tell her if he doesn't understand it. When he is ready, she tells him to give her the answer out loud instead of writing.

Scenario 1 describes how an application could be used to help Sofia with two use cases:
- Create a field trip and share it with her students, their parents and guardians;
- Share an exercise for her class that can be answered by Nuno as well as the other students;

3.2.2 Scenario 2 - Nuno

Scenario description:

Nuno interacting with a new friend.

Nuno is in the school yard before classes. There he sees the new student who just got to his class. The new student wants to be friends with Nuno. He approaches Nuno and asks if he wants to be friends with him, maybe they can keep each others contacts and play together when they go home. Nuno thinks it is a good idea. He goes to his tablet and add the new friend.

Nuno answering an exercise.

Nuno is in his regular education portuguese class where his teacher asked the students to answer an exercise. She told him he could answer out loud

instead of writing. Because he prefers speaking over writing, he choses to do so.

Nuno doing homework.

Later that day, at home, Nuno is doing his homework when he has a doubt regarding one of the questions. He contacts his teacher to ask for help on that.

Nuno sharing a memory.

In the next portuguese class, the teacher gives back all students their answers to the exercises. Nuno receives a paper where his teacher had written down his answer and gets happy for having a good mark. He then feels like telling everyone about it. To do so, he goes to his tablet, takes a picture and shares it.

Nuno checking the schedule of a field trip.

A month after that, on the day of the field trip, Nuno is at home eating his breakfast and decides he wants to know the schedule for the day. To do so, he goes to his tablet and opens the field trip. He feels comfortable to see the schedule and who is accompanying him.

Nuno saving a memory.

A few hours later, already in the field trip, Nuno wants to take a picture with his friends and save it so he always remembers the good time he his having. He goes to his tablet, takes the picture and saves it next to his other pictures of memories he cherishes.

Nuno sharing memories with Gabriel.

On the next day, when Nuno is back at school he talks to his best friend Gabriel who could not go to the field trip. Nuno feels sorry for him and wants to show him all the nice things he saw so his friend can feel like he was there too. To do so, he goes to his tablet and sends Gabriel all the pictures he took.

Scenario 2 describes how the application can be used on the move to help Nuno fulfill seven use cases:

- Add new friend;
- Answer an exercise;
- Requesting help for his homework;
- Share pictures with his family and friends;
- Check field trip information;
- Saving memories;
- Send photos to his best friend.

3.2.3 Scenario 3 - Laura and Beatriz

Scenario description:

Beatriz commenting Nuno's picture.

Beatriz is at school and notices, on her phone, that Nuno posted a picture. She opens the picture and gets happy for her brother, realizing he had a good mark on an exercise. She writes a comment on the picture, saying she is happy for him.

Laura speaking with Nuno's teacher. Later that day, Laura is at home when she remembers she wanted to ask Nuno's teacher how his learning is coming along. To do so, she goes to her phone and sends a message to Nuno's teacher.

Scenario 3 describes how the application can be used on to help Laura and Beatriz fulfill two use cases:

- Comment Nuno's memory board events.
- Send messages to teacher.

3.2.4   Scenario 4 - Gabriel

Scenario description:

Gabriel helping Nuno with an exercise.

Gabriel is in his portuguese class where he just finished the exercise his teacher asked him to do. Some of the students, like Nuno, are still doing it. A few minutes later he gets a notification containing a message from Nuno on his tablet. Nuno is struggling with the exercise and has asked for his friend's help. Because Gabriel already finished, he is allowed to assist students who ask for his help. He replies to Nuno but does not give him the full answer as he wants him to be able to get it by himself.

Gabriel chatting with Nuno

Later that day, Gabriel receives a message from Nuno. Nuno wanted to thank him for the help on the exercise they made in class. Gabriel answers saying that Nuno can ask for his help anytime. He just wants his best friend to be in regular education class with the rest of their friends.

Scenario 4 describes how the application can be used to help Gabriel fulfill two use cases:

- Helping Nuno with a school exercise.
- Chatting with Nuno.

3.3 Use Cases

Now that the scenarios have been defined, the use cases can be inferred. The use case actors are given by the Personas: Nuno and Gabriel are Children, Sofia is a Teacher, Laura is a Parent and Beatriz is a Family Member.

Memories can be shared in many ways so, for that, the term Event was used. In the context of the application, *Event* is used to refer to items that children can share with others, namely pictures, images, drawings, text, expressions and voice recordings. To support the sharing of those Events between the users, three containers were created: Timeline, Memory Board and Secret Chest. They differ in terms of Event visibility and in the way they are displayed, as explained in table 3.3.

	Display Type	Visibility
Timeline	Timeline view ordered chronologically.	Child, guardian and parents.
Memory Board	Random disposition of Events with title, thumbnail, creation date and description.	Child, guardian, family, friends and teachers.
Secret Chest	Random disposition of Events with title, thumbnail, creation date and description.	Child

Table 3.3: Differences in Timeline, Memory Board and Secret Chest.

Considering all of the above, the following use cases represent actions that each of these actors can perform in the application.

3.3.1 Use Case Diagram

Figure 3.1: Diagram composed of the Use Cases of each role.

3.3.2 Use Case Flow

The following tables illustrate the flow of events that occurs when the user performs an action. From the action itself, to the reaction by the application and the device.

For illustrative purposes, a few examples are presented in what follows while the tables for the remaining use cases are in appendix A. Furthermore, even though all use cases were considered, for demonstration, only the use cases for the children are represented in this manner. They represent the two main forms of communication, direct messages and sharing memories as well as answering an exercise and they assume the user is already logged in and on the main page.

Chat with Friends

Table 3.4 illustrates the use case flow explaining the user's action and the reactions it causes on the application, the user's device and the friend's device.

Use Case: Chat with Friends

User: Nuno

User's Action	Application	User's Device	Friend's Device
Selects friend from main screen.	Gets friend's info	Displays friend's page	
Selects "Chat"	Gets conversation history	Displays conversation	
Selects the text area		Displays Virtual Keyboard	
Writes message and selects "Send"	Sends message to friend, displaying a notification if the friend is not in the conversation screen	Displays message in the conversation	Displays message in conversation screen or notification for that message if user is elsewhere.

Requirements

Interaction: App navigation using touch; Text input using touch with virtual keyboard.

Functional: The application must allow user to chat with "friends".

Table 3.4: Use Case flow for "Nuno chatting with a friend" as well as interaction and functional requirements.

Create Event in Memory Board

Table 3.5 illustrates the use case flow explaining the user's action and the reactions it causes on the application and the user's device.

Use Case: Create Event in Memory Board

User: Nuno

User's Action	Application	User's Device
Selects "Memory Board"	Gets events from database	Displays Memory Board Events
selects "Create Event" as picture, image, drawing, text, voice, expression		Displays interface for event creation
Fills Event information and selects "Confirm"	Saves event to database	Displays successful message

Requirements

Interaction: App navigation using touch; Image recording using device's camera; Text introduction using virtual keyboard; Voice recording using device's microphone; Expression selection using touch; Screen drawing using touch.

Functional: The application must allow children to create different types of Events in Memory Board.

Table 3.5: Use Case flow for "create Event in memory board" as well as interaction and functional requirements.

Answer Exercise Using Alternative Methods

Table 3.6 illustrates the use case flow explaining the user's action and the reactions it causes on the application, the user's device and the teacher's device.

Use Case: Answer Exercise Using Voice Recording

User: Nuno

User's Action	Application	User's Device	Teacher's Device
	Detects new event posted by Nuno's teacher	Shows notification of new exercise and makes it available in Classroom page	
Selects "Classroom"	Gets available exercises from database	Displays Classroom page with available exercises	
Selects exercise to answer		Displays exercise page	
Selects "Answer Exercise"		Displays available alternative methods	
Selects "Voice Recording"		Displays voice recording interface	
Selects "Start Listening", gives answer and selects "Finish"	Saves answer in database	Displays finish message and returns to Classroom screen	Shows Nuno's answer in list of answers for the exercise

Requirements

Interaction: App navigation using touch; Voice recording using device's microphone; Screen drawing using touch; Pictogram selection using touch.

Functional: The application must allow students with SEN to answer exercises with alternative methods.

Table 3.6: Use Case flow for "answer exercise using alternative methods" as well as interaction and functional requirements.

3.4 Requirements

Considering the complete set of use cases, some of which illustrated in the previous section and presented in appendix B, a list of requirements was compiled.

3.4.1 Functional Requirements

The following functional requirements define features that the system should support to enable the users to perform the desired actions.

1. **General requirements.**
   The application:
   - should be able to adapt to the users, whether children with ASD, children without ASD, guardians, family members or teachers;
   - must be able to identify users

2. **Requirements regarding children interaction with the application.**
   The application should allow children to:
   - answer the exercises created for them;
   - create Events as:
          - pictures;
          - images;
          - screen drawings;
          - voice recording;
          - text.
   - tag friends in Events;
   - share Events;
   - search Events;
   - add friends;
   - see other children Events;
   - search other children Events;
   - ask for for the help of a classmate;
   - chat with other children, family members, guardians and teachers.

3. **Requirements regarding family member and guardians' interaction with the application.**
   The application should allow family members (which includes, e.g, the sister) and guardians to:
   - see the Timeline and Memory Board of children they are related to.
   - comment the Events of the children they are related to.

   The application should allow parents and guardians to:
   - register their children accounts;
   - communicate directly with the teachers of their children;
   - edit the information about their children;

- create exercises for children to answer;
- create Events as calendar entries, on their children's Timeline;
- search their children's Events.

4. **Requirements regarding teacher interaction with the application.**

   The application should allow teachers to:
   - add children to their classes;
   - communicate directly with the parents and guardian of each child;
   - create exercises.

3.4.2 Interaction Requirements

Based on how the users are going to interact with the application, the following Interaction Requirements can be inferred.

Modality	Device Capability	Interaction
Touch	Touch Screen	The application must allow user's to navigate using touch inputs; The application should allow users to create screen drawings;
Visual	Camera	The application should be able to track children's gaze;
Auditory	Microphone	The application should be able to record user's voice;
	Speakers	The application should be able to recognize user's speech; The application should be able to give feedback using speech synthesis.

Table 3.7: Interaction Requirements

Now that we have obtained a clear understanding of the users of the system trough the Personas, Scenarios and Goals methodology and we defined the system requirements based on them, the first two steps of the user-centered design are completed. The next step is the development of the proof of concept.

Development of a Proof of Concept

This chapter describes the <u>A</u>daptive <u>M</u>ultimodal <u>I</u>ntegrated <u>C</u>ommunication for <u>Al</u>l (AMICA), the proof of concept developed based in the requirements derived in previous chapter.

Figure 4.1: AMICA's proposed logo.

Adaptive Multimodal Integrated Communication for All (AMICA) is a cross platform application that aims to assist children with communication and social interaction problems, in their daily lives, especially at school. To that end, children with Autism Spectrum Disorders were chosen as a focus group given that the condition meets the issues we are addressing. It is a context aware application that will change its behavior based on the user. This means that it is capable of being used both by children with communication problems and without, by family members, parents, guardians and teachers. Three main components were chosen to cover the motivations of the Persona and the proposed user stories and scenarios based on them: direct conversation, Events and Activities.

Even though we took children as the center of this dissertation, as studied in the Chapter 2, assisting communication between teachers and parents is also relevant. Therefore, AMICA facilitates not only the communication between children with ASD and other children, their parents and teachers but also between parents and teachers themselves.

To address the children's communication issues, trough a set of multiple modalities, children that would not otherwise communicate well with others, will be able to express themselves either by chatting with their friends using text, pictures, images or even their voice or creating Events like diary entries. To address their fear of the unknown, parents and teachers can create Activities as field trips and specify places and schedules so the children can be aware of what to expect. Apart from assisting with communication it is also meant to assist teachers when it comes to teaching students with SEN. Many teachers have a major difficulty in including these students in their classrooms. AMICA can help them connect with all of their students not only as a place where they can make class Activities available but also by adapting the content to the type of student allowing for alternatives that might address different characteristics of the children.

Therefore, with this dissertation, in the form of this proof of concept consistent with the objectives proposed in Chapter 1, we show that it is possible to have a single application capable of being used by users with different roles and types of communication problems, in different devices and platforms that assists in their contact with each other. This application is the groundwork that will allow new features to be added in the future as a continuous effort.

4.1   Iterative User-centered Development

The development method used in our work is Iterative User-centered focused on Personas, Scenarios and Goals. As explained in 2.5.2 each iteration is started by defining the requirements, followed by the development of the necessary components for the requirements to be met and finally an evaluation with users.

Overall, the development of the Application comprised four iterations:

1. Initial mock-up of the application;
2. Children interaction with the application and others;
3. List of Activities and Activity details;
4. Creating and answering Activities.

A more detailed description of the main aspects of each iteration is presented in the following sections.

We opted to include children in the evaluations only when the application already had a stable base and all features related to the children could be tested.

4.2 AMICA's Multi-platform and Multi-device Architecture

In this section we describe the architecture of AMICA taking into consideration our objective of making it a multi-platform, multi-device Application.

4.2.1 Architecture

Considering the technologies referred in section 2.6, figure 4.2 represents the overall architecture of AMICA. Given that the Application is going to be developed using Cordova and web technologies, namely HTML, JavaScript and CSS, it can be accessed by any device prepared for such technologies. They allow us to code only one version of the application that can be deployed in multiple platforms. Users can access the Application on their devices by accessing the website on their desired browser. However, to demonstrate an easier way to access the Application, we deployed an Android version. This version has the exact same code as the web version, however it was compiled by Cordova into an Android Package file (apk) so as to be ran by an Android device. Android runs the application trough a web view, thereby, simulating a native application to the end-user.

The web version as well as all the services and databases will be deployed on a server running in the schools that adopt the system. All services are be developed using Spring and Java and all databases using PostgreSQL. Services are then ran on Tomcat. That way, except when accessing AMICA through a mobile device running the mobile version of the Application, all logic is ran on the server, taking workload away from the user's device. Therefore, communication with the school server is absolutely necessary otherwise the Application would not be able to run.
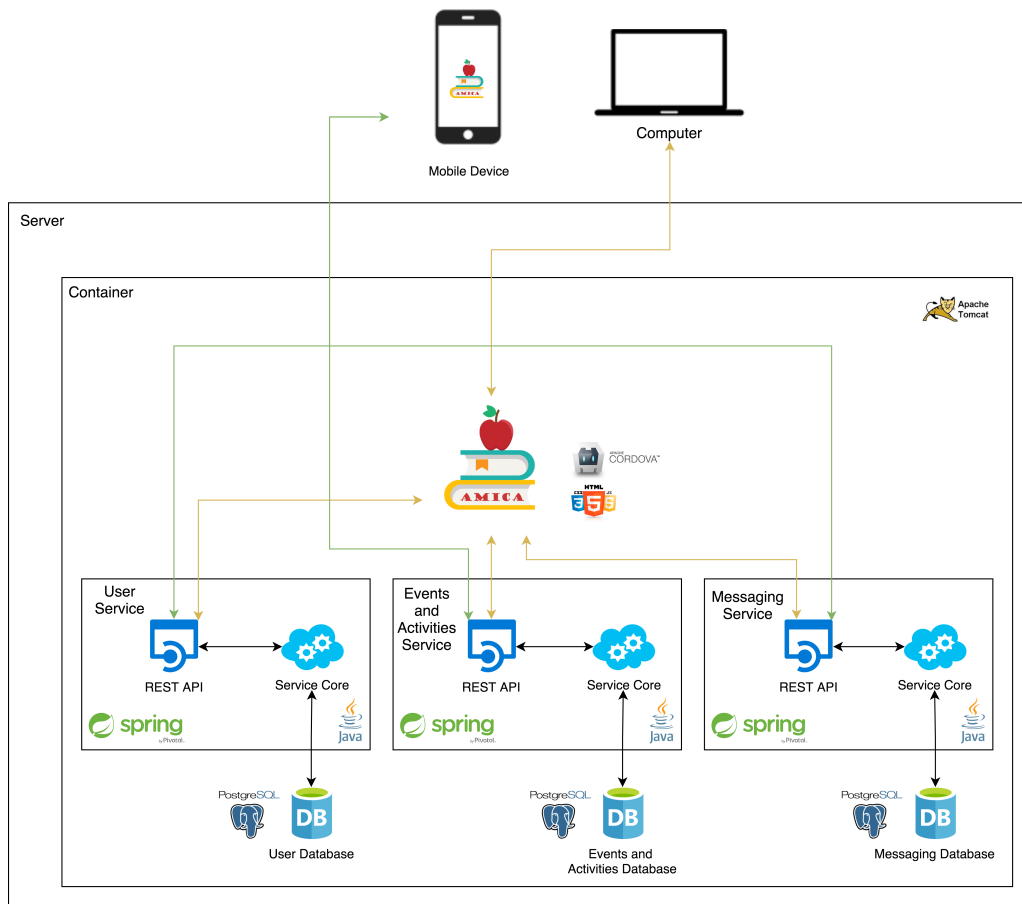
Figure 4.2: AMICA's overall architecture.

Figure 4.3 represents the architecture from the perspective of the user, considering the two main locations where the Application will be used.

As explained above, all services and the web version of the Application will be running on a server owned by the school.

Users accessing AMICA trough the mobile application will have the Application logic on their devices and it will connect to the school server to communicate with the services. On the other hand, users accessing AMICA trough the web version will have everything running on the server.

Figure 4.3: AMICA from the perspective of the users and locations.

4.3 First Iteration - Mock-ups

Iteration one consisted on the design of the mock-ups for the Application. The mock-ups were evaluated internally by a multi-disciplinary team and served as base for the interface.
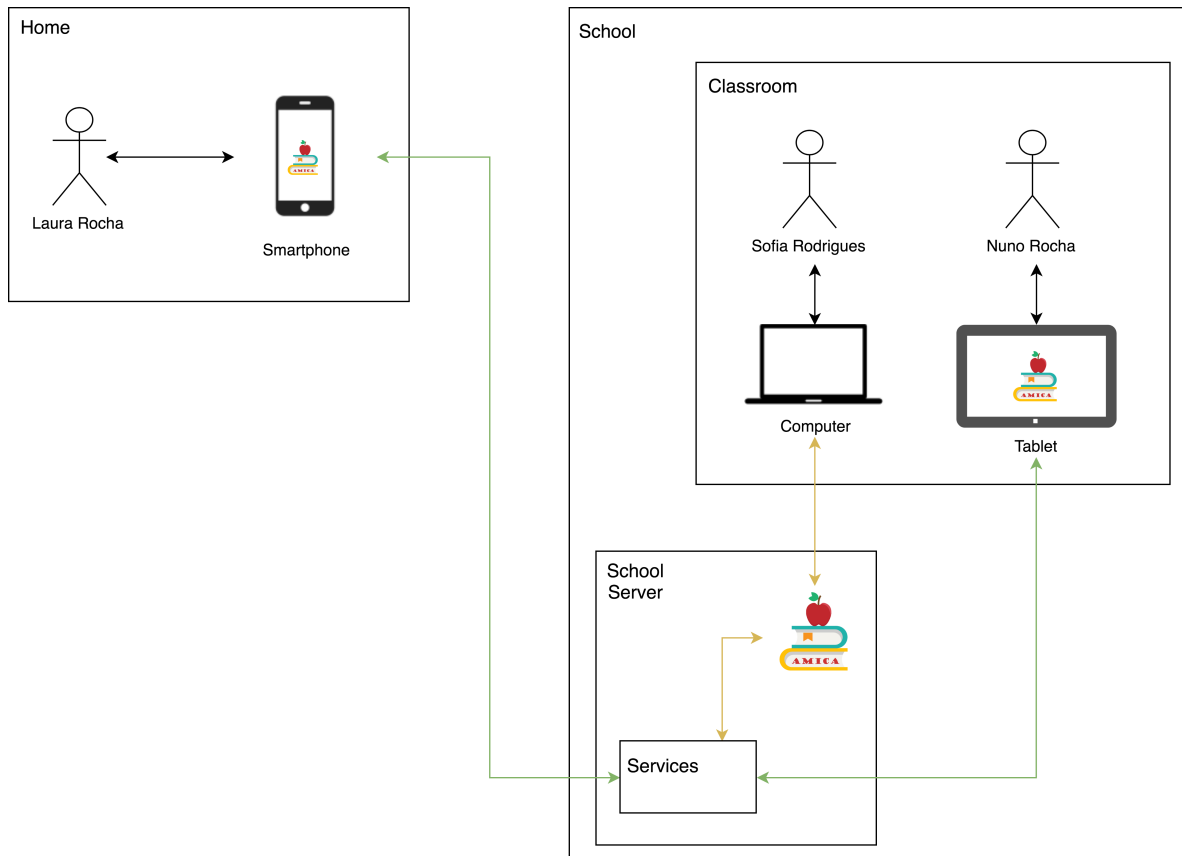
They show the way users can interact with the Application having in mind the core forms of connection: direct messages, sharing of memories.

4.3.1 Mock-ups for Children Interaction with the Application

Henceforth, the term "friends", when used alone, will refer to users related in the Application. This includes school friends, family members, guardians and teachers. Children mock-ups were designed having in mind what the interface should look like to be appealing and easy to use by children. The Application Hub is designed to be a place where all functionalities could be easily accessed from. It is divided into four main areas. First, in the top of the screen, children can see their friend's avatars in a way similar to social networks so that direct communication with them is easily recognizable. In the middle, they can access school or family Activities as well as communication with the family. At the bottom children can access their Events or Events they are tagged in.

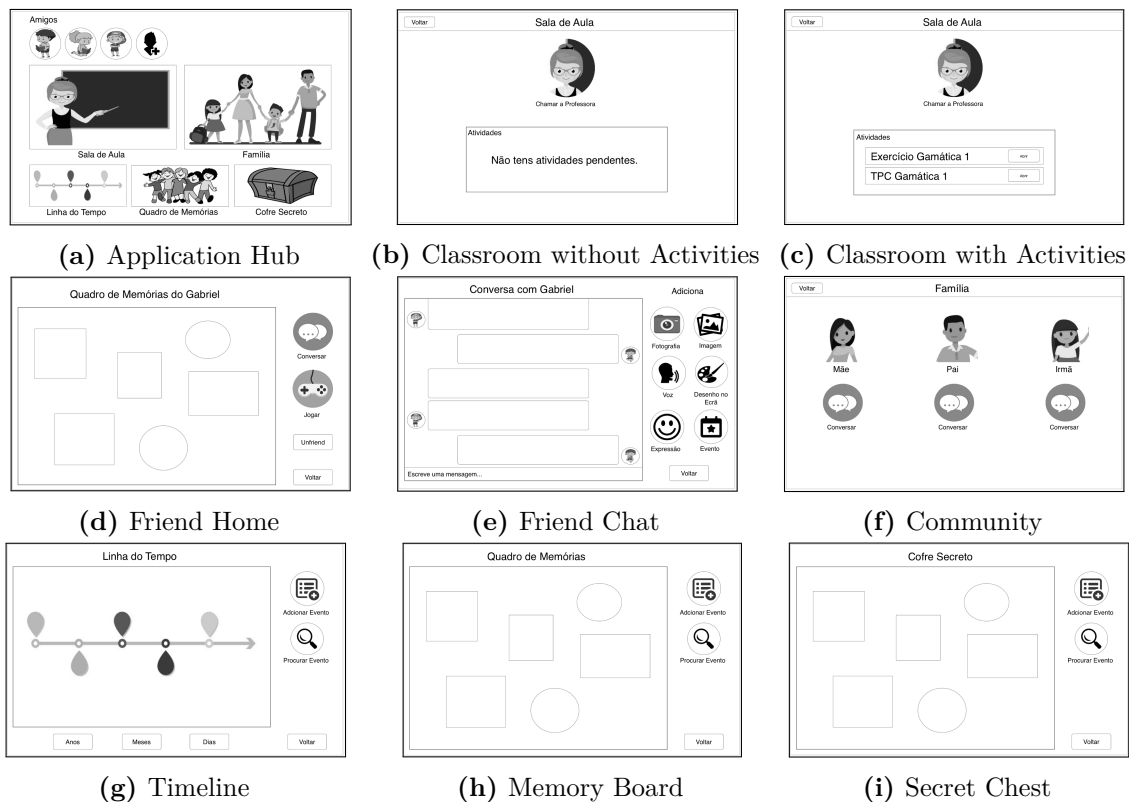**(a)** Application Hub **(b)** Classroom without Activities **(c)** Classroom with Activities

(d) Friend Home **(e)** Friend Chat **(f)** Community

(g) Timeline **(h)** Memory Board **(i)** Secret Chest

Figure 4.4: Children View Mock-ups Part 1

(a) Event Details   **(b)** Add Event   **(c)** Add Event Picture

(d) Add Event Image   **(e)** Add Event Drawing   **(f)** Add Event Text

(g) Add Event Expression   **(h)** Add Event Voice   **(i)** Search Event
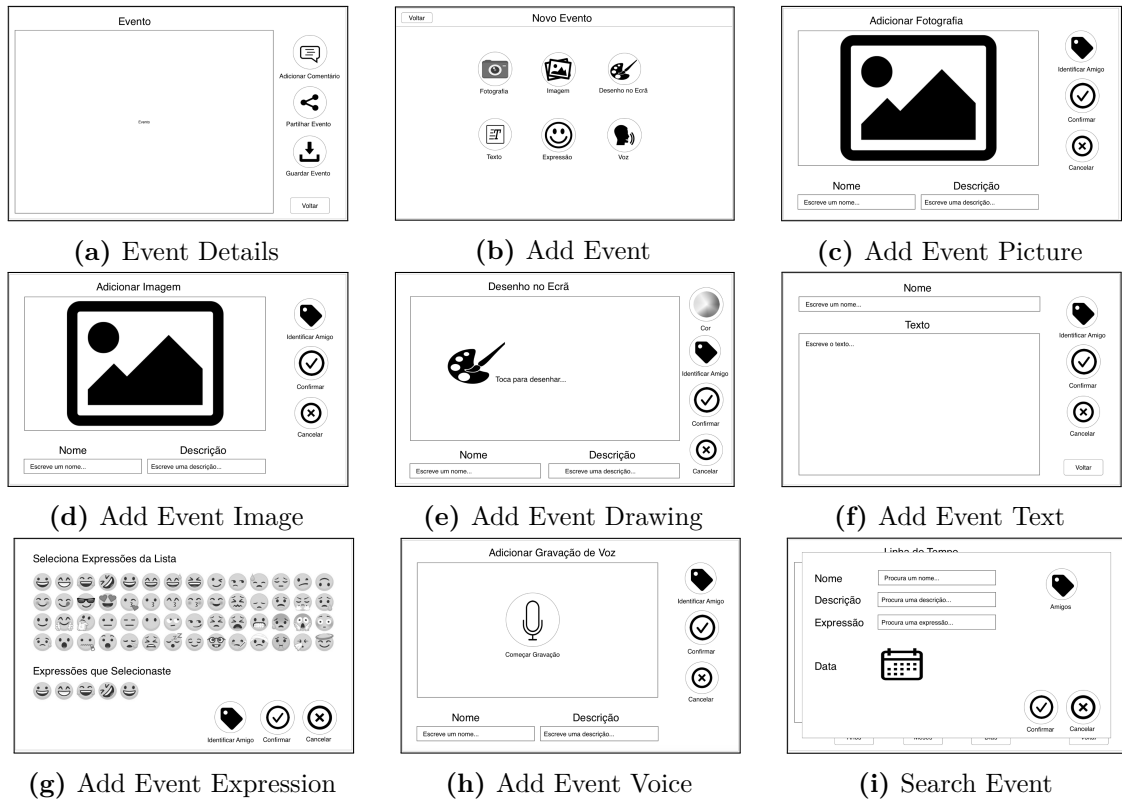
Figure 4.5: Children View Mock-ups Part 2

4.3.2 Mock-ups for Teacher Interaction with the Application

Teacher mock-ups were designed to have a more minimalistic interface where all features were clearly accessible. The Application Hub is divided into three areas so teachers could easily access the most important features: classroom, students and parents and guardians.

(a) Application Hub   **(b)** Classroom   **(c)** Add Activity

(d) History of Activities   **(e)** Activity Details   **(f)** Current Activities

Figure 4.6: Teacher View Mock-ups Part 1

(a) Students   **(b)** Student Details   **(c)** Student Conversation

(d) Parents and Guardians   **(e)** Parents Details   **(f)** Parent Conversation
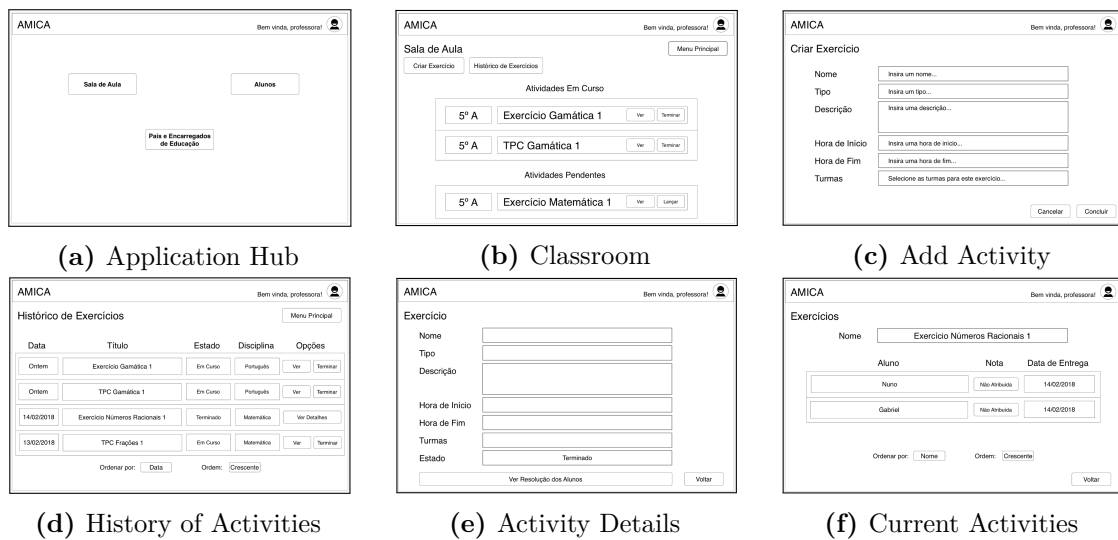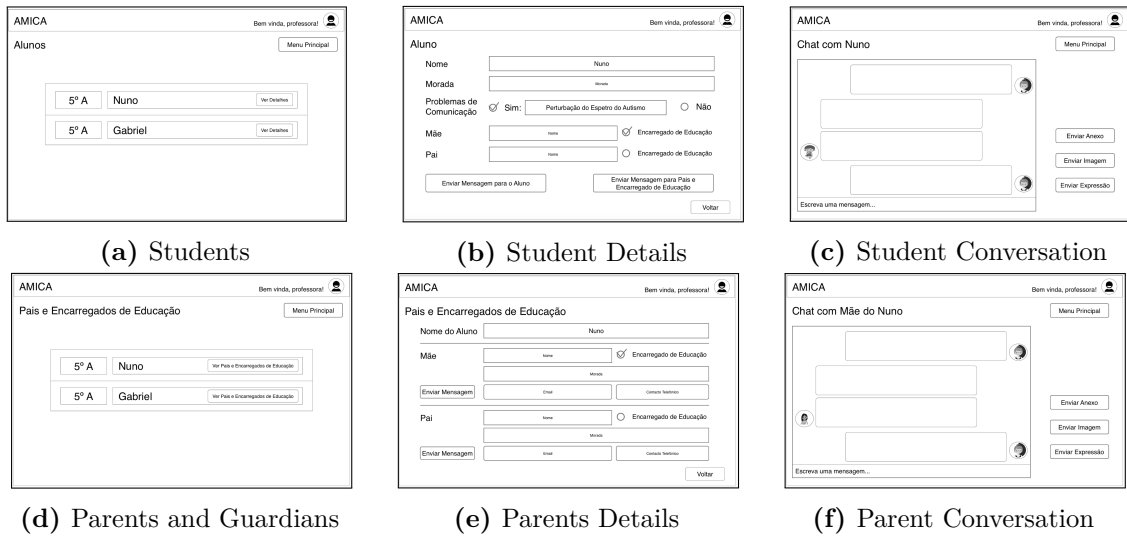
Figure 4.7: Teacher View Mock-ups Part 2

4.3.3 Mock-ups for Family Interaction with the Application

Family mock-ups where designed to have the same type of minimalistic interface as the teacher's where all features were clearly accessible. The Application Hub is divided into three areas so teachers could easily access the most important features: school, children and events.

(a) Application Hub   **(b)** School   **(c)** Teacher Chat

(d) Children   **(e)** Children Timeline   **(f)** Children Memory Board

(g) Event Details   **(h)** Event List   **(i)** Student Conversation

Figure 4.8: Family View Mock-ups

4.4 Second Iteration - Children Interaction with the Application and Others
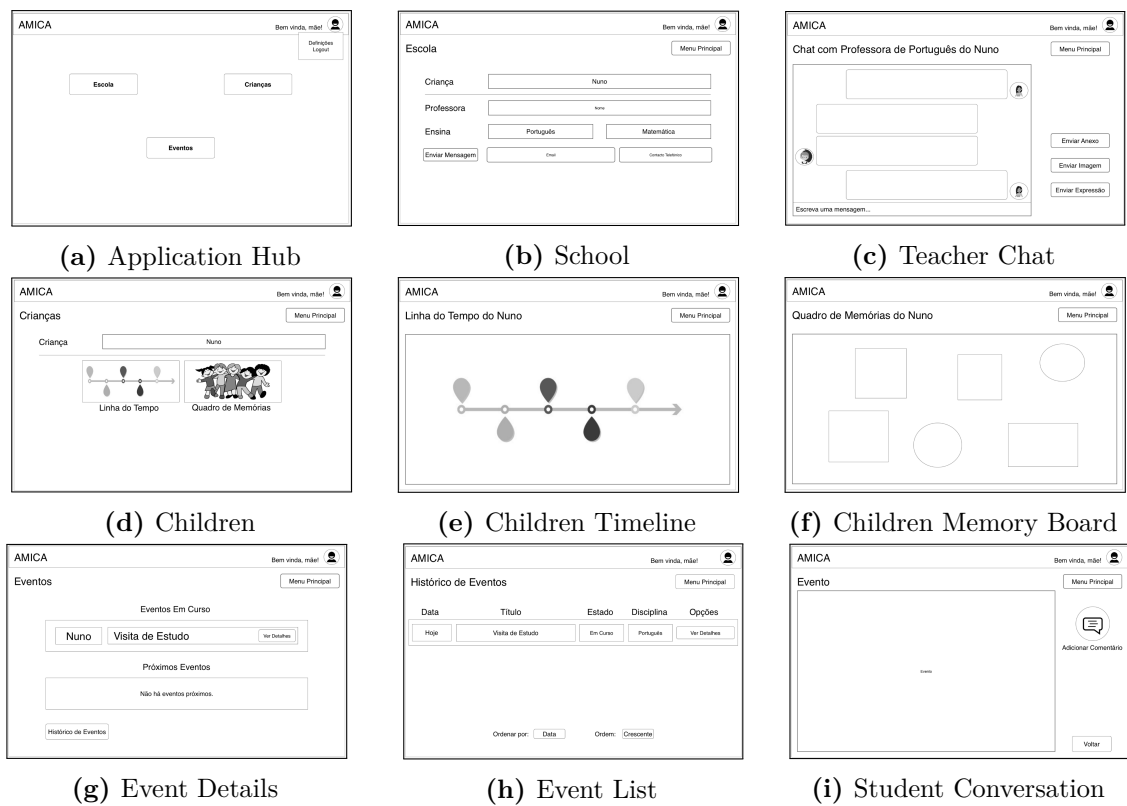
Taking into consideration the target users of the system, we concluded that the features that should be implemented first were those of the children (see section 3.4), given that AMICA is designed with special focus on children with communication problems.

4.4.1 Requirements

After choosing children specific features as the primary focus for this iteration, it is necessary to choose which features take precedence over the others, focusing on the core features that will make children use the Application. The first component is Events. As stated in chapter 3, Events is the term used to refer to items that children can add to their Timeline, Memory Board and Secret Chest, namely pictures, images, drawings, text, expressions and voice recordings. Not only that, Events are the main way for children to interact with the other users of the Application as they will allow children to express themselves to others and keep track of what's important to them, like a diary.

With that in mind, the functional requirements for the second iteration are as follows.

The Application should be able to:

- allow children to create Events as:
  - pictures;
  - image;
  - screen drawings;
  - voice recordings;
  - text.
- tag friends in Events;
- share Events;
- search Events;
- see other children Events;
- search other children Events;
- allow children to chat with other children, family members, guardians and teachers.

4.4.2 Development

The second iteration is the most time consuming of all as it encompasses the creation of the Application and back-end to support it.

Development was made in stages. Firstly, the implementation of the children Application Hub. Secondly, the Timeline, Memory Board and Secret Chest. Thirdly, the Event Details. Fourthly, the Conversation. Fifthly the Community, Children and Students (as they are very similar). Finally, in sixth place, the Authentication and the Application Hubs for family members and teachers.

Children Application Hub

The children Application Hub is designed to have more visual cues with images that are intended to provide a more appealing interface for children.

Two changes were proposed in the design of the children Application Hub, when reviewing the mock-ups. The first was the action when selecting one of the friends' avatars. Instead of taking the child to the friend's home, where the friend's memory board would be available, we opted to a more direct approach. The friends' avatars were intended to provide access to the friends' conversations as that would be the desired action in the majority of the times. In sum, selecting the avatar of a friend will now take the user to the conversation with that friend. To complete the first change, the second change was the alteration and rename of the family area to include all of the child's community. Should the children want to access information on their friends or their friend's memory boards, this would be available trough the community area. This way, the new Application Hub would still be divided into four areas as in the mock up, however, the family area would be replaced by a community area that the children would access whenever they wanted to interact with their school friends, family, guardians or teachers.

In sum, from the Application Hub, children can quickly access:

- their **friends'** pages to chat or watch their Events;
- the **Classroom** to access school Activities;
- **Community** to access information about family, friends and teachers;
- **Timeline**, **Memory Board** and **Secret Chest** to create or watch their Events.
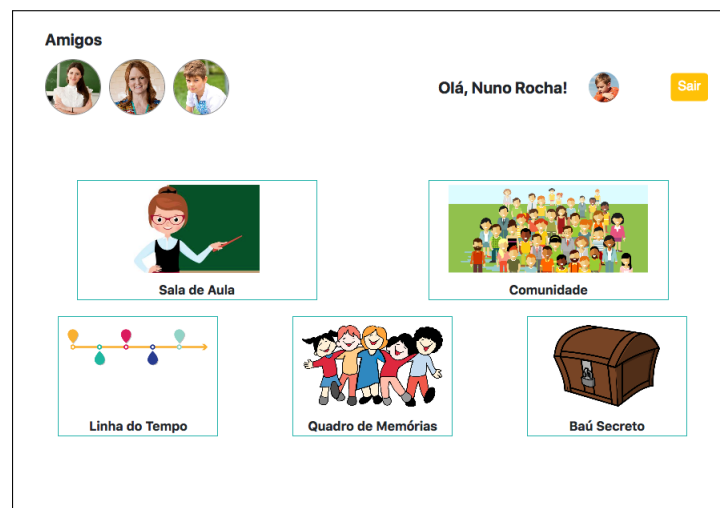

Figure 4.9: Children Application Hub

Timeline

The Timeline displays Events in chronological order. As stated in table 3.3, the Events in the Timeline are only visible to the child who created them, to users that have been tagged on them and to the child's parents and guardians. The Timeline is the default Event container

but Events on the Timeline are not restricted to it. Events on the Memory Board will still show on the Timeline, however, Events on the Secret Chest will not. Children can create Events as pictures, images, drawings, text, expressions and voice recordings.

(a) Timeline View

(b) New Event Type Selection

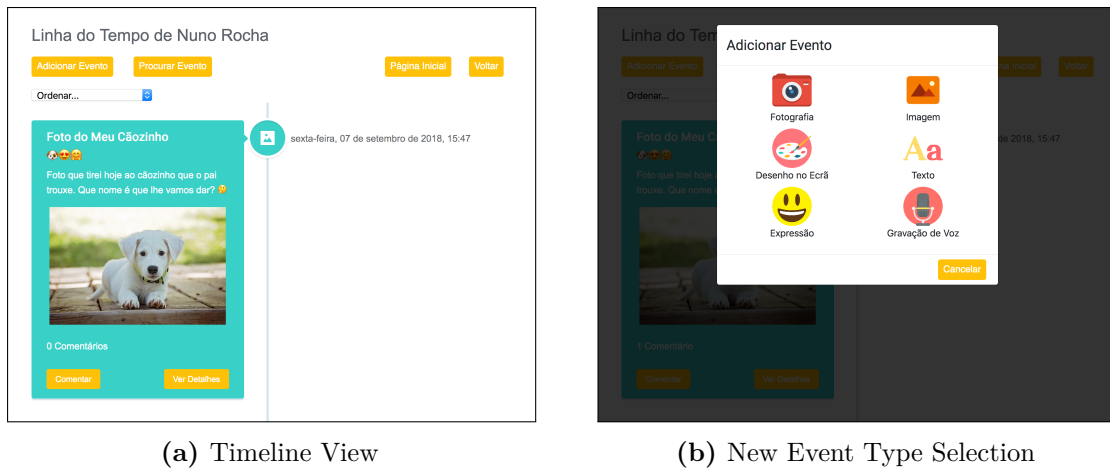**Figure 4.10:** Timeline

Users can search Events based on one or all of the following parameters:

- **term**, searches keywords or text in title and description;
- **expression**, searches expressions in the form of emojis on the expression field;
- **type**, searches by type;
- **friends**, searches by tagged friends;
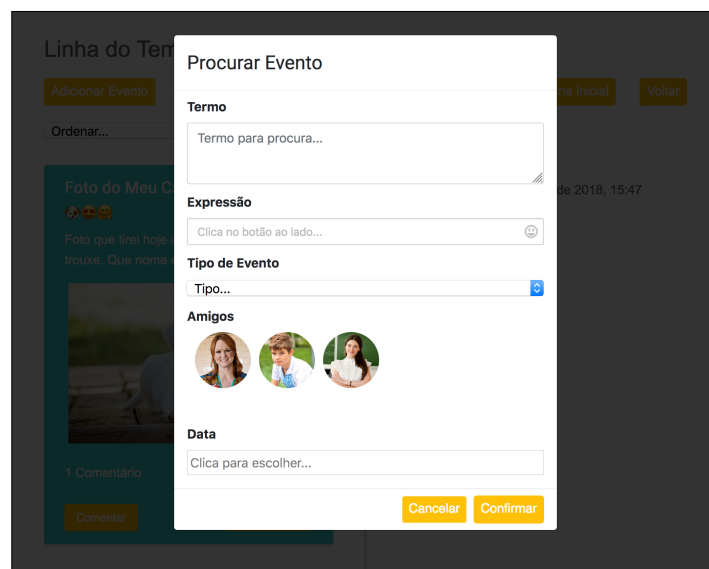- **date**, searches by creation date.

Figure 4.11: Timeline Search

Memory Board

The Memory Board displays Events that the child wanted to highlight. As stated in table 3.3, the Events in the Memory Board are visible to the child who created them, their family members, friends and teachers.
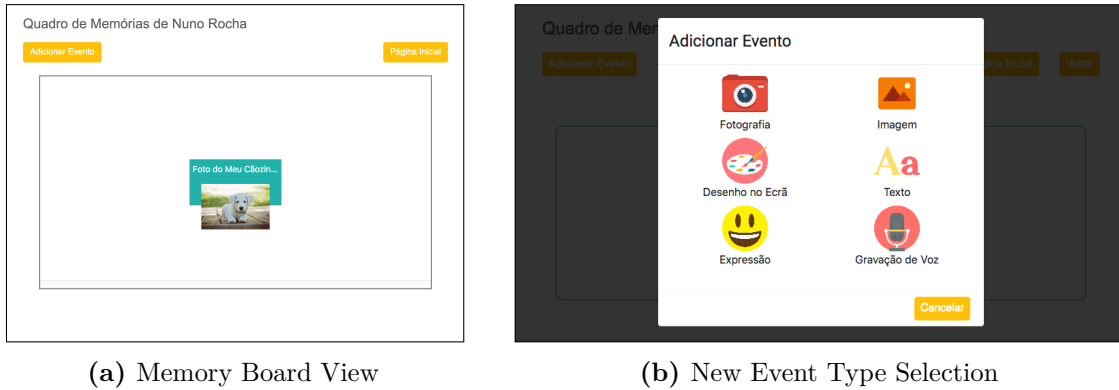

(a) Memory Board View

(b) New Event Type Selection

Figure 4.12: Memory Board

Secret Chest

The Secret Chest displays Events that the child wanted to keep secret. As stated in table 3.3, the Events in the Secret Chest are only visible to the child who created them.

(a) Secret Chest View
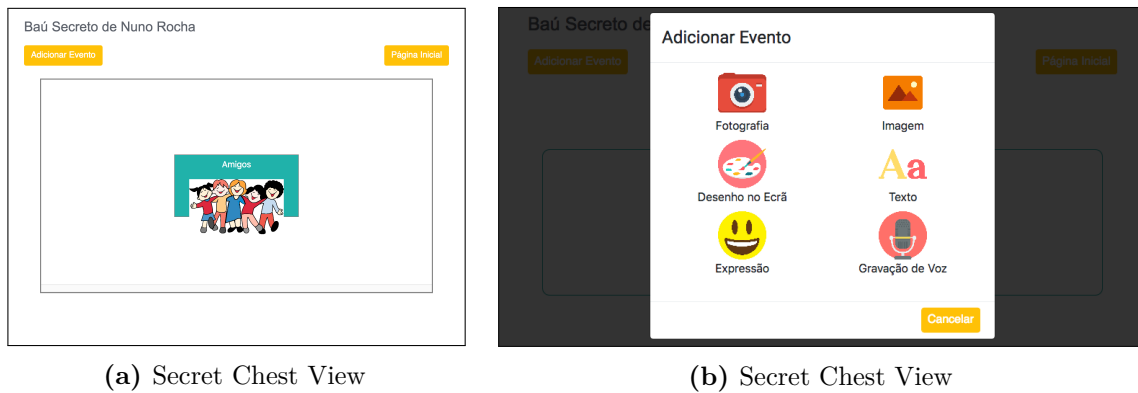
(b) Secret Chest View

Figure 4.13: Secret Chest

For better understanding, let us refer to Timeline, Memory Board and Secret Chest as Event containers. Events can be created directly in any of them and they will have the visibility defaults of that container. However, the owner can freely move Events between containers thereby changing their visibility.

Event Details

The Event Details shows the details of the Event as well as any comments it may have. The owner will have the options to move or delete the Event and the viewers will have the option to comment it.
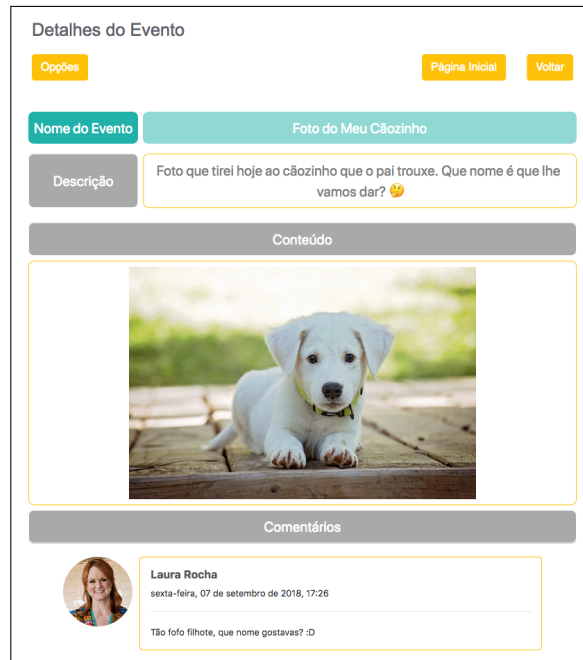
Figure 4.14: Event Details

Conversation

In the Conversation, users can send messages as text, images, voice recordings and drawings.

Activities will also be shown on the parent-child or teacher-student Conversation when created if they are created by a parent or teacher, respectively.

Figure 4.15: Conversation

Community, Children and Students

The Community, Children and Students have the same layout, displaying a list of users and the option to show their information.

(a) Details Hidden   **(b)** Details Expanded
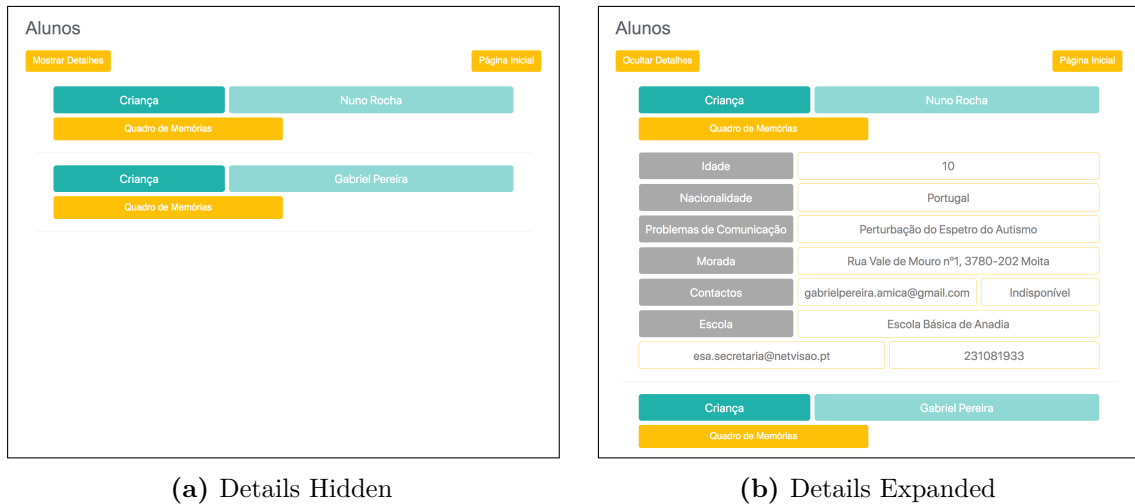
Figure 4.16: Students View

Family and Teacher Application Hubs

To better fulfill the objectives of the parents, that want to have more contact with their children's teachers and their children's progress in school, the family Application Hub was changed to allow direct access to teachers and Activities.

Therefore, the family Application Hub allows access to features related to contact with school and children, namely:
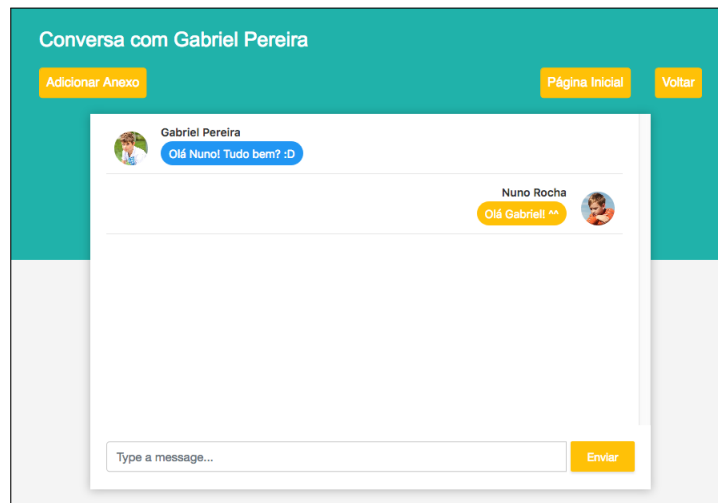
- **Teachers** to see their children's teachers and send messages;
- **Activities** to see their children's Activities;
- **Children** to see their children and send messages.

Figure 4.17: Family Application Hub

The teacher Application Hub was also changed. For clarity, the Classroom area was renamed to Activities to better describe its content.

Therefore, the teacher Application Hub allows access to school related features, namely:

- **Activities** to see and create school Activities;
- **Students** to see students and send messages;

66

- **Parents and Guardians** to see parents and guardians and send messages.

Figure 4.18: Teacher Application Hub

Authentication

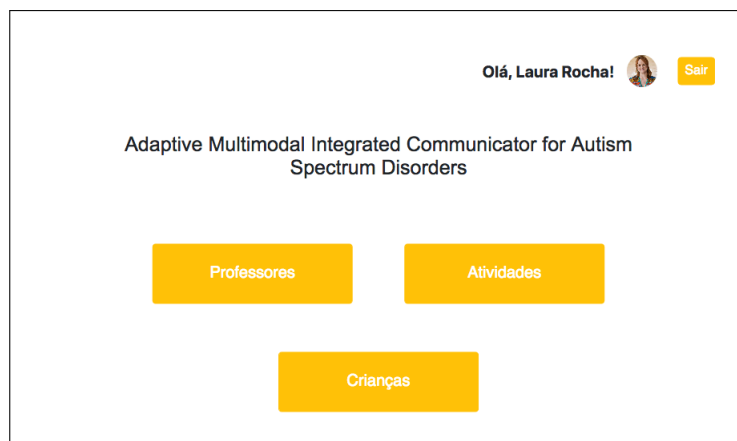Firstly, given the Application is meant to be used by different types of users, an authentication method is necessary. Furthermore, the Application can be used on different devices including a web browser, so a method of authentication that is capable of signing in a large amount of users across multiple devices is required. In this case, we chose Google Sign-In.
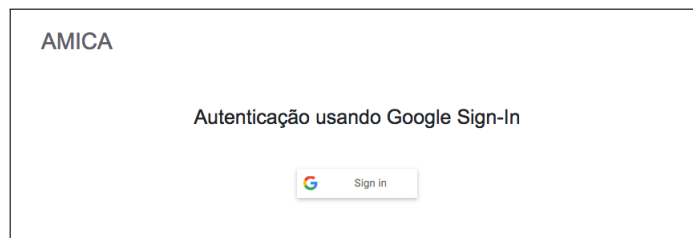
Figure 4.19: Login with the option for Google Sign-In.

By signing in to their Google accounts, the users are agreeing to the usage of their basic information by the system. After signing in to their account and Google successfully identifying the user, a token is generated and used to authenticate the user in AMICA's User Service. In return, the User Service will provide the application with the user information that will be used on operations in the application and on communications between Application and services. One of the used parameters in this step is the type of user. There are five possible user types: child, parent, guardian, family or teacher. This information will be used by the Application to access which home layout to be shown to the user out of the possible three: child, teacher and family. Once the application assesses the type of user that is logged in, it redirects him to the respective Application Hub.

4.4.3 Evaluation

Being the first effective contact with users, we wanted to evaluate the interface to identify possible usability problems. For that, we chose to perform an Heuristic Evaluation.

We asked four users to evaluate the application, henceforth, called evaluators. The evaluators consisted of three male and one female. All were students of Computer and Telematics Engineering and were, therefore, familiar with Heuristic Evaluations. At the time of the evaluation all had twenty four years old. The evaluators were invited to freely use the Application in the persona of Nuno Rocha. If they encountered any usability problem they should report it in the corresponding Nielsen Heuristic.

At the time of this evaluation, the teacher features were already being developed, specifically the Classroom that had a specific layout for the list of Activities. The evaluators were invited to preview the Classroom and suggested that the Activities layout should also be applied to the list of Events in the Memory Board and Secret Chest.

4.4.4 Results

Table 4.1 illustrates the results of the evaluation, more concretely, presents each problem represented as a letter for identification, followed by the recommendation given by the evaluator, the corresponding Nielsen Heuristic and the severity.

Problem	Recommendation	Heuristic	Severity
A	Modify the layout of the Memory Board and Secret Chest to match the layout of the Activities.	Aesthetic and minimalist design	Major
B	Add a Notification Center to the Application main page.	Visibility of system status	Major
C	Notify the owner of an Event that the Event was commented.	Visibility of system status	Major
D	Notify users when they are tagged in Events.	Visibility of system status	Major
E	Create an information menu to see relevant information about the Application.	Recognition rather than recall	Minor
F	Use the information menu to explain the Application color scheme.	Recognition rather than recall	Minor
G	Use the information menu to explain the differences between the three Event containers.	Recognition rather than recall	Minor
H	Add to the Timeline the number of comments on each Event.	Visibility of system status	Minor
I	Make the layout of the Event Details cleaner.	Aesthetic and minimalist design	Cosmetic
J	Allow users to click on the user avatar in a comment to navigate to the home page of that user.	Flexibility and efficiency of use	Cosmetic
K	Modify status messages to disappear after a pre-established time.	Flexibility and efficiency of use	Cosmetic
L	Add the user online status in the conversation page.	Visibility of system status	Cosmetic
M	Add details about Events to the Timeline without needing to open the Event.	Flexibility and efficiency of use	Cosmetic
N	Replace buttons in the children interface with the equivalent icons.	Match between system and the real world	Cosmetic
O	When errors occur, specify error messages so the user knows how to proceed.	Help users recognize, diagnose, and recover from errors	Cosmetic

Table 4.1: Usability problems found in the Heuristic Evaluation of second iteration.

Analyzing the results, we find that four issues were given severity major, four were given minor and seven were given cosmetic. Eleven of the recommendations refer to new features while four refer to modification of already existing features. The evaluators found particularly relevant the implementation of a notification center and a information menu in the Application Hubs with both of these features referred in six out of eight of the usability problems with

severity grater than cosmetic. They also felt that updating the layout of the memory board and secret chest was extremely high priority. Then, the addition of the number of comments to the events in the Timeline should be addressed. The remaining of the usability issues were considered cosmetic and should, thereby, be addressed if there is extra time available.

4.5 Third Iteration - Supporting Activities

Activities, at this point, are exercises and field trips that parents and teachers can create for children to answer and be aware, respectively. Activities are one of the most important forms of interaction between children with ASD, parents and teachers as they represent our approach on fear of the unknown, a characteristic inherent to the child and adaptability to all of the students, one of the motivations of the teacher.

With that in mind, the third iteration, the focus is put on children interaction with family and teachers in the form of Activities, specifically implementing the features to support creating and answering Activities.

4.5.1 Requirements

The changes proposed by the evaluators of the second iteration resulted in new requirements for the third iteration.

Given the feedback of the evaluators of Iteration 2 on the list of Events and the list of Activities, we thought it was relevant, to keep a level of consistency, that the list of users should have the same minimalistic layout with important information available upfront. That way, in the list of users, list of Events and list of Activities, the most important information is upfront and accessible from the list, without having to open them. The Timeline layout, however, was not changed to match the new layout of the Memory Board and Secret Chest as we wanted to maintain the time relation between Events that the Timeline provides.

(a) Memory Board

(b) Secret Chest

Figure 4.20: New Memory Board and Secret Chest

The Community, Children and Students were adapted to reflect the changes explained above.
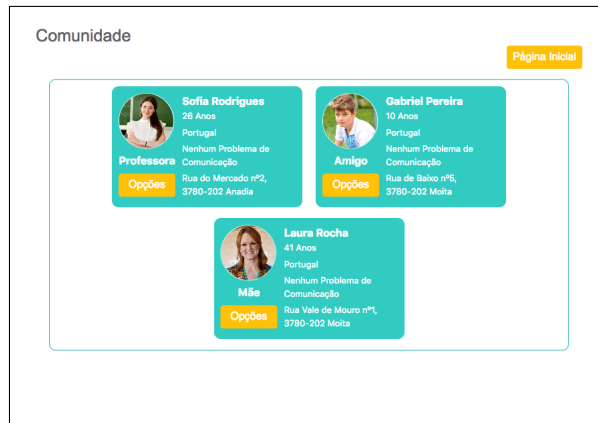
Figure 4.21: Community

All Application Hubs were modified to include the proposed notification and information areas. This addition of a notification area also implied adding support for notifications on the messaging service. The notification area is similar to all users, independently of their role. It will show notifications from newer to older with a default of twenty unseen notifications. Users are free to dismiss notifications one at a time or all at once. The mobile version of the Application, installed on user's devices, will also trigger a notification on the operating system whenever a notification is received and the application is paused, i.e, when the user launched the application but it is not running in foreground at the moment when the notification is received.

As suggested, the information area shows relevant information about the Application.
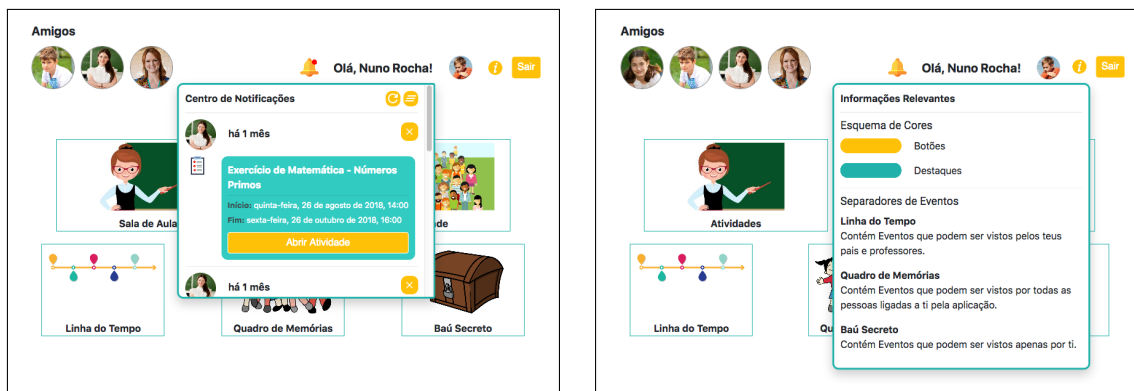
(a) New View with Notification Area

(b) New View with Information Area

Figure 4.22: Children Application Hub

(a) Family View with Notification Area

(b) Teacher View with Information Area
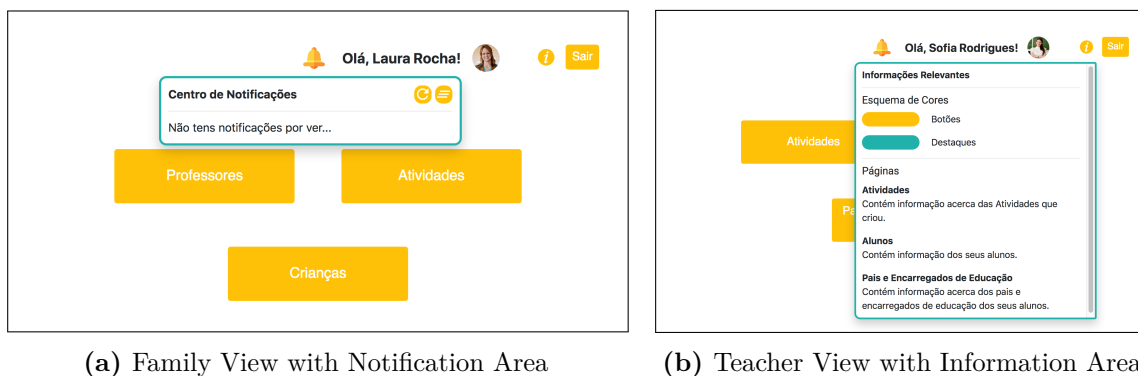
Figure 4.23: New Family and Teacher Application Hubs

The look of the Event Details was made more minimalistic while still making the content of the Event the main focus and showing all its information at the same time.
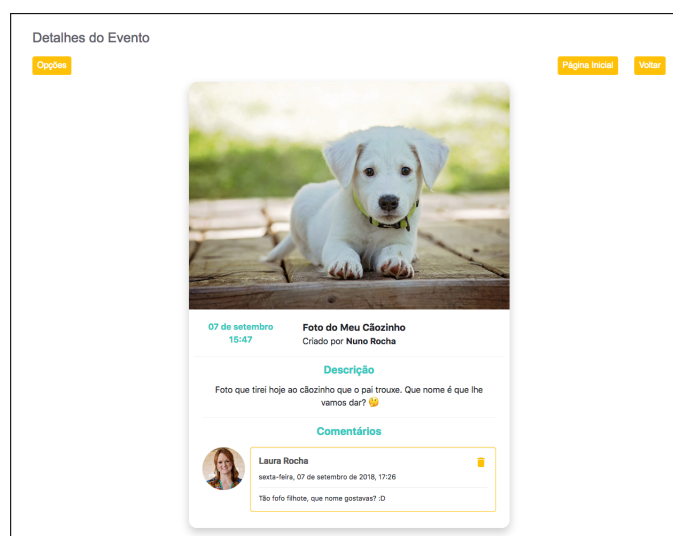
Figure 4.24: New Event Details

Once the requirements originated by the evaluation of the second iteration were addressed, we looked again to section 3.4 for the new requirements for the third iteration.

To help parents and teachers keep all Activities documented, the Application allows the download of the children's answers so they can be printed and evaluated. To that end, a few answers were also simulated.

With that in mind, the new requirements for the third iteration are as follows.

The Application should:

- allow teachers and parents to:
    - view Activities they created;
    - download children answers.
- allow children to:
    - view Activities created for them;

4.5.2 Development

As stated at the beginning of the chapter, at this time, Activities can have two major types: Activity with questions or field trip. In the future, new types may be added. To support testing during development, a few Activities were created directly in the database, representing each of the possible types, and the focus was put on listing them and showing their details.

Activities

The list of Activities shows the Activities created for the children, sorted in three ways: past, ongoing and future Activities.

Figure 4.25: Activities, Student View

The list of Activities for parents and guardians shows Activities created both by them and by their children's teachers.
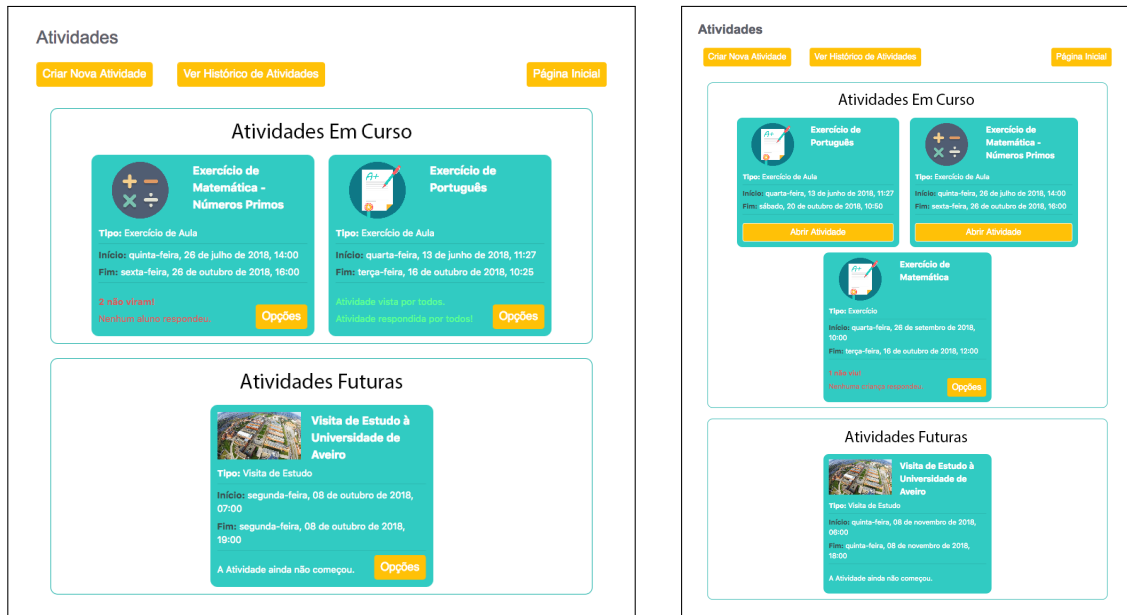
(a) Teachers View   **(b)** Parents View

Figure 4.26: Activities

The Activity Cards inform the user of name, start and finish dates, type and status of the Activities. Each Activity has also an associated image for quick identification of its type. Users can set a custom image when creating the Activity or, if they chose not to do so, a predefined image will be set. The status of the activity shows relevant information for users based on their roles. Children see whether ot not they have opened or answered the activity while Parents and Teachers see how many children opened the Activity and how many answered.

Figure 4.27: Activity Card

Activity Details

The Activity Details shows two different layouts representing the two types of Activities available: Activity with questions and field trip. Both layouts show the Activity title and creator as well as the start and finish dates.

Depending on whether or not the Activity has been answered, the layout of the Activities with questions is different. If the user is a child and the Activity has not been answered, the page shows the questions and a button to answer. If the Activity has been answered, the page shows the questions and the child's answers. If the user is the parent or teacher that created the Activity and the Activity has no answers, the page shows a message saying no child answered. If any of the children answered, the page shows the Activity's answers status and the option to either view the children's answers or download them.

(a) Students View

(b) Teachers/Parents View

Figure 4.28: Activity Details without Answers

The teachers and parents have an additional option: If there are children that did not answer or did not see the Activity, they can encourage them to answer, thereby making the children's Applications show the Activity Details for that Activity.
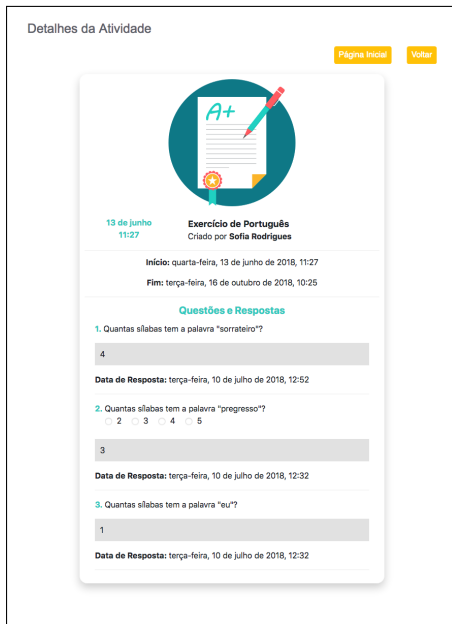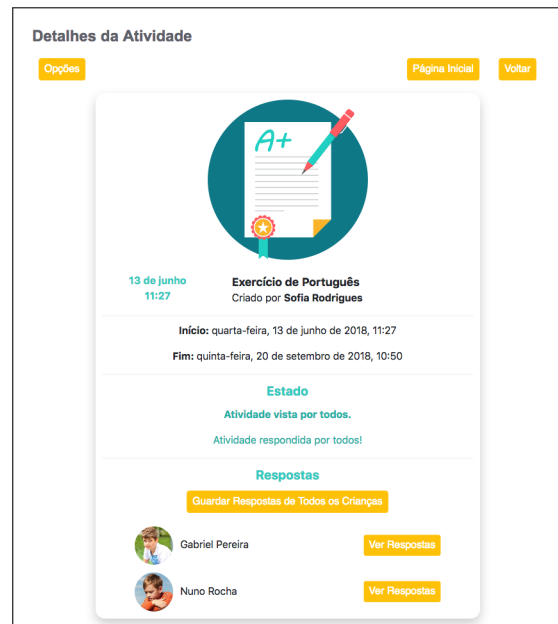
(a) Students View   **(b)** Teachers/Parents View

Figure 4.29: Activity Details with Answers

If they choose to download the student answers, the answers are compiled into a PDF file that can be saved to the device's storage. The compiled file will show the questions and answers as well as a field for the grade.

Figure 4.30: Nuno's Activity Answers

Children with ASD like to be sure of what to expect. Therefore, to add predictability, the field trip Activity shows a description, the people accompanying the children and the schedule,

consisting of places and estimated time of arrival.

Figure 4.31: Field Trip Details

4.5.3   Evaluation

For this evaluation we focused on how well users learned the system and how easily they could achieve the tasks we proposed. To do this, we invited the users, henceforth called evaluators, to follow a set of tasks simulating the usage of the Application by three Personas: Nuno, Laura and Beatriz. The evaluation was conducted on a Concurrent Think Aloud manner where the evaluators were told to speak their thoughts as they went trough the tasks. Given that iteration three encompassed changes to iteration two and the evaluation itself was different, tasks related to iteration two were also implemented in this evaluation. Therefore, the tasks focused on creating and viewing Events, communication with other users and viewing Activities. To maximize the results, all evaluators performed all tasks.

The evaluators consisted of three male and two female. At the time, all were students at the University of Aveiro and all were twenty four years old. They had no special knowledge of Human-Computer Interaction and were meant to test the Application as a regular user.

Generally all evaluators were able to perform all tasks in the expected way with only a software bug being noticed when taking pictures on the computer. We took particular interest in seeing if the evaluators accessed the right areas of the application for each task. For instance, as Nuno, when asked to send a message to his teacher, all evaluators immediately assumed they could achieve that by selecting Sofia's face in the Application Hub. One evaluator, when asked to see the information about a field trip, thought he would find it in the Timeline but immediately said it also made sense for field trips to show in the Activities.

After all tasks were completed, evaluators were told to fill a System Usability Scale questionnaire.

4.5.4   Results

Table 4.2 represents the questions asked in the SUS questionnaire and the answers given by each evaluator, represented by e1 to e5.

Question	Answers				
	e1	e2	e3	e4	e5
1. I think that I would like to use this system frequently.	5	5	4	5	3
2. I found the system unnecessarily complex.	1	1	1	1	1
3. I thought the system was easy to use.	4	5	5	5	4
4. I think that I would need the support of a technical person to be able to use this system.	1	1	2	2	1
5. I found the various functions in this system were well integrated.	5	5	4	4	4
6. I thought there was too much inconsistency in this system.	1	1	1	1	1
7. I would imagine that most people would learn to use this system very quickly.	4	1	5	5	5
8. I found the system very cumbersome to use.	1	1	1	1	1
9. I felt very confident using the system.	4	5	4	5	4
10. I needed to learn a lot of things before I could get going with this system.	1	1	1	1	1

Table 4.2: Results of the SUS questionnaire of evaluation 3.

After calculating the questionnaire results, the Application scored an average of 93 points, therefore scoring above average and above the score in which users would recommend to a friend.

Analyzing the results, we can be infer that users need not only a briefing of the Application before using it but also a briefing of its objectives and the motivations of the Personas that lead to them in order to be familiarized with the concepts of Events, Event containers and Activities and fully understand their relation. Question 5 revealed that some evaluators thought some functions could be better integrated. The scores, however, were decisively above average so this point does not need to be address immediately and can be addressed in future iterations.

4.6 Fourth Iteration - Creating and Answering Activities

The fourth Iteration focused on allowing parents and teachers to create Activities and children to answer them.

4.6.1 Requirements

No interface changes were made to iteration three as that was not revealed necessary by the evaluation. However, the identified bug was fixed.

As explained above, iteration four focuses on creating and answering Activities so, looking back at section 3.4 the requirements for this iteration are as follows.

The Application should be able to:

- allow teachers to create Activities as:

    - tests;

    - class exercises;

    - homework;

    - field trips.

- allow parents to create Activities as:

    - exercises;

    - field trips.

- allow children to answer Activities created for them;

4.6.2 Development

At this point, we focused on two main aspects. Firstly, allow parents and teachers to create new Activities, keeping in mind the motivation of the teacher to be able to create exercises only once that the Application then adapts to the children. Secondly, allow children to answer exercises in different ways (if the parents and teacher allow them to do so).

Creating Activities

In the Activities, teachers and parents have the option to create new Activities. Pressing the button show the steps to create a new Activity. All Activities, no matter their type, start by a general information view, that prompts the user to set the Activity name, type, start date, finish date and a cover image. The user must only insert the name and type. Dates and cover image are optional.
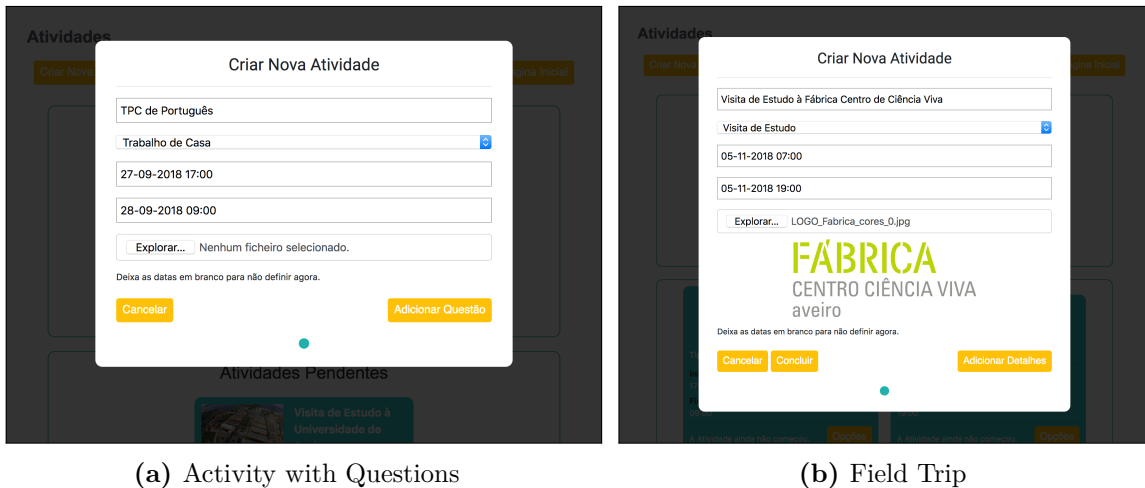
(a) Activity with Questions   **(b)** Field Trip

Figure 4.32: New Activity General Information

If the user chooses a type that is related to an Activity with questions, the next step is adding questions. To do so, the user has to insert the question text and the type of answer. This can be open answer, multiple choice or personalized answer. If the type is open answer, children have a text area to answer as they see fit. If the type is multiple choice, children have a set of options available to chose from. If, however, the type is personalized answer, the application displays the options for alternative answer available at the time (see figure 4.39).
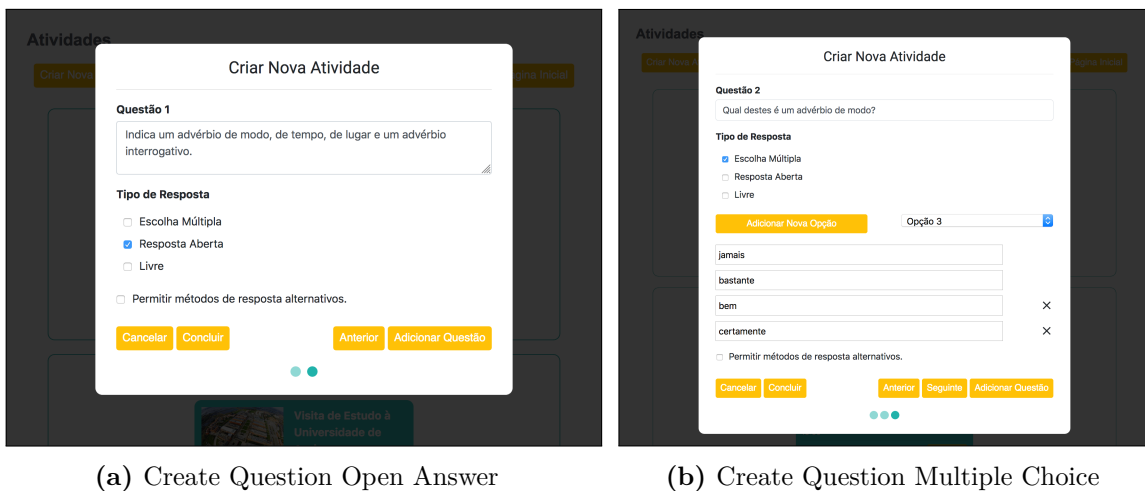
(a) Create Question Open Answer   **(b)** Create Question Multiple Choice

Figure 4.33: New Activity with Questions

If the user choses field trip as the type of Activity, the next step is adding the field trip information. Field trip information consists of a description, destinations and chaperons. The application shows a list with known destinations that were registered on previously created field trips. The user can chose to create new ones by inserting the name, location, type, and an image. Both for known destinations and new ones, the user always has a field to introduce the estimated time of arrival to that destination for that field trip.
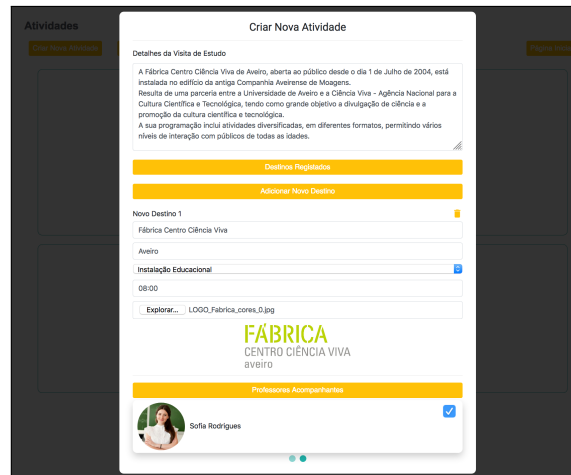
Figure 4.34: New Activity Field Trip Details

Finally, the application also shows a list known chaperons that consists of teachers registered in the system. Users can add new ones on the available area. In the future it may be relevant to also list registered parents as known chaperons, however, for the time being, to add parents as chaperons of a field trip, the user needs to insert their names in the area of new chaperons.
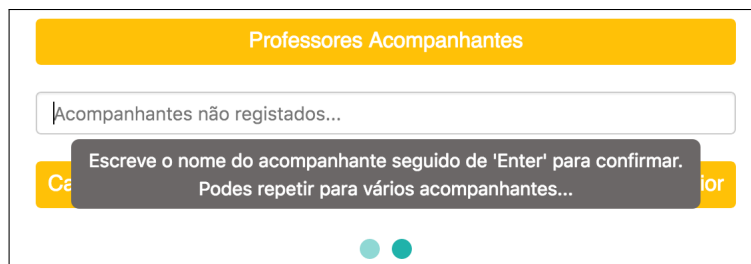
Figure 4.35: New Activity Field Trip - Add New Chaperons

After adding as much questions as needed, in Activities with questions, or after adding the information regarding the field trip and destinations, in field trip Activities, the user can conclude the process and select the visibility of the Activity. If the user is a teacher, the application shows the classes associated to the teacher and, if the user is a parent, it shows the children associated to the parent. Teachers can select whole classes or individual students.

(a) Class Selection   **(b)** Student Selection
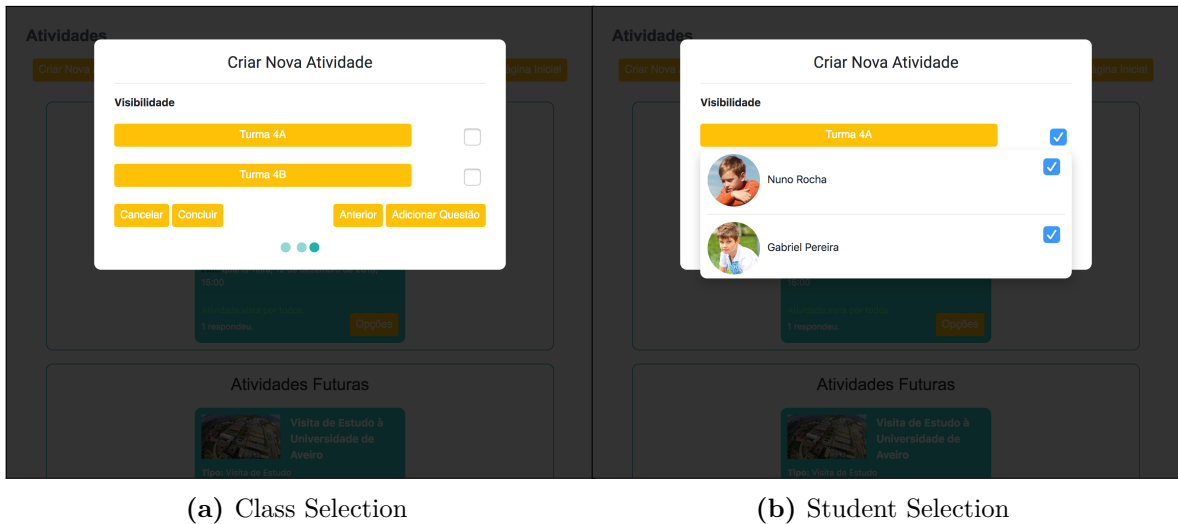
Figure 4.36: New Activity visibility

Answering Activities

In the Activities Details, children have the option to answer the questions if the Activity is of type Activity with questions. Depending on the type of answer that is selected for each question, children are shown different layouts. If the selected type is open answer, the Application displays a text area for the child to answer.
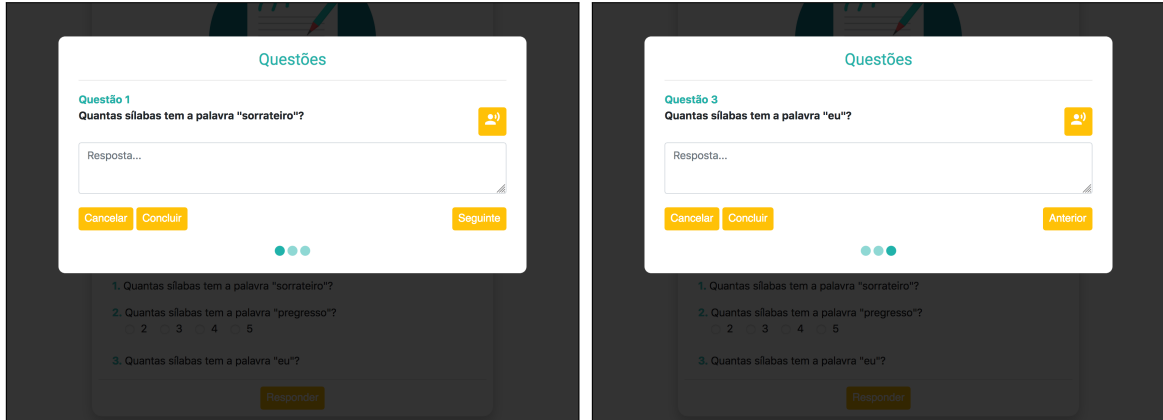
Figure 4.37: Question with Open Answer

If the selected type is multiple choice, the Application displays the options that the teacher, parent or guardian made available for that question.
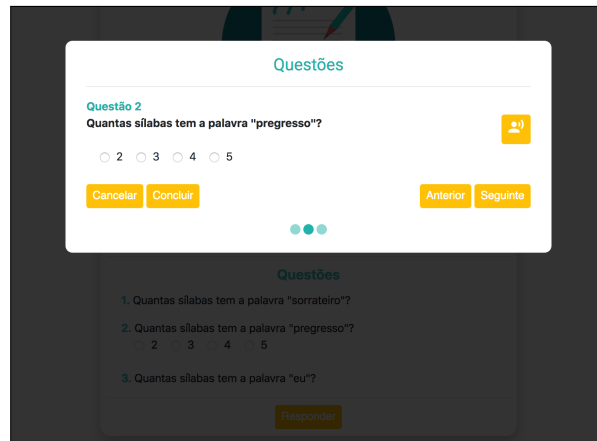
Figure 4.38: Question with Multiple Choice Answer

Finally, if the selected type is personalized answer, the Application displays a set of alternative answer methods. The children can then chose the one they want.
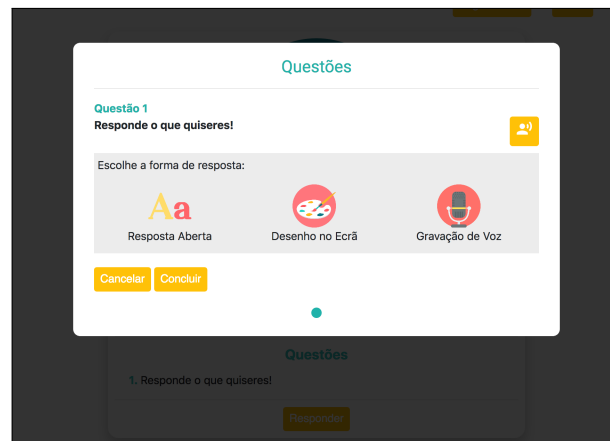
Figure 4.39: Question with Free Answer

(a) Text

(b) Drawing

(c) Voice Recording
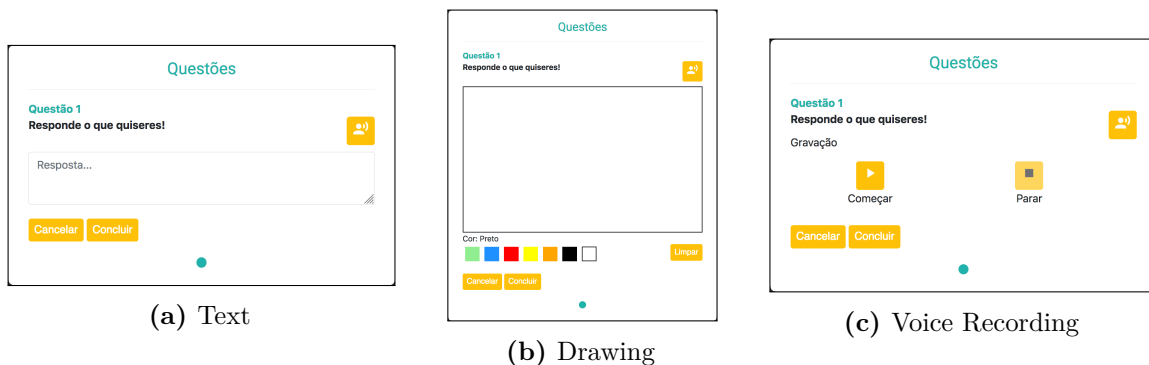
Figure 4.40: Free and Alternative Answer Types

These options are also available for children with communication issues should the parents or teachers enable the alternative answer methods for each question.

4.6.3 Evaluation

Since this iteration already provides the first complete approach and the major usability issues were already addressed in previous iterations, it was considered important to include children in this evaluation.

Similarly to the evaluation of iteration three, in this evaluation we focused on how well users, henceforth called evaluators, learned the system and how easily they could achieve the tasks we proposed. This time, however, including tasks related to the creation and answer of Activities. To do this, we invited the evaluators to follow a set of tasks simulating the usage of the Application by four Personas: Nuno, Laura, Beatriz and Sofia. The evaluation was conducted on a Concurrent Think Aloud manner where the evaluators were told to speak their thoughts as they went trough the tasks. To maximize the results, all evaluators performed all tasks and tasks related to iterations two and three were also performed in this evaluation. Therefore, the tasks focused on creating and viewing Events, communication with other users and creating, viewing and answering activities. The evaluators consisted of two male and two female. One of the male evaluators was a child of twelve years old. The others were twenty four, thirty seven and forty years old.

The child was given a brief explanation of the Application, for context. After that, he was asked to perform all tasks related to Nuno, in a simpler manner.

During the evaluation, the evaluators noted the following features that could be made clearer.

- When asked to answer an exercise with voice recording, two of them clicked the button to read the question out loud.
- When asked to send a message to Sofia, the users selected Sofia's picture on the Application Hub. We asked them why they assumed they could perform the task in that way. They told us they are used to doing so on messaging applications. However, all agreed to changing the title from "Friends" to "Chat with..." or a similar title as long as it removed ambiguity.
- When asked to send a message to Nuno's teacher, one evaluator noticed that it would not be clear who is Nuno's teacher if there were more teachers on the list. Therefore, the evaluator agreed that the information about the child or children related to each teacher should also be made clear on the teacher's card.

After all tasks were completed, the adult evaluators were told to fill a System Usability Scale questionnaire.

4.6.4 Results

The child was not asked to fill the SUS questionnaire as we tried to maintain the evaluation more informal.

He performed the tasks without difficulties and noticeably enjoyed exploring the features of the Application. After he finished the tasks, we asked him if he would like to use the Application, if he thought an Application like this would be useful for classes with students

with SEN and, finally, if he thought children with communication problems would benefit from having the multiple forms of interaction implemented in the Application. The child responded affirmatively to all questions even though he noted that he was never in a class with students with SEN but could imagine that an Application like this could make such children spend more time in regular education classes.

Table 4.3 represents the questions asked in the SUS questionnaire and the answers given by each adult evaluator, represented by e1 to e3.

Question	Answers		
	e1	e2	e3
1. I think that I would like to use this system frequently.	4	5	5
2. I found the system unnecessarily complex.	1	1	1
3. I thought the system was easy to use.	4	5	4
4. I think that I would need the support of a technical person to be able to use this system.	1	1	1
5. I found the various functions in this system were well integrated.	5	5	5
6. I thought there was too much inconsistency in this system.	1	1	1
7. I would imagine that most people would learn to use this system very quickly.	5	5	5
8. I found the system very cumbersome to use.	1	1	1
9. I felt very confident using the system.	4	5	4
10. I needed to learn a lot of things before I could get going with this system.	1	1	2

Table 4.3: Results of the SUS questionnaire of evaluation 4.

After calculating the questionnaire results, the Application scored an average of 95 points, therefore scoring above average and above the score in which users would recommend to a friend.

In general, the evaluators received the Application well. Analyzing the SUS scores, we can verify that questions 3, 9 and 10 show the majority of non-optimal results. Therefore, we can infer that the Application still has room for improvement. However, the evaluators did not stress aloud any major difficulties during the evaluation. From what we could perceive, the users may occasionally access the wrong area of the application to perform a task, but they quickly realize when they do so. Some of the areas can be made clearer, for instance, the Friends area of the children Application Hub can be renamed to "Chat with...", while others become clear after a single use, for instance, understanding that exercises and field trips can

be found in the Activities area, while Events can be found in the Timeline.

The images and icons used in the application are placeholders and can be found in Resource Links.

CHAPTER 5

Conclusions

In this chapter, we recapitulate our work, present the main results, analyzing the objectives and propose possible additions for future iterations.

5.1   Summary of the Work

The work we developed in this dissertation was composed of six main stages, described as follows.

Background

1. Study of the areas that compose the background of our work, as described in chapter 2. Firstly, people with communication problems, focusing on children with ASD and its main characteristics, methods to assists communication and teaching children with SEN. Secondly, multimodal interaction and how it can be used to assist people with difficulties of interaction. Thirdly, the UCD method for developing systems. Fourthly, technologies used to develop multi-platform, multi-user applications. Finally, in fifth place, examples of existing applications for children with ASD.

Part One of Development

2. Study of the Personas having as support the ones defined in the dissertation of Ana Leal [5], creation of scenarios based on the Personas and their motivations and finally, inferring Requirements based on the scenarios.

Part Two of Development

3. Primary study of the application, consisting in the choice of the development method, followed by the definition of the architecture and the development of mock-ups as a primary way to show how users can interact with the system.

4. Start of the development of the system, consisting in the creation of the systems, databases and primary features of the application based on the first group of requirements. This is followed by a primary evaluation of the application focused on usability problems.

5. Implementation of the features and changes related to second group of requirements that were given by the previously established list and by the usability problems revealed in the previous evaluation and finally, an evaluation with users focusing on how well they learned the system and how easily they could achieve the tasks we proposed.

6. This stage followed the same structure of the previous one with the exception of the requirements. This time they were only given by the third group of requirements on our list as no changes were proposed by the users. In this stage, the application implemented all of the proposed requirements and was thereby ready to be tested with children.

5.2   Overall Analysis

Considering the objectives we had established and the work we developed, we consider that we have successfully reached the objectives.

We studied a specific group of people with a very extensive list of characteristics as well as the people they most interact with. We identified the problems they faced, defined scenarios and proposed ways in which we could assist them trough the usage of a multi-platform, context-aware application. To improve communication, we propose a chat in which users can send direct messages and attachments to each other as well ways in which they can share memories with their friends and family. To add predictability we allow teachers and parents to create activities as field trips and insert schedules and places. That way, children have a place they can access in order to be aware of what to expect so they do not get nervous. To make sure children have different options to interact with the other users and the application, we added different modalities. That way we maximize the options for children and make them more prone to use the system. To help teachers educating students with SEN, we propose ways they can create activities with questions that students with SEN can interact with in different forms. Question can be read to them and they can answer using voice, drawings or text. To help parents better keep track of their children's education, we allow them to send messages directly to their children's teachers.

With that being said, we could not demonstrate all of our objectives. Features like voice recognition, gaze tracking and multi device cooperation could not be implemented. Its potential uses and benefits for the users are explored in the next section.

Ultimately, we provide a proof-of-concept application that is a basis for future developments. It allows us to demonstrate the objectives of our work even though the time constraints associated with the dissertation did not allow us implement all features, therefore, leaving room for future development.

5.3 Future Work

Regarding the application we developed it would be interesting to conduct tests in schools were it could be tested with other children, teachers and parents. Then, in a later stage, conduct tests with children with communication problems. This would further approximate our proof of concept to an application that could be used in a large scale.

As explained in the beginning of the chapter 4, AMICA serves as the groundwork for new features to be added.

The features we implemented represent our approach to the motivations of the Personas. In the future, however, new motivations or new Personas may become relevant, thereby creating the need to expand AMICA to support features that address other problems. These new features may be additions to already existing ones, for example, adding new types of activities or new ways to answer questions or may be new features entirely, that can be added to the Application Hub of the users.

Some interesting features that could be implemented are:

- **Pictograms**

  Pictograms would be another form of interaction to help children communicate with others. It could complement or entirely replace the virtual keyboard on already existing features like conversations or answering exercises or it could be the base for a new feature like symbol-to-speech.

- **Gaze Tracking**

  Gaze tracking could have different applications. It could assist children with ASD when it comes to make eye contact with others, for example by requesting them to look into the eyes of a person in a picture or the eyes of a virtual avatar in order to login. It could help parents and teachers by maintaining a history of the level of attention of the children when answering exercises by studying the amount of time they are looking at the screen.

- **Voice Recognition**

  Voice Recognition could also have different implementations, always focused on getting children to talk. It could completely replace touch input in some areas like navigation. It could introduce new types of exercises where children would need to read the sentences presented on the screen and show immediate results.

- **Multi-device Cooperation**

  Multi-device Cooperation could be another way of getting children to interact with one another. This could be used, for example, in the context of a game where users would need to follow a map that could only be seen by placing multiple devices together.

These are only a few examples that could be added in the future to make AMICA more interesting not only for children but for parents and teachers as well.

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Appendices

Use Cases

The following are the remaining use case flow diagrams for the children.

A.1 Login

Use Case: Login -> Failure

User: Nuno

User Action	Application	User's Device
Selects application icon	Gets challenge from database -> Look to avatar and greet him	Displays challenge and starts recording voice
Says "Hello, how are you?" but does not look to avatar	Recognizes that user is not looking towards avatar and does not accept login	Displays warning message

Requirements

Interaction: App navigation using touch; Voice recording using device's microphone. Gaze tracking using device's camera.

Functional: The application must allow children to login by overcoming the presented challenge; The application must be able to track child's gaze; The application must be able to record voice.

Use Case: Login -> Success

User: Nuno

User Action	Application	User's Device
Selects application icon	Gets challenge from database -> Look to avatar and greet him	Displays challenge and starts recording voice
Looks to avatar and says "Hello, how are you?"	Compares answer to possible answers -> Valid; Gets user's friends and family information	Displays application main menu

Requirements

Interaction: App navigation using touch; Voice recording using device's microphone. Gaze tracking using device's camera.

Functional: The application must allow children to login by overcoming the presented challenge.

A.2 Add Friends

Use Case: Add Friends

Users: Nuno and Friend (already using the application)

Nuno's Action	Friend's Action	Application	Nuno's Device	Friend's Device
Selects "Add Friend" in the friend's panel			Displays friend addition panel, requesting the users to bring their devices together	
	Selects "Add Friend" in the friend's panel			Displays friend addition panel, requesting the users to bring their devices together
Approaches tablet to Friend's phone	Approaches phone to Nuno's tablet	Recognizes each account, marking them as friends	Shows Friend in friend's panel	Shows Nuno in friend's panel

Requirements

Interaction: App navigation using touch.

Functional: The application must allow children to add friends.

A.3 Remove Friends

Use Case: Remove Friends

User: Nuno

User Action	Application	User's Device	Friend's Device
Selects friend from main screen.	Gets friend's info	Displays friend's Memory Board	
Selects "Remove Friend"		Displays confirmation dialog	
Selects "Confirm"	Removes friendship relation from database	Removes friend from friend's panel and returns to main screen	

Requirements

Interaction: App navigation using touch.

Functional: The application must allow children to remove friends.

A.4 Create Event in Timeline

Use Case: Create Event in Timeline

User: Nuno

User Action	Application	User's Device
Selects "Timeline"	Gets events from database	Displays Timeline Events
selects "Create Event" as picture, image, drawing, text, voice, expression		Displays interface for event creation
Fills Event information and selects "Confirm"	Saves event to database	Displays successful message

Requirements

Interaction: App navigation using touch; Image recording using device's camera; Text introduction using virtual keyboard; Voice recording using device's microphone; Expression selection using touch or speech recognition (device's microphone); Screen drawing using touch.

Functional: The application must allow children to create different types of Events in Timeline.

Use Case: Create Event in Secret Chest

User: Nuno

User Action	Application	User's Device
Selects "Secret Chest"	Gets events from database	Displays Secret Chest Events
Selects "Create Event" as picture, image, drawing, text, voice, expression		Displays interface for event creation
Fills Event information and selects "Confirm"	Saves event to database	Displays successful message

Requirements

Interaction: App navigation using touch; Image recording using device's camera; Text introduction using virtual keyboard; Voice recording using device's microphone; Expression selection using touch or speech recognition (device's microphone); Screen drawing using touch.

Functional: The application must allow children to create different types of Events in Secret Chest.

Use Case: Save Event to Secret Chest

User: Nuno

User Action	Application	User's Device
Selects "Memory Board"	Gets events from database	Displays Memory Board Events
Selects an Event	Gets event details from database	Displays Event details
Selects "Save Event to Secret Chest"	Changes visibility of event to Secret Chest, removing it from Memory Board	Displays successful message

Requirements

Interaction: App navigation using touch.

Functional: The application must allow children with ASD to save different types of Events in Secret Chest.

Share Events with Friends

Use Case: Share Events with Friends

User: Nuno

User Action	Application	User's Device
Selects "Memory Board"	Gets events from database	Displays Memory Board Events
Selects an Event	Gets event details from database	Displays Event details
Selects "Share Event"	Gets friends list from database	Displays friends list
Selects friends to share event with and selects "Share"	Makes events available to friends and sends a notification to their devices	Displays success message

Requirements

Interaction: App navigation using touch.

Functional: The application must allow children to share events with their friends.

Use Case: Search Events

User: Nuno

User Action	Application	User's Device
Selects "Timeline"	Gets events from database	Displays Timeline Events
Selects "Search Event"		Displays search form
Fills form with desired parameters and selects "Search"	Searches Events for matches to desired parameters	Displays Event matches

Requirements

Interaction: App navigation using touch; Text introduction using virtual keyboard; Speech recognition using device's microphone;

Functional: The application must allow children to search events by introducing different search parameters; The application must be able to recognize specific search parameters like "Happy Events", "Events today", "Events next week", among others.

Remove Events

Use Case: Delete Events

User: Nuno

User Action	Application	User's Device
Selects an Event from Memory Board, Timeline or Secret Chest	Gets Event details from database	Displays Event details
Selects "Remove Event"		Displays confirmation dialog
Presses "Confirm"	Removes event from database	Returns to previous screen

Requirements

Interaction: App navigation using touch;

Functional: The application must allow children to delete their events.

Use Case: Answer Exercise Using Pictograms

User: Nuno

User Action	Application	User's Device	Teacher's Device
	Detects new event posted by Nuno's teacher	Shows notification of new exercise and makes it available in Classroom page	
Selects "Classroom"	Gets available activities from database	Displays Classroom page with available activities	
Selects exercise to answer	Gets preferred user answering method from database and compares to options made available by the teacher -> Match for Pictograms	Displays exercise page	
Selects exercise text area	Checks result for answering method	Displays Pictograms	
Answers and selects "Finish"	Saves answer in database	Displays finish message and returns to Classroom screen	Shows Nuno's answer in list of answers for the exercise

Requirements

Interaction: App navigation using touch; Select pictograms using touch.

Functional: The application must allow students with SEN to answer exercises with pictograms.

Answer Exercise Using Speech Recognition

Use Case: Answer Exercise Using Speech Recognition

User: Nuno

User Action	Application	User's Device	Teacher's Device
	Detects new event posted by Nuno's teacher	Shows notification of new exercise and makes it available in Classroom page	
Selects "Classroom"	Gets available activities from database	Displays Classroom page with available activities	
Selects exercise to answer	Gets preferred user answering method from database and compares to options made available by the teacher -> Match for Pictograms with option for voice recording and speech recognition	Displays exercise page	
Selects exercise text area	Checks result for answering method	Displays Pictograms	
Selects "Speech Recognition"		Displays voice ready interface	
Selects "Start Listening" and gives answer	Attempts to match answer to teacher's inserted answer options -> Succeeds	Displays answer	
Selects "Finish"	Saves answer in database	Displays finish message and returns to Classroom screen	Shows Nuno's answer in list of answers for the exercise

Requirements

Interaction: App navigation using touch; Speech recognition using device's microphone.

Functional: The application must allow students with SEN to answer exercises with speech recognition.

Use Case: Call Teacher During Classes

User: Nuno

User Action	Application	User's Device	Teacher's Device
Selects "Classroom"	Gets available activities from database	Displays Classroom page with available activities	
Selects "Call Teacher"	Sends notification to teacher's device requesting her assistance		Displays notification saying that Nuno needs assistance

Requirements

Interaction: App navigation using touch.

Functional: The application must allow children to let the teacher know they need assistance without disturbing the class.

Ask for Friend's Help

Use Case: Ask for Friend's Help

User: Nuno

User Action	Application	Teacher's Device	Friend's Device
Selects "Ask for Help" from exercise screen	Gets friends who already finished the exercise	Displays friends who already finished the exercise	
Selects "Gabriel"	Sends notification to Teacher's device	Displays notification that Nuno is asking for Gabriel's help -> Approves	
	Sends notification do Gabriel's device		Displays notification that Nuno is asking for help

Requirements

Interaction: App navigation using touch.

Functional: The application should allow children to ask friends in the same class for help.

Use Case: Help Friend

User: Gabriel

User Action	Teacher's Action	Application	Nuno's Device	Teacher's Device
Accepts Nuno's request by selecting "Help" in the notification, writing his suggestion and then selecting "Send"		Sends Gabriel's suggestion to teacher for approval		Displays Gabriel's suggestion
	Approves of Gabriel's suggestion	Sends suggestion to Nuno's device	Displays Gabriel's suggestion	

Requirements

Interaction: App navigation using touch.

Functional: The application should allow children to help friends in the same class.

APPENDIX B

Services and Databases

AMICA's back-end will consist of three services that will serve as connection between the Application and the databases. Each service contains its own database that only it can access and each of them exposes a REST API to be accessible from the Application.

Each one of AMICA's services will be related to a major element necessary to properly meet the objectives it is trying to demonstrate.

B.1   User Service

The User Service will manage all information related to the users. In short it will manage user information and relations between users both personally and at school.

When the user wants to perform an action that is related in any way to other users, the Application will call the relevant method on the API either to access information or change it.
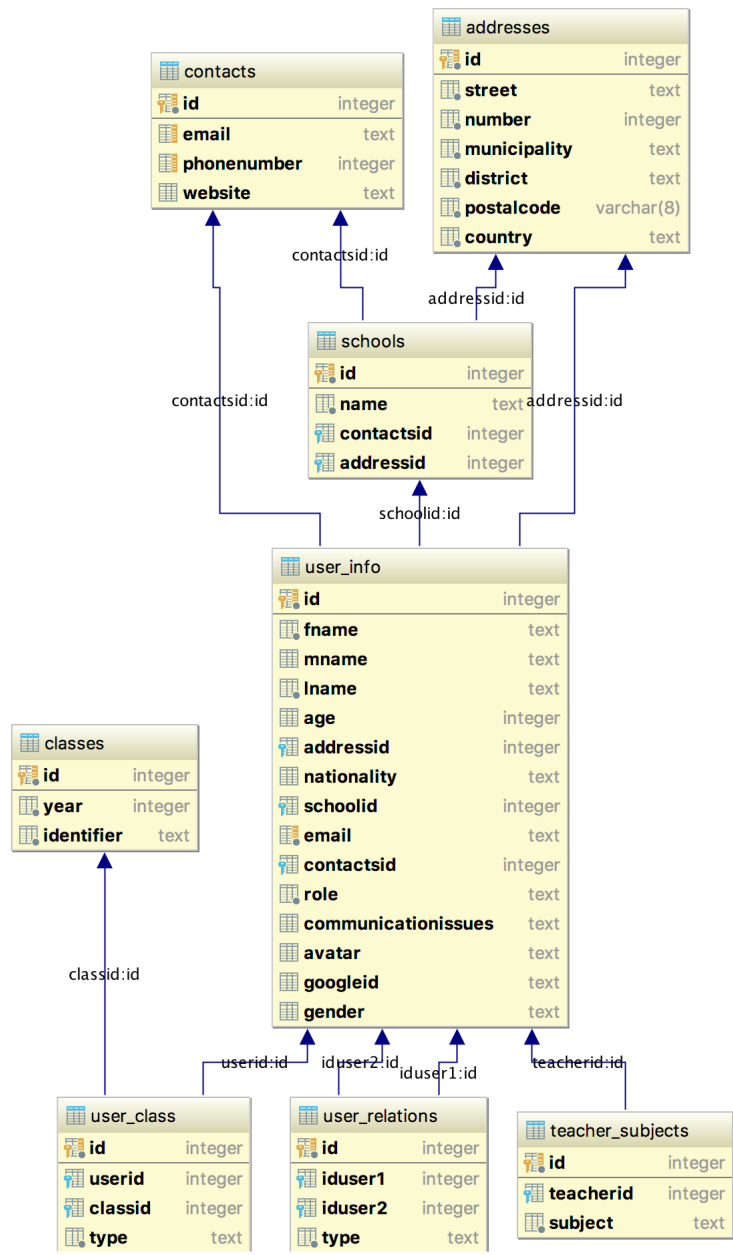
Figure B.1: User Database Diagram

B.2 Events and Activities Service

The Events and Activities Service will manage all information related to Events and Activities.

Information related to Events includes details on the Events themselves, for example, name, type, dates and also Event visibility and comments. Event visibility refers to the event location within AMICA, meaning Timeline, Memory Board or Secret Chest.

Even though Events and Activities share, in part, the same structure, they are significantly different. Similarly, information related to Activities includes details on Activities themselves, for example, name, type and dates. Activities are divided in two major types: field trips and Activities with questions.

Activities with questions range from simple class exercises to exams. The service will manage questions created by the teachers or parents and answers given by the children.

For field trip Activities, the service will manage destinations and estimated times of arrival to create schedules as well as managing the people responsible for accompanying the children.

Figure B.2: Events and Activities Database Diagram

B.3   Messaging Service

The Messaging Service will manage trade of information between instances of the Application. This can take two major forms: direct messages and notifications.

Direct messages refers to the interaction between users in the form of messages in chat. Notifications refers to messages triggered by actions of a user that are sent to all instances of the Application where another user is logged in.

Notifications are triggered when user A:

- comments an Event owned by user B;
- creates a new Event and identifies user B on it;
- creates an Activity and makes it visible to user B;
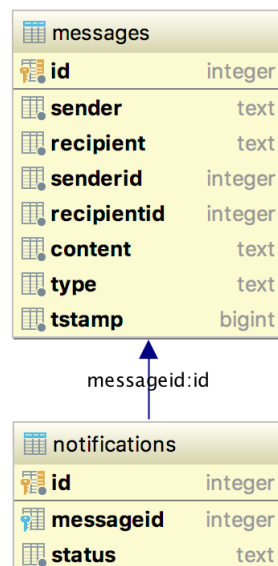- sends a direct message to user B when user B is not in the chat page.

Figure B.3: Messaging Database Diagram