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RoleBot: Exploring Robot Roles for Children with Visual Impairments

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To all children.

Resumo

O pensamento computacional pode ser considerado uma estratégia que permite estruturar a forma de resolver um problema, através da formulação inicial da mesma e modelação de possíveis soluções. Tem-se provado uma importante ferramenta na formação de crianças e jovens. Em termos educacionais, permite desenvolver a capacidade criativa, lógica e estratégica na resolução de problemas, estando associado ao desenvolvimento cognitivo e lógico.

O ensino de pensamento computacional pode ser incorporado em diversas matérias, como a programação, matemática, biologia, música e línguas [1]. Pode também ser usada uma abordagem usando robôs, que podem potenciar um contacto mais divertido e imersivo, sendo já vários os estudos que demonstram [2] e que provam que o ensino de uma matéria através de um robô é no mínimo tão eficiente quanto os métodos tradicionais [3]. Para além da eficiência no ensino, os robôs podem ainda permitir o desenvolvimento das capacidades de interação social e certas habilidades, como por exemplo, a empatia, através de atividades em grupo que potenciem a colaboração entre os seus elementos. A colaboração enquanto estratégia de aprendizagem usada em grupos apresenta benefícios, tais como o desenvolvimento de habilidades sociais, a sensação de estar a trabalhar em parceria com colegas rumo a um objetivo comum, e promove a discussão, partilha de conhecimento, apresentação de argumentos, e negociação de decisões [4].

No entanto, a maioria dos robôs dependem muito do uso da visão, não sendo inclusivos para crianças com baixa visão ou cegas. Isto pode potenciar não só problemas na aprendizagem de crianças com algum tipo de limitação visual, mas também fomentar a não inclusão das mesmas em atividades com os colegas, diminuindo a interação social e contribuindo para o isolamento social que é conhecido como um dos maiores desafios associados à falta de visão [5].

Assim, torna-se importante a adaptação e criação de robôs que sejam acessíveis para crianças cegas, garantindo não só a igualdade de oportunidades, mas também a inclusão destas crianças em atividades com crianças normovisuais.

Embora existam alguns kits computacionais que podem ser usados por qualquer pessoa independentemente do nível de visão, usando apenas a voz como input, essa redução de interação pode tornar a experiência menos apelativa e cativante, que são características de atividades desenvolvidas com kits computacionais. Para além de estes kits também não promoverem a colaboração, que ajuda não só no desenvolvimento de habilidades sociais, como também facilita a inclusão de pessoas com deficiências visuais; eles exploram sempre o robô enquanto um agente passivo que se limita a executar instruções ordenadas pelo utilizador.

Baseado nestas limitações, identificámos a necessidade de explorar kits computacionais com abordagens mais abrangentes (e inclusivas), que incluam crianças com problemas visuais ou cegas, focados não só na acessibilidade mas também nas características que possam permitir que as atividades sejam cativantes e apelativas. Por estes motivos, propomos explorar a colaboração entre a criança e o robô, através do uso de papéis de acordo com as habilidades da criança. Contribuímos assim com o design e desenvolvimento de um sistema que permite realizar atividades inclusivas e

interativas, promovendo a colaboração através da exploração de papéis. Além de explorar a importância dos robôs na aprendizagem e na colaboração, o nosso sistema propõe-se a fomentar o nível de atenção e motivação para aprender das crianças, através do uso de um robô mais interativo.

A análise das entrevistas apresentadas no terceiro capítulo, permitiu-nos adquirir conhecimento sobre as técnicas de ensino atualmente usadas e de que forma é a acessibilidade abordada. Para além disso, a perspetiva de um professor de educação especial que tem também dificuldades de visão, providenciou-nos estratégias e formas de lidar com crianças cegas e com dificuldades de visão no contexto de uma classe com crianças normovisuais, permitindo a inclusão.

Esta tese introduz o RoleBot, que permite a criação de atividades que estimulem a aprendizagem de pensamento computacional explorando o robô enquanto um agente não passivo. O Rolebot consiste num sistema que faz uso de um kit computacional adaptado para desenvolver atividades com crianças cegas e normovisuais. Este kit computacional usa peças tangíveis acessíveis para crianças cegas. Para além do kit computacional, o nosso sistema é também composto por uma aplicação web desenvolvida por nós constituída por uma interface onde o utilizador pode introduzir o input a dar ao robô, e do sistema que faz o tratamento do input dado, comunicando posteriormente com o robô. Nas atividades desenvolvidas com o nosso robô é possível escolher um de dois modos, que correspondem aos papéis que o robô pode assumir na interação com a criança: tutor e colega. Em ambos os papéis o robô faz um discurso introdutório onde se apresenta e explica a atividade, descrevendo como é que a criança deve proceder durante a mesma, e termina convidando a criança para brincar. As diferenças entre os dois modos consistem no nível de conhecimento do robô.

No modo tutor o robô tem conhecimento sobre a atividade e guia a criança ao longo da mesma, mostrando um elevado grau de confiança sobre as sugestões que faz. Neste modo o robô ajuda a criança a escolher as peças a serem escolhidas, faz comentários que sugerem se a peça selecionada é correta ou errada, e caso seja errada dá uma pista sobre a peça que deveria ser usada. Quando a criança demora mais de 10s a escolher uma peça, o robô também intervém, fazendo uma sugestão sobre a peça a usar. Caso a criança erre a sequência, no fim de a executar o robô dá uma explicação sobre o porquê de a sequência estar errada; quando a sequência está certa o robô felicita a criança, fazendo uma dança após dizer que a sequência estava certa.

No modo colega o robô não tem muito conhecimento da atividade, mostrando incerteza nos comentários que faz durante a interação. Apesar de o robô incentivar a criança a escolher a próxima peça, ele não faz sugestões sobre a peça que deveria ser escolhida. Sempre que a criança escolhe uma peça, o robô faz um comentário que confirma a validação da peça, não sugerindo se a mesma está correta ou errada. Quando a criança mostra incerteza sobre a peça a ser introduzida de seguida, o robô pede ajuda à criança sobre a peça a usar em seguida, não sugerindo nenhuma peça. Caso a criança escolha o bloco errado, o robô questiona a criança sobre a mesma, pedindo por vezes uma explicação sobre o porquê de ter sido essa a peça escolhida. Se a sequência introduzida estiver incorreta, após o robô a executar incentiva a criança a tentar fazer a atividade novamente, sem explicar o porquê de a sequência estar errada; caso a sequência esteja certa, após executar a sequência o robô felicita a criança e dança.

Após o desenho e implementação do Rolebot, desenvolvemos uma atividade para ser desenvolvida usando o mesmo. A atividade desenhada consiste em a criança ajudar o robô a fazer um caminho entre dois pontos, usando as peças tangíveis com direções. De modo a facilitar a visualização do caminho que o robô deve percorrer, usámos blocos de tapetes para brincar, onde cada movimento que o robô faz está enquadrado num desses blocos. No final do caminho está uma garrafa de água, onde o robô pretende chegar porque está com sede.

De forma a avaliar o nosso sistema, conduzimos um focus group com professores experientes no ensino em turmas com crianças com diferentes habilidades visuais, providenciando-nos o seu ponto

de vista acerca do RoleBot, e contribuindo com sugestões de atividades a realizar com o sistema e recomendações sobre o comportamento do robô na interação.

Palavras-chave: Robôs, Acessibilidade, Pensamento Computacional, Colaboração, Papéis

Abstract

Computational thinking can be considered a strategy that allows people to learn how to structure the way of solving a problem and therefore it has become an important tool to form children and teenagers. There are several ways of teaching computational thinking, but the most popular is through computational kits. Computational kits provide an engaging and fun way of learning while developing CT concepts and can be used to foster collaboration in a mixed-ability environment.
Noticeably, most of the computational kits for children are designed for children without visual impairments. For visually impaired children it can be a challenge to follow a robot´s actions and perceive their location, which can potentiate the isolation of these children. Although some work has been done on accessible computational kits, using audio interactions and tangibles, the robot usually plays a passive role, by only executing the child commands´. We aim to explore the robot playing a more active role, by using the roles usually used in class, tutor, and college.
In this thesis we present RoleBot, a system that allows the development of computational thinking skills, by using a computational kit with some specifications such as the exploration of roles, providing more interactiveness on the activity increasing children's engagement in the activity.

Keywords: Robots, Accessibility, Computational Thinking, Mixed-ability, Collaboration, Roles

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List of Abbreviations and Acronyms

IT - Information Technology
VI - Visually Impaired
LASIGE - Large-Scale Informatics Systems Laboratory
CT - Computational Thinking
ARS - Active Role Switching
SET - Special Education Teacher

Chapter 1

Introduction

Over the years, schools have changed their approach, which consisted of teaching children with visual impairments in a different environment apart from sighted children, to teaching children regardless of their level of vision in the same environment. Although this new approach allows inclusion, it is also important to investigate the tools that are used in class and make sure they are accessible for everyone.
Technology has changed the way children are taught these days, with new and advanced tools being introduced in class. Having in mind the importance of technology today, schools began to introduce basic computational thinking concepts in early ages. Computational thinking can be considered a strategy that allows people to learn how to structure the way of solving a problem and therefore it has become an important tool to form children and teenagers [6]. There are several ways of teaching computational thinking, but the most popular is through computational kits since it allows enhancing the engagement in the activity, improving children's results.
It is important to have disabilities in mind when designing not only computational kits for children, especially because when they are in school, they are still discovering themselves and developing their personalities, but also the activities and learning strategies used with them. Therefore, it is important to adapt activities to include everyone despite the level of vision.

1.1 Motivation

Robots are an engaging way of teaching pupils, keeping them motivated while learning [7]. They also allow the development of different activities designed to be performed in groups, stimulating collaboration and social skills. Most existing robots require vision to operate the robot or understand what the robot is doing, creating a barrier between sighted and Visually Impaired (VI) peers which potentially contributes to a sense of isolation of the latter.
Existing approaches that focus on accessibility rely mostly on voice interactions, which turns out to be an experience not as rich as it would be with any other robot, lacking the fun and engagement factors. Some work has been done on developing computational kits that do not rely on voice interactions. For instance, Torino [8,9], a physical programming language to teach computational thinking, allows exploring collaboration in a mixed-ability environment, using beads to program instead of voice interactions. However, it can only be used in a limited context since actions are audio-based and sequential and does not explore spatial activities that promote spatial cognition which is very important for blind people.

Although this effort to create approaches to include children with different levels of vision is extremely important, the whole point of using an educational robot to make the learning experience more fun, captivating and engaging can be lost, since they´re not much interactive and computational kits can end up not being an appealing experience anymore. It is important to rethink the whole design and look for ways of adapting kits ensuring that they are efficient, educational, and fun.

Finding ways to create computational kits that fulfill the needs of a specific audience with limitation, detecting guidelines that should be followed to make the kit as accessible as possible, to join and please mixed-ability groups can be really challenging. There are some examples of approaches used in a mixed-ability environment [8,9] in which blind peers felt confused since they could not be aware of what was happening. This highlights the importance of following specific guidelines to assure the accessibility of the computational kit. Accessible computational kits allow the use of the kit by anyone, regardless of their vision level and provide awareness of what is happening for everyone, by providing detailed audio and/or haptic feedback in the addition to the visual feedback.

Despite these limitations, studies that explore teaching children, regardless of their vision level, using robots as a tool [10,11] have shown that there is great potential in using robots as a teaching tool. However, studies exploring teaching computational thinking to children, using robots in a mixed-ability environment, only use it as a passive agent, not exploring its full potential.

1.2 Research goals

In this thesis, we will design and implement an accessible system. This system will be later be used to explore the use of roles in interactions between the robot and the child, by having the robot playing two different roles, in the context of learning computational thinking.

As a starting goal we will investigate the existing computational kits and analyze its specifications and how accessible they are. We will also go through what has been done regarding robots and blind children and perspectives on how to foster collaboration, getting into the definition of collaborating and investigate and explore the existing teaching techniques.

In general, we want to find effective ways of fostering children's learning capabilities having accessibility in mind. We hope to achieve this by designing an activity with the purpose of teaching computational thinking, using a computational kit and exploring the multiple roles that the robot can assume. This activity will be designed throughout several stages and evaluated in the end by educators.

The main goal of this work is to explore peer teaching techniques, in the context of collaboration in a mixed-ability environment in activities that make use of computational kits encouraging interaction between the robot and the child, fostering the learning ability.

To achieve this goal, we will:

1. Explore previously made studies regarding computational thinking teaching, computational kits, and accessibility
2. Understand together with IT (Information Technology) teachers of children aged 5-11 how they introduce and approach computational thinking and how is accessibility approached
3. Understand teaching approaches used in schools with sighted and VI children
4. Develop a system that allows children, regardless of their vision level, to learn computational thinking interactively
5. Evaluate our system with teachers that work with VI children daily

1.3 Approach

To achieve the objective of this thesis, we divided the process in three phases:

- Preliminary study: First phase of the project on which we researched the importance of teaching computational thinking and how to approach it in a mixed-ability environment with VI children, resulting in our related work. We also studied and explored the current teaching practices in schools and how accessibility is approached by interviewing IT teachers.
- System Design and implementation: Second phase of our project on which we designed our system, RoleBot, that explores roles as a teaching technique in the context of teaching computational thinking, having in mind accessibility considerations.
- System Evaluation: Third and last phase, presenting the RoleBot to teachers with experience in mixed-ability environments to get feedback on the system and suggestions on how to improve the system.

1.4 Contribution

Currently, computational thinking is already introduced in schools, often using computational kits. Some work has also been done on how to adapt computational kits and activities to teach computational thinking in order to make them accessible for everyone despite their vision level. Although some studies have used the robot as a not so passive agent, exploring different roles, this approach hasn´t been used in the context of teaching computational thinking.

In the course of the present work, we present three contributions:

- Requirements collection for designing an accessible system through related work and several interviews which led to several relevant conclusions
- An accessible system to explore robot’s roles as a teaching technique aiming to increasing interactiveness and engagement in the context of teaching computational thinking to VI children
- Validation of RoleBot and the activity designed by primary school teachers with experience on teaching blind children

1.5 Publications and Outreach

- The results of the analysis of the interviews to IT teachers resulted in the following publication: Marta Carvalho, Filipa Rocha, João Guerreiro, Hugo Nicolau, Tiago Guerreiro, and Ana C. Pires. 2022. “*Current Practices in Teaching Computational Thinking to Children: Accessibility is an AfterThought*”, ACM IDC’22 workshop on Co-designing with Mixed-ability Groups of Children to Promote Inclusive Education

1.6 Context

This master´s thesis was developed at LASIGE, which has been working on projects approaching the use of robots in a mixed-ability environment, focusing on accessibility. These projects allowed the department to study and explore visual impairments, inclusion and how to design activities and adapt computational kits to be used in mixed-ability environments. Some solutions and activities have been developed and tested during the years.
Over the years, LASIGE has worked in collaboration with Escola Básica dos Olivais, a school for children until the 9th grade with sighted and VI children. This collaboration has allowed the lab to work and test on the projects, to improve them and come up with new ideas and solutions.
Some of the considerations of the solution of this study were based on prior work conducted by the research team. In addition, the first interview study (section 3.1) was done in collaboration with other members of the research team. This collaboration was particularly helpful due to the difficulties in scheduling studies with teachers and/or children during the covid-19 pandemic.

1.7 Document Structure

The remaining sections of this document are organized as it follows:

- Chapter 2 -" Related Work"
  This chapter describes the motivation of our work, analyzing and going through studies and work that explore topics that we found interesting in the context of our work

- Chapter 3 -" Understanding computational thinking and accessibility considerations"
  On chapter 3 we present the findings of interviews performed with IT and special educational teachers in order to get some understanding on the teaching panorama in Portuguese schools

- Chapter 4 -" Design of RoleBot"
  In this chapter we provide the development process of our system, describing the design and implementation details of RoleBot

- Chapter 5 -" User Study"
  In this chapter we go through the findings of the user study where we presented our system. The user study arose some suggestions of updates on our system activities in which it could be used

- Chapter 6 -" Conclusions"
  This chapter summarizes our work and final conclusions of the work we present on this thesis.

Chapter 2

Related Work

2.1 Computational thinking

Over the last years, along with the digitalization, it has become more important to ensure children are prepared and have the skills to deal with the world´s transformation. Digital technology has had an incredible growth, never seen before in any innovation in the history of civilization. According to an Oxford University researchers' study [12], 47% of all jobs will disappear in the next 10 years as new jobs will arise. Therefore, there is a need to prepare children to be able to develop their digital literacy, so that they will be prepared for the future [13]. At schools, this has been approached with the introduction of robotics, which involves electronics, mechanics, artificial intelligence, and computer science, allowing users to improve their knowledge on CT.

Robots [14] provide an efficient and fun way of learning computational thinking with any other subject implicit. Activities performed with a robot might be related to subjects such as biology, music, mathematics, or languages, among others. Besides this, learning using a robot can make learning more engaging, fun, and interesting than the traditional teaching strategies [15].

Programming with robots from a young age helps children structure the way they think when facing a problem [6]. Therefore, it is extremely important to start introducing robots to children at an early age. Given this, the industry answered to this concern with a range of computational kits that have been placed on the market for the last decade.

There is a large variety of educational computational kits, with different types of input, sounds, lights, sensors, and feedback. Most of them target a specific age, however, there are already some that are designed to be appealing to a wide range of ages.

Some work on making computational kits accessible provide basic guidelines that should be followed when designing an accessible computational kit, explaining how some design decisions should be done. There are already some kits that had accessibility as a main goal, following these important guidelines.

2.2 Computational Kits

Several educational robots and computational kits have been developed for the past years [16] with the aim of teaching different subjects. Each one has a specific age target and its own characteristics, varying substantially from each other. There are three main groups of computational kits: physical

kits, virtual kits and hybrid kits. This classification is based on some main design features that these kits differ on. Physical kit´s components are tangible and typically consist of a physical robot, a set of coding blocks and some supporting materials such as maps, craft materials, storybooks, or coding cards to help children structure their thinking. Virtual kits are basically applications for mobile or computer, usually in the form of video games with different difficulty levels. Hybrid kits are the kits that include tangible and virtual parts. There are two types of these kits [17], kits with robots and a graphical environment have a physical robot usually used for feedback, a mobile-based coding application and some supporting materials; and kits with virtual sprites and tangible programming environments that consist of a virtual game and tangible blocks to control a
virtual sprite.

In this thesis, we decided to focus on physical kits with electronics and hybrid kits with virtual/tangible programming blocks. Since virtual kits are usually used by being combined with tools included on the two other categories of computational kits, we will not consider it as a category itself in our work. Therefore, although this category will be omitted, its kits will still be considered as part of the other two categories. We considered physical kits with electronics the ones that allow operating the kit using tangibles or buttons and hybrid kits as kits that require using a touchscreen.

Robots can be used not only as a tool to teach computer science and electronics but also to teach other subjects with computational thinking implicitly. Cellulo [18,19] consists of a robot where the only possible input is through touch, physically moving the robot. The robot can move and be moved. When used together with other cellulo robots, they can do patterns and show behaviors. This robot is specially used to teach physics since they can show in effective way atoms move depending on the physical state of a material. This robot can can also be used as a tool to teach handwriting, as well as Curlybot, since both robots are able to record a movement and reproduce it as many times as wanted.

Figure 2.1: Cellulo Robot

Age Range. Most of the computational kits target a specific age range, depending on what children can do. In general, kits intended for children in young ages are more basic, exploring the use of buttons on the robot to operate the robot and lights as well as the robot's behavior to give feedback. There are however some robots designed to be used by children in early ages that make use of sensors or tangibles to operate the robot.
Generally, kits designed for older children (+7 years old), instead of using tangibles or buttons on the robot to control it, are composed of a much more complex robot with different sensors and on which the user has more control over. Most of these kits consist of a robot and an application that should be run on a device to control the robot. This way, it is possible to make the kit appropriate for different age ranges, since the complexity of the activity entirely depends on the robot. So, the same robot might have different apps with different themes and difficulty levels, varying from programming with images, text blocks, or text, as we can see on.
There are several computational kits and various studies and projects using different approaches. In this thesis we gathered the ones that we found more relevant, having in mind what we aim for, which we succinctly resume in this section along with a table that synthesizes the main characteristics of each one.

2.2.1 Physical Kits with electronics

The physical kit with electronics BeeBot [20], is one of the most popular for children aged 4-7 and allows children to develop some of the computational thinking concepts. The robot looks like a bee and has some buttons on the top with the 4 different possible directions, as well as an enter, a clear and a pause button. Children perform activities to make the bee go from one place to another, using the direction buttons. This requires the child to train decomposition, do a sequence and train and debug. This robot has already had some updates since its first presentation, and other similar robots have appeared in the market, as for example Robot mouse [21].
On a completely different approach, there´s Robotito [22,23], also targeting the same age range. Robotito is operated indirectly, by manipulating the environment, not having any buttons, but instead some sensors that afford this interaction. This robot is designed to follow a color, following a specific direction depending on the color. For example, if the card is red, the robot turns left. The other way of controlling the robot is using the distance sensor. The robot scans its surroundings and moves towards the furthest object.
There are also some robots that use tangibles to control it. Cubetto is a kit composed of several maps, a robot, a programming board, and tangibles. Children must place tangibles on the board according to the path they want the robot to follow on the map, avoiding obstacles. Dr Wagon [24] uses a similar concept in a different way, the kit is composed of a robot and tangibles. Each tangible has an instruction which the user is required to align, depending on what they want the robot to do. Instructions include directions, conditionals, variables as well as loops. It is also possible to change the robot´s appearance. Kibo [25], with a similar appearance, also works identically, allowing light and tangible blocks as input, which are scanned by the robot. Elkin et al. [26] presented a study using Kibo to teach programming concepts to preschool children aged 3-5 years old which showed Kibo can be efficiently used with children aged 3 on activities that make use of sequencing and loop concepts.

Besides these robots, we decided to include on this classification robots that allow two types of interaction: through buttons/sensors and using an app. Microbit [27,28], designed for children 8-14 years old, is mainly characterized by its tiny size, defined as a “pocket-sized codable physical computing device”. It allows three types of input: buttons, light sensors and through a mobile app. The robot uses it´s LED screen to give output. Similarly, Ozobot Evo[29,30,31] and Sphero [32,33] allow two types of input to control the robot, environment manipulation (using lines and colors) and through a mobile based application. Although Ozobot Evo has a specific target age, 6-12 years old, due to the low complexity of operating a robot through environment manipulation and the fact that the app uses blockly, intended for children; Sphero targets people +8 years old, since the mobile app allows programming using virtual blocks and text programming. Ozobot is an incredible versatile robot, [29] presents a study that successfully explores teaching kinematics with ozobot in order to improve student´s graph interpretation skills, and there are also studies exploring activities using Ozobot with the computational thinking development in mind [30,31]. Sphero has a lot of online supporting material with instructions, fun activities to do with the robot, and structured activities to develop computational thinking.

Figure 2.2: Ozobot Robot

Figure 2.3: Sphero Robot

2.2.2 Hybrid Kits with virtual/tangible programming blocks

In a different computational kit´s classification, are the hybrid kits which involve controlling the robot using a device with the robot´s apps. In general, these robots are adaptable to different age ranges, since they have more than one app that allows evolving from programming beginner, with images and text blocks [34,35], to expert, using text to control it. Some of them even allow sound recordings that are programmed to be heard in certain situations.

After investigating some robots that can be put into this category, we gathered some that we considered to be more suitable to our approach. In the table available in Appendix A at the end of this document, we highlight the ones that we found more relevant, pointing out their main features.

Coji [36] is a robot that uses emojis and symbols as a programming language, making it easy for children 4-7 years old to understand and manage to operate the robot. The face of the robot is a screen that plays different face emojis, giving feedback on the user's input. It also gives audio feedback. On a different target age range, Cue [37], designed for children 11-15 years old, allows the three types of programming: images, virtual text blocks and text. The personality can be personalized and although limited, it supports audio recording. It also has programmable lights which can be especially important when using the robots with children that should´not be overstimulated. With a similar appearance there ´s Dash [38], intended for anyone older than 6, also allowing the three types of virtual programming. Similarly to Cue, allows limited audio recording and has programmable LEDs. However, to program the robot using the different approaches, the user has to download different apps on the device, which can be considered as a disadvantage.

Thymio [39,40,41,42,43] is a very versatile robot since it targets a wide range of ages, 4 to 99 years old. The robot allows a huge variety of different interactions. It also supports the three types of virtual programming and it is especially useful for people who want to learn how to code, since it provides a real time conversion of what's being programmed with images or text blocks to code in Aseba programming language. It has open source software and a memory slot card which grants no limited audio recording slots. The LEDs are also programmable.

2.2.3 Computational Kits designed for VI children

Although most robots require vision abilities to operate with it, in order to give input and perceive correctly the output, some kits have been developed, considering visual impairments.

Torino is a computational kit developed inclusive to blind children. It consists of a physical programming language to teach computational thinking to children 7-11 years old in a mixed ability environment encouraging collaboration. It has audio feedback and physical representations (beads), distinguIshable by touch and with high contracting colors. Although it is an accessible kit, it has a limited context since actions are sequential audio based and does not allow activities to develop spatial cognition, which is highly important for blind people [44]. Thieme et al. [8] explored collaboration in a mixed-ability environment, evaluating the interaction between children. The study's findings suggest that beads, as tangible pieces that shall be touched and shared, enable collaboration, supporting the importance of touch, audio feedback and visual representation for inclusive designs. Collaboration happened naturally, since children would help each other, discuss opinions and negotiate towards a consensual solution.

Neto et al. [45] presented the first study exploring a robot as an input/output tool to learn skills in a mixed ability context. The robot gives haptic, visual, tactile and audio feedback. Results showed that every child was able to correctly perform the activity regardless of the level of vision with a notable high level of interest and engagement. In the study, each child had a robot. While one of them would draw a geometrical form, the other would have to guess the shape it was, since their robot would mirror the other one.

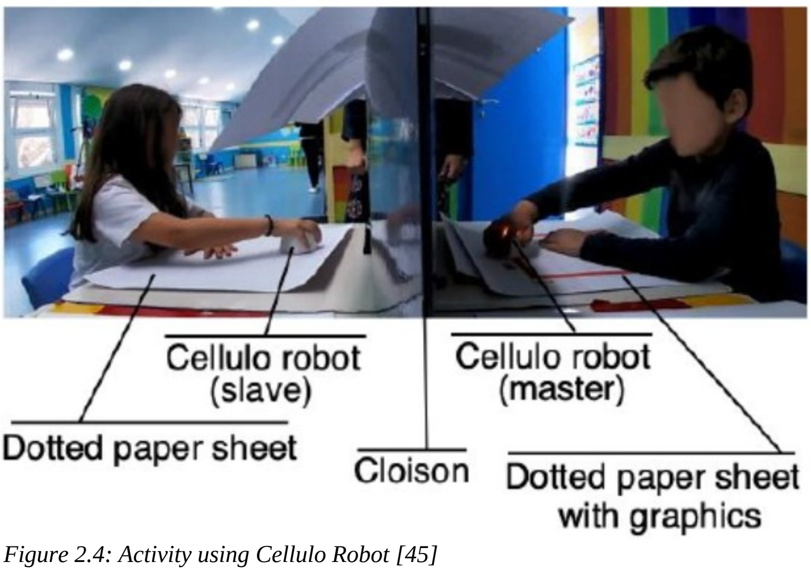

Figure 2.4: Activity using Cellulo Robot [45]

During the study researchers noticed that participants collaborated, communicated and helped each other. Although in 80% of the cases the geometrical form was found by the pairs, the speaker was not in-built in the robot, so the sound would come from a speaker in a different location which can be confusing especially for VI children while learning spatial concepts. We can also consider this study to have some flaws since only 3/10 pairs had VI children, which can lead to wrong conclusions when analyzing the study's results.

Ozobot was also used to create an educational game in a mixed-ability environment [46]. The study presents co-design workshops which contributed to inclusive game design guidelines and game development evaluation. Although VI and sighted children enjoyed the activity, not all groups behaved the same regarding collaboration. While in some groups peers would collaborate with each other, working on negotiation, other groups did not collaborate as much, not including VI peers in the activity.

2.2.4 Accessibility Considerations

Although accessibility has not been much explored on robots, some studies have already presented some results from which a few conclusions may be taken of. These conclusions, provided from observation and user feedback give us some orientation on how to adapt a computational kit. Antunes et al. [47] explores the use of Ozobot in a story telling activity in a mixed-ability context, providing a prototype that can be used in activities with sighted and VI children. Pires et al. [38] explored programming an adapted robot using tangible blocks and a map. In the study researchers found not only that the use of tangibles, maps, and robots all together fostered inclusion and collaboration but also feedback and feedforward helped VI children to keep aware of all actions and increased the learning curve. In this specific study, the computational kit was adapted to be accessible for VI children. Each block had an in-built play button to enable children to listen to the corresponding action, feedback/feedforward mechanisms were added to the robot, and all of the kit elements had tactile cues.

Although the study in Antunes et al. [47] is focused on inclusive game guidelines, some of the topics are general and can be applied to other activities. In the co-design sessions, the importance of including multi-sensory feedback and not sticking only to audio feedback was highlighted. It was found that a good way to introduce the robot to children was to use crafting to personalize it, and maps increase engagement as well as including learning objectives. Researchers also found the distribution of different roles between peers an efficient way of encouraging collaboration.

Milne et al. [48] explains the design considerations while developing a web-based application on a touchscreen laptop to introduce children to programming focusing on accessibility. This application targets children 5-7 years old and uses non-visual techniques to give children cues on which text blocks fit together. The main design considerations to make web-based applications accessible consisted on:

- Universal design, usable regardless the user´s vision level
- Touchscreen based
- Allow non-visual program exploration and construction, in order to be accessible all elements should allow exploration via sound output to give information about the element itself and spatial information. “Drag and drop” elements should be replaced with “select, select, drop” which is more accessible for blind children

- Support for audio, producing audio output makes the experience more enjoyable not only for blind children

2.3 Collaboration

Collaboration is frequently fostered in schools to encourage pupils to work together towards a common goal while learning. Collaborative learning has been shown to have multiple advantages such as developing higher-level thinking skills and boosting pupils' confidence and self-esteem [49]. Collaboration is also known for improving the way pupils work in groups and their problem-solving skills.

Working in groups collaboratively requires pupils to communicate with each other, present their own arguments and opinions while justifying, discussing ideas, and negotiating towards a consensual solution. Multiple work has been done on exploring collaboration and its benefits. Hamm et al. [50] goes through the benefits of pupils working collaboratively in groups, in particular promoting social skills, gives pupils a sense of partnership which may lead to new friendships.

Teachers often make use of collaboration in mixed-ability groups to provide pupils with lower school grades a safe environment where they can expose any doubts or express opinions without the concern of being judged. Saleh et al. [7] explores collaboration in pupils with different overall school grades (low, average, and high). The results of the study support the idea that all pupils benefit from mixed-ability collaboration, enhancing the learning process. Results also show pupils were more motivated to learn in groups instead of the traditional way. However, this study only had male genre participants, which can lead to generalization errors due to a non-representative sample.

Mixed-ability groups are a great way of encouraging collaboration since each peer can contribute to the group in a different way. Therefore, for all of these reasons, mixed-ability collaboration can be an interesting strategy to use with children with different visual abilities. Since low vision/blind children often suffer from isolation, this approach might help them to develop social skills and interact with other children while learning and developing other important skills.

Sallnas et al. [10] explores collaboration in a mixed ability environment while learning geometry with two haptic and visual prototypes. The study uses two prototypes, the first one to learn angles, allowing pupils to feel angles and figure´s shape. The second prototype required pupils to work collaboratively in groups and consisted of an upper view from a room with geometrical objects that had different textures, so that pupils could recognize different geometrical shapes and move them around. Although the second prototype caused some difficulties for VI pupils due to being a dynamic environment which specifically caused blind pupils to be unaware of changes. In the first prototype pupils discussed and collaborated within the group, negotiating a consensual final solution, supporting a very good level of collaboration well and being very inclusive since VI actively participated in the activity.

2.4 Teaching techniques and roles

Nowadays, teachers make use of several teaching techniques and strategies in order to improve children's learning abilities. According to Hughes [51], teaching is more complex than it is generally assumed, claiming that a teacher makes several decisions on their teaching strategy, which can be synthesized into two aspects: the structure of the content and the behaviors to be attained by the students.

Marie Hughes defines teaching acts as the basis of teaching strategies, stating that teacher acts could be wrapped in the following categories: Controlling (acts that tell children what to do and how); Facilitating (acts to check, demonstrate and clarify); Content Development (acts to elaborate the structure of the problem); Personally responsive acts; and Positively and Negatively affective acts. Hughes claimed that the quality of teaching, which directly influences how children learn, is directly related to the acts that the teacher employs. For instance, when a teacher mainly uses controlling acts, they tend to limit children's intellectual activity to memory and recall, whereas content development is more related to developing mental processes such as thinking ability.

Cooperative learning, which “involves students working together in small groups on a structured activity” [52], consists of developing the mental processes required to learn to think, and therefore, making use of the act of content development. Cooperative learning is one of the methods that focus on active learning, which has been proven to have better learning results than the traditional method of sitting and listening, or according to Hughes, the controlling act [51]. Teaching Techniques that make use of cooperation [53], are known for helping in developing social skills, promoting negotiating and discussion, allowing students to give feedback to each other.

2.4.1 Cooperation Roles

In an activity exploring collaboration in the context of cooperative learning, participants naturally make use of different roles, which can be divided into tutor, tutee, and peer. These roles usually depend on the participant's knowledge, confidence, and their individual tendency towards extroversion/introversion. The difference between these roles lay on how active each participant is in the activity, while a tutor participant usually teaches other children, tutee participants are more passive and let other children lead the activity; the peer role is usually adopted by children that are more neutral, assuming both tutor and tutee roles.

2.4.1.1 Robots cooperating with children

Some studies have explored cooperation using robots as a tool, while making use of collaboration in the context of cooperative learning, both in groups and one-to-one situations.

Regarding the use of the robot in groups, Zaraki et al. [54] approaches collaboration using a robot, in a group of 2-3 children, having the robot playing the tutee role and children playing tutor. Children place toys around the room and teach the robot the position of each toy and its name, then the robot is tested pointing at each toy and saying its name while children give feedback on the robot being right or wrong.

Figure 2.5: Activity exploring roles [54]

Many studies have explored collaboration in a one-to-one environment with a robot. Chen et al. [55] explores a robot approaching the three roles, on a one-to-one activity, defining the peer role as a mixture between tutor and tutee, based on the child's performance. The study explores how the interaction paradigms influence the learning and effective experience, having three conditions: the robot as a tutor, being an expert that does not make mistakes and gives the child feedback; as a tutee, being a curious learner with lack of vocabulary knowledge; and as a peer, using an ARS (Active Role Switching) to determine which role to be at each turn - tutor or tutee. The results showed that the peer condition had significantly higher results in joy, affective play, smile, and children learnt better than they did in the other two conditions, followed by the tutor condition regarding the learning results.
Several works have been done on exploring learning by teaching [54,55,56,57], having results that show that not only children tutoring robots can be part of an efficient teaching technique but also that children perceive whether the robot is learning or not. In Chandra et al. [56], although the condition in the study is the robot in the tutee role and the child tutoring it, results show that children perceive the robot as a peer, probably due to the robot being continuous learning, as a child would.
Regarding accessibility, there is not much work done on employing these activities with children with disabilities. However, Zaraki et al. [54] performed a study on children with autism, concluding that not only did children manage to successfully complete the activity, but also had a positive impression on the activity, concluding that it can be applied on activities including children with autism.

2.5 Discussion

Computational thinking is known to be an important skill to start developing at an early age. Computational kits have been used as a tool to teach computational thinking since it can increase the engagement in the activity. There is a wide variety of different computational kits, ranging from physical kits with electronics to hybrid kits with virtual or tangible blocks. Although most computational kits are not accessible for VI children, there are already some computational kits that use audio and haptic feedback as well as physical input to make them accessible for VI children. Some kits also allow you to program and manipulate the lights on the robot, so that they can be customized for children who might get overstimulated by lights.
Most of the computational kits can be used in groups of two or more children, allowing the exploration of collaboration as a teaching technique. Collaboration is often used in class to enhance children's communication and social skills while improving their problem-solving skills and building up their self-esteem.
In the context of a mixed-ability environment collaboration can play an important role to achieve inclusion by allowing children with different visual abilities to work together on a task while getting to know each other. Therefore, it is crucial to design activities that can be accessible for every child regardless of their vision level.
In addition, most of the computational kits that are accessible, allowing its use in a mixed-ability environment usually place the robot as a passive peer on the activity. We think it could be relevant to explore the robot playing different roles in which its knowledge would differ, just like it naturally happens in a group of children that collaborate in a task. Not only would this make children perceive

the robot as a peer, instead of just a machine, but it could also enhance the engagement of the activity. Therefore, we decided to design and implement a system that explores the robot playing different roles.

Chapter 3

Understanding Computational Thinking and Accessibility Considerations

The Related Work gave us relevant knowledge on the importance of learning computational thinking at an early age and how collaboration can be an effective teaching technique, potentially promoting inclusiveness. To explore collaboration and the use of roles, we started by understanding the current panorama of teaching IT in Portuguese schools. There were several topics we needed to understand, specifically teaching techniques currently used, the teaching of computational thinking, and accessibility in class. For that, we interviewed IT teachers to perceive how computational thinking is taught, also focusing on accessibility since we wanted to understand if accessibility is being considered in class and how.

The findings of these interviews led us to conclude that accessibility is not taken into consideration. Despite having VI students in class or students with other disabilities, teachers use mechanisms in order to deal with limitations, instead of taking accessibility into account. This can lead to the increase of the cognitive load of the activities for blind children since they are required to memorize how to work with hardware and its keywords and interface.

To have some understanding of accessibility in class and teaching to VI children, we decided to interview a special education teacher who is himself also VI.

In this chapter, we present the findings of these interviews regarding current teaching techniques in computational thinking, the educational use of robots, and the potential of exploring robots' roles.

3.1 Interviews to IT Teachers

To understand the teaching techniques and methods used in schools and how teaching is approached in a mixed-ability environment, we conducted an interview study with informatics' teachers. The study involved 6 teachers, aged between 22 and 57. The participants have different experiences in teaching, their experience time in teaching ranges from 1 to 33 years, while some of them work in regular schools (private and public), others give extracurricular classes. These teachers work in schools with different socio-economic context. Table 3.1 summarizes the participants who took part in the study and their characterization.

P.	Previous Experience	Time of teaching	Type of classes	Duration of the	Students Age Range	Number of students in

		experience		**course**		**class**
P1	Universitary Teacher	—--	extracurricular	—-	10-11	9-11
P2	Teacher in professional highschool	6 years	curricular	trimestre	6-16	15-25
P3	no	1 year	extracurricular	1 year	10 years	4-10
P4	—-	2 years	extracurricular	1 year	6 and 15-16	—--
P5	IT teacher	33 years	curricular	—--	10-18	25-30
P6	School monitor	1 year	extracurricular	semestre	7-17	3-12

Table 3.1: Identification and characterization of the participants and their corresponding ID (P – Participant)

3.1.1 Method

Participants. We interviewed 6 informatics teachers, one male, and five females. Out of the 6 interviews, 5 of them were conducted in presence, in each teacher school in Lisbon, and 1 was conducted online via video call since the participant was abroad. All the teachers work in different schools, with their experience years ranges from 1 year to 33 years. The average time of the interviews was 1h, although the interview with P1 took 3h. While 2/6 teachers were working in regular schools, having experience in curricular classes, 4/6 taught in extracurricular courses. The age range of the students these participants teach range from 6 to 17 years old. Regarding the number of students in class, we can deduce that classes in regular schools have more children in the class (15-30) than extracurricular classes (3-12).

Procedure. To get some understanding of the current IT teaching panorama in Portugal, we decided to interview six teachers with different backgrounds and teaching experiences. There were several topics approached, such as the benefits of introducing computational thinking to children, informatics teaching techniques, the use of technology, and teaching blind children. In the interview, we focused on understanding how computational thinking is first approached to children, which concepts are taught, and the difficulties did children feel and the use of technology in class. We also inquired about children with learning difficulties and/or disabilities, focusing on VI children to understand how teachers need to adapt materials and techniques to teach these children and how it is different from teaching children without any impairment. The six interviews were all audio recorded, with the permission of the participants which allowed us to transcribe each interview. To analyze our qualitative data, we performed a thematic analysis [58,59]. We started by generating general initial codes based on the interview questions and analyzed all the interviews, looking for more specific codes which helped us find and identify patterns across the six interviews. Afterward, we refined our codes by reanalyzing all the interviews along with the codes we created, which were then grouped into six different themes in our code book. This analysis led us to the following findings.

3.1.2 Findings

3.1.2.1 Computational Thinking

The introduction of computational thinking at an early age is known for having several benefits. Most of the participants considered the development of logical thinking as the major benefit. However, other participants stated that it also stimulated an improvement in organization skills and when taught with other subjects, such as geography and mathematics allowed a revalidation of pre-acquired knowledge. Developing math concepts, creativity, and learning English vocabulary were also some of the benefits pointed out by teachers.
“Logical thinking, without any doubt. Also, in this case, that they´re developing games, creativity” (P6)
“There's a revalidation of knowledge. These small projects can be the bridge for the teacher of another subject to continue talking about the disciplinary contents we introduce” (P2)

4/6 of the participants said that throughout the year the complexity of the taught contents would increase along the school program.
“I use the coding hour first, so that they can understand simple things and how it works(...) we start with simple things and as the year goes by the steps increase, in other words, they perform more complex tasks” (P5)
The programming concept taught by the participants converged into variables, conditionals, loops, and debugging.
“First, I teach sequences, loops, conditionals, and usually we spend some time on it with different missions/projects. Later on, I introduce functions with variables” (P1)

In terms of logical thinking, abstraction, decomposition, and pattern recognition were referred by all participants as the components of computational thinking that they approached in classes.
“Decomposition, abstraction, pattern recognition, logical thinking” (P3)
Some of the participants (P5 and P6) stated that they “teach how to think”, which appeared to be a consensus among all participants since the other participants also had this idea implicit during their interviews.

Regarding the initial approach to programming, while two of the participants said they would have a first exploratory class “the first class is exploratory in which I tell them to explore and tell me what they found out”(P2); ½ of the participants said that in the first class they would explain what they were going to learn during the course “I would tell them what we were going to do, a game, an app, what the goal was and how we would get there”(P4)

3.1.2.2 Teaching Strategies

As for teaching strategies, one of the things that all participants considered crucial to teach programming is adapting teaching strategies: “if the strategy is well adapted, they will always get to the point” (P5), “the problem is not programming, it's the way we prepare our students for programming and the stimulus we give them” (P2)
Participants mentioned several teaching strategies. P1 and P5 prefer having “several short duration activities during class” (P5), teaching a concept that then students need to use in an activity; whereas P3, P4, and P6 try to make students feel the urge to understand which concepts they should apply in

the activity. “I would… try to explain a lot and make them feel how they would need the concept” (P3)
Most of the participants think that although most of the students showed more difficulties in practice, they believe this happens because they previously did not understand the theory, and P2 said they would use the strategy of “explaining theory with practice. They only understand when they know the theory. But they will only understand theory when they see it in practice, so I think it's a matter of us having the courage of inverting things and then we understand that it all makes sense”

Out of all the teaching strategies referred by participants, there was one that was highlighted for being mentioned by all of them, which is the analogies to teach programming concepts. Two of the participants even said that they thought of analogies as an essential tool to teach younger children since they believe that “The younger ones need relating everything that they learn with something that they already know” (P2)
The most mentioned analogy was regarding the concept of variable, using a box and explaining that “a box store things, but only one at once, just like a variable”(P4), as well as using “the pants pocket as a variable where I can place one card at the pocket to count each tree I saw and at the end, I can count the number of cards and know how many trees I saw”(P2). P2 mentioned some analogies to teach the concept of algorithm, such as “making a cake recipe, exchanging a light bulb, the GPS saying the right directions”, while P1 referred a “glossary to teach a loop because they need to organize everything until there's nothing left to organize; a cat that discovers mysteries for debugging since when we debug we are looking for clues and trying to solve, improve the code”.
P5 said in the context of computational thinking, she would try to “use the body so that children could scale the space, for example going around this table, the number of steps for example, so that they understand what their step is, their foot”
In the context of using a robot as a teaching tool, one participant also mentioned some analogies, for example “pretending the robot is a firefighter and counts the number of people in a building so that we can know how many people need rescue and the robot returns the number of people it detected with its sensors and then returns that value. Therefore, we need a variable to save that value” (P1)

3.1.2.3 Teaching Strategies for mixed-ability environments

As for children with learning difficulties, 2/6 of the participants said they would plan the position of the students in the class, “doing the neighbor relationship method so that strongest students can help students who have more difficulties” (P2). P5 claims to use a strategy that consists of instead of “reducing the concepts taught, giving children with difficulties more time to complete tasks (...) most of them take 45 minutes to do the test, a student with special needs takes 90, but does the same test”, having special attention to these children and after she explains the concepts “take advantage of the time students being creative and applying the concepts I taught to go and help children that have learning disabilities”

Participants had several suggestions regarding adapting the techniques currently used in classes so that they could become more inclusive, including children with different levels of vision. One of the things pointed out was the importance of all children using the same materials, claiming that “if all of them had the same tools it would be easier. I mean, if everybody had tangibles it would be easier if there was a child with visual impairments in the class”.(P3) Tangibles were suggested by most of the participants, since it allows to visualize the output and program how the output is done, “we could use a tangible interface, just like a robot and that's why I think robots would be a good idea because robot allows the visualization of the output. Children can program the sound and lights. I would definitely go for an interface that they could touch" (P1). Some of the advantages of using tangibles are related to facilitating abstraction and allowing interaction with the environment, since "they have different things, they interact with the environment, with their outputs" (P1). One of the participants also stated that it would "motivate children and help them learn easier" (P3), referring to the engagement.

Whereas P3 suggested the use of "web tools" through browsers so that programs could be supported through screen readers, P4 proposed a pre-course for children with visual impairments so that they could "dominate the application and when I said 'go here, do this, do that they would know how to do it because they would already be familiar with the platform"

3.1.3 Discussion

The findings of the interviews performed with the six IT teachers provided some useful and interesting insights on teaching computational thinking and teaching in a mixed ability environment.

First, the importance of introducing computational thinking at an early age was unanimous, and several advantages such as the development of logical thinking, the stimulation of the creativity, and improvement of organization skills were stated.

Participants emphasized the need of adapting teaching strategies and approaches to make it easier for children to abstract and understand the concepts taught. Allowing children to explore the tools they will work with can make them feel more comfortable and familiar with it so that they understand how the tools work by themselves, instead of having someone telling them what to do and how in a first approach.

Teaching programming concepts can be challenging since there is a need for abstraction and children have the need of having real examples or comparisons to situations and things that they already know to understand concepts. Teaching theory through practice is an interesting teaching strategy that can effectively help children to understand abstract concepts easier.

In the context of teaching in a mixed-ability environment there are some things that we should have in mind. Some of the participants preferred not reducing the content taught to children with disabilities and giving these children more time to complete the task and more attention during classes. One of the teaching strategies used is the neighbor method which consists of placing weak children next to strong children, so that the student with difficulties can be helped throughout the activity. This strategy can be seen as a version of using the tutee and tutor roles.

Regarding the tools and materials used in a mixed-ability environment, most participants thought of tangibles as a nice tool to promote inclusiveness since it allows one to visualize the output. It was emphasized that it should be used by all children in class regardless of having or not any disability, to promote inclusiveness. Robots were pointed out as an example of tangibles that would fit these requirements, having some other benefits such as the ability to program sounds and lights, allowing interaction with the environment and touching the interface, and enhancing engagement.

These findings gave us some insights, ideas, and design considerations on how to design computational thinking activity in a mixed ability environment and resulted in a publication to the ACM IDC Workshop on "*Current Practices in Teaching Computational Thinking to Children: Accessibility is an AfterThought*" [60].

3.2 Interview with a special education teacher

After having some understanding of teaching techniques currently used and how to approach teaching in a mixed-ability environment from the perspective of regular teachers, we decided to include the point of view of a special education teacher focusing on visual impairments. Therefore, we interviewed a teacher, who is himself a VI person and has 23 years of experience in education for children aged 10-15 years old. In this interview, we aimed to explore how accessibility is and should be tackled in a mixed-ability environment and the use of collaboration and roles as a teaching technique.

3.2.1 Method

To acquire the perspective of a teacher with teaching experience on children with disabilities, accessibility, inclusion, and cooperative learning, we interviewed via video call a special education teacher who is himself VI. We approach several thematics, from which we highlight teaching techniques in a mixed ability environment, the use of robots in education, specifically in an inclusive environment, collaboration, and the use of roles in a mixed-ability environment. The interview was audio recorded which allowed us to transcribe it afterward, and use the method of thematic analysis [58,59], by coding the interview and finding codes and patterns which led to the following findings.

3.2.2 Findings

3.2.2.1 Teaching Techniques in a mixed-ability environment

Teaching children with mixed-visual abilities often means that children may have other disabilities -- e.g., cognitive -- which may affect their learning capabilities. This leads to the need to adapt the learning content to be more appropriate to different abilities. For instance, SET (Special Education Teacher) mentioned that “the curriculum needs to be adapted for them, it must be a proper program, and, in this case, informatics provides a more ludic way of doing it, in color games, ludic games. For instance, memorizing games, color games, matching cards games”. In the case of informatics, adaptation can be done in many ways, such as “small sentences in words, little sets of words, searching on the internet, very simple tasks… YouTube, platforms that exist, game websites, pastimes, maybe primary school level, very simple things”.

When we talk about VI children, we need to distinguish children that are just visually impaired from children who have visual impairments associated with other conditions that limit their cognitive abilities. The differences in teaching children who are just visually impaired are only technical, “having some support material, a braille book, a tablet, a computer, a screen reader but all of the rest is the same”. However, when children are not only VI but also have cognitive or motor limitations it is essential to use tangible objects regardless of being technological to stimulate these children to learn. Technology can be used as a tool to “awaken attention and curiosity and captivate and hold a student with a disability in a task”, having the advantage of “allowing accessibility for blind and VI people”. The SET also sees potential in using technology to “recover parts of the brain, certain parts of the brain, from certain children or students who are handicapped, who have this disability and maybe we could work on that”. Teaching IT to VI children can be challenging since children are required to learn and memorize “the commands and key combinations” to be able to use a computer. The participant finds robots an interesting teaching tool that could solve the limitations of introducing IT using a computer, also having the advantage of allowing “to arouse attention and curiosity and captivate and

hold a student with a disability in a task" since it is "a 3D object that has volume, color, and texture". One of the suggestions made regarding the educational use of a robot for VI children was to teach directions, "to learn what's ahead, behind, left, right, up, down, we can perfectly get a robot to do it".
To include robots in teaching in an environment of mixed visual skills, it is necessary to pay attention to some essential requirements, to ensure that the robot is accessible, namely "appealing colors, we would probably have to have something that is used a lot that is the so-called RGB, the LEDs. So, something that was stimulating but not overly stimulating so as not to distract from the essentials. In the case of a blind student, purely blind, we would have to be careful with the haptic part. Because sometimes, we want to show a certain object to a blind child, but what is intelligible to us with the eyes is not intelligible in the same way with our hands. So, we must simplify, we have to stylize, for example, we cannot make the Eiffel Tower exactly as it is, because there are details that will be lost, there are details that will muddle them".

3.2.2.2 Collaboration

Collaboration can foster inclusion specially in a mixed-ability environment. The SET believes that to achieve inclusion in a class it is necessary to talk about the differences and standardize the instruments used to facilitate accessibility, arguing that "we only have inclusion when people with some type of disability and the paraphernalia they use become invisible". For example, a VI student of his class who used an iPad "showed, explained how he used it, taking pictures to the board, saving the pictures on the iPad, and his colleagues accepted that and that's it, the iPad is now invisible".
The participant sees great potential in collaboration between children with mixed visual abilities, claiming that sighted children "have a great acceptance and receptivity towards their classmates with some kind of disability", especially if they are involved in the same activities. It is important to have some considerations when designing activities for a mixed ability context, such as the engagement of the activity, "the secret lies in building a captivating activity, according to age". Robots can be used as a tool to enhance engagement since they can be playful and used in a group context and "inclusion is done like this, all together, learning together in the same space, and in this case with robotics all playing together".
To promote this collaboration and inclusion, awareness actions are carried out in classes where students with visual impairments or some types of visual impairment are present, "we do a braille contest, for example we launch small excerpts of texts for non-visually impaired students to try to transcribe and it is a challenge for them and then there are prizes for the best transcripts. So, we always try to involve, we try to demystify this Braille thing, this thing about magnifications, about telescopes". Regarding the formation of groups, the participant believes it is important to split VI children, who are usually a minority around groups with sighted peers, claiming that "if I have a student with low vision, I have to do group work and he is part of the group of sighted colleagues".

Collaboration is known for having several advantages in the development of soft skills. The participant recognizes several advantages in collaboration, namely, "solving problems, overcoming barriers, moving forward with something that the boy with low vision is having some difficulty with and can ask his colleagues for help. And sometimes even without asking, there is that complicity". In addition to these advantages that have results that can be immediately observed, there is still, in general, the influence that this may have on society, because "inclusion also says that we have a micro society that is the school and then if inclusion works at school, we must bring inclusion… it is reflected in society, which is macro-society. And these inclusive practices are then reflected abroad".

There are some considerations that must be considered when testing these activities with children of mixed abilities, such as the speech. Comments including the see verb is one of these examples. See doesn't necessarily mean looking at and it is a verb that doesn't offend VI children, as the participant said, “we say “look, did you see that?” and then it seems that they hit their mouth. Eh, but he's blind, how can I say this any other way? No, there is no other way, it is seen. Because the process of seeing can be a lot, the eyes only look, they do not see, so the process of seeing is very complex. Treat children the same, with the necessary adaptations when they are needed”.

In activities where the robot is used as a teaching tool, for the participant, there is a concern in the affective relationship that children would have with the robot, because an affective relationship will probably arise, therefore the participant suggested “the robot being so cold with them”, to guard against the “dependence that could later be created between the child and the machine".

Several activities were suggested to do with the robot, most of them related to learning directions and mobility, such as “a robot that goes from point A to point B and says to the child, “put your hand on my shoulder and come with me” ... It was spectacular for pre-orientation and mobility”. The participant sees a lot of potential in these activities being introduced in early ages, before children using the walking stick: “Imagine what it's like before you put a walking stick in the hand of a blind boy, he can take the robot for a ride. Thinking that the robot has sensors, it has a camera, or two or five or ten, it has artificial intelligence, it recognizes the space and takes it. In the school recess, for example, and he starts talking to him “do not let go of me. Leaving me is dangerous”. It was also suggested the robot memorizing phrases that each child frequently repeated and then reproducing them, which could create a bond between the robot and the child, giving the example of an autistic boy who he teaches that “during the day, often uses the expression “oh boy!”. So, imagine the connection, the bond that would be created between them”.

3.2.2.3 Use of roles

Roles are usually explored in class in the context of having children with more knowledge teaching children with more difficulties in the contents. However, this aren´t usually explored in a mixed-ability context. The participant explained that they “have children who have better grades, who have more habits and working methods, who help, even by indication of the class director, colleagues with more difficulties in the subject A, B, or C. But this is something that has nothing to do with children with disabilities. They are all treated equally”. Usually, when the teacher does not make the groups according to roles, children make the groups by themselves depending on their bonds with each other, “they form groups and get along better with some people and get along better with others”.

In general, “peer work is created, going through mentorships, going through informal groups, sometimes a little group or another here a little forced by us”. For the participant, although there are several advantages in exploring roles in teaching, in his opinion it should not be forced, as if there were “here a rule “Look, from now on, Francisco will be Antonia’s mentor because Francisco has 5 the story and Antonia has 2”, right? There are several conditions here that children are thinking about”. Thus, he considers a more natural and less forced approach to the use of roles, “a purer, more sincere collaboration, so to speak, and that serves our ultimate interests, which are success, right? Perhaps collaboration is better. But sometimes it's hard to find collaborations that work this well because that later turns into playfulness, clowning, complicity then turns into many things and that's it.”

Regarding the use of a robot in the exploration of roles in a context of mixed visual skills, the participant says that “Of course I would consider it. Let's go ahead with it, it's already late, it's late", and it has many positive points, such as "inclusion, learning, experiences”.

On exploring roles, and which ones would be most beneficial for students, the participant showed some preference on the peer role, believing that “both as partners is a very forward thing… That would be ideal”, and “the more natural the interaction the better, right? And if we go down this path of spontaneity…”.

3.2.3 Results

According to the participant, regarding blind and VI children that do not have any other disability, the only adaptation needed is adapting materials, such as using a tablet, or braille books. However, if a child who is VI has any other disability, the activities and materials should be adapted and instead of the traditional teaching methods, contents should be taught through more ludic activities. In the participant´s opinion, the use of tangible robots, regardless of being electronic or not, enhances the children's engagement in school activities. There are several benefits of using technology in education, since it appeals their attention, such as captivating them along with the activity, maintains the attention of impaired students in a task, allows accessibility and may help recover some parts of the brain that might be underdeveloped. Using tangibles and accessible robots in schools would be a major progress in accessible education, since nowadays VI children mainly use computers with screen readers which might be too demanding since it requires them to memorize several keyboard combinations.

The participant sees a lot of potential in teaching VI and motor impaired children using robots, since it ´s a tool that enables activities that satisfy the requirements to get the child's attention through the activity. However, there are some things that should be kept in mind when designing an activity using the robot as a tool, such as the lights that should be appealing but not too stimulating, supporting haptic feedback but not too detailed and the robot not being too emotional and affective.

Regarding the use of cooperative learning, the participant sees great potential in using collaboration as a teaching technique since it promotes inclusion. The participant was also very excited when asked about his opinion on approaching collaborative roles in activities using robots as a tool, considering it the ideal setup for learning in an engaging and inclusive environment and providing children with a fun, valuable experience. In their opinion, the ideal condition would be to explore the peer condition. The main idea for an activity exploring roles using a robot was teaching directions.

3.3 Discussion

Having some insights on the current teaching practices and how accessibility is approached (or not) gave us the motivation to work on a solution accessible for everyone despite their vision level. These interviews provided us with some useful and important information on different topics. Besides validating the importance of teaching computational thinking at an early age and the potential of using robots in an educational context, they also acknowledged collaboration as a teaching technique that fosters inclusion and has several benefits. Robots were pointed out as an outstanding tool to use in a mixed-ability environment, since it makes the task more enjoyable, captivating their attention and engaging them in the activity. Exploring the robot as a more active agent, instead of assuming the passive role as we are used to, was an idea received with great enthusiasm, since it can generate more engagement.

Therefore, we believe that the exploration of roles in an activity in a mixed-ability environment in the context of teaching computational thinking has enough potential for us to move forward and design the system.

Chapter 4

Design of RoleBot

The prior chapter and its interviews gave us some understanding of the teaching techniques currently used in computer literacy not only in general but also in mixed-ability environments and provided us some positive feedback on the use of robots in an activity that explores roles. RoleBot is the system we developed to allow performing activities to use in that context.

RoleBot focuses on providing children with an accessible, playful, and engaging activity in which they interact with Dash while developing computational thinking skills. Our solution consists of an accessible system that makes use of a computational kit as a tool to teach computational thinking. To test the system, we designed an activity that we will use as a case scenario of RoleBot.

This chapter describes the design and implementation of a solution that would meet the requirements we identified in the previous chapters. RoleBot is implemented using JavaScript, HTML, and CSS as programming languages and a set of libraries, jQuery,

WonderJS and Tangible Object Placement Codes. We also used WebPack to bundle our modules.

Next, we get into the motivation of RoleBot and the steps we took in the process of designing a system using a computational kit to support computational thinking, in a collaborative learning context with children with mixed-visual abilities and present the findings of the focus group.

4.1 Motivation

Introducing computational thinking at an early age has shown to be not only fundamental but also very important since it improves children's logical thinking and prepares them to be able to solve real-world problems. Some schools are introducing computational thinking and using robots as a tool which according to some studies [61] improves children´s engagement and has effective results.

According to the special education teacher we interviewed, activities using a robot in a mixed-ability context would have an enormous potential since it would trigger their curiosity and keep them focused and interested in the activity, besides providing a playful and meaningful experience.

Most of the activities using robots explore the robot in a passive role, having the robot execute the instruction the child provides. Although studies exploring computational thinking using a robot show that children can learn at least as much as they would using traditional teaching techniques, they only explore the robot as a passive agent. Most of the studies explore the child interacting with the passive robot, or a group of children interacting in a collaborative context but also with the passive robot. Given the success of these studies, since children have not only shown great results but also expressed excitement and engagement and considering the positive results of other studies using robots as active agents, we decided to explore different roles the robot could take, giving to the robot more agency in the activity instead of having just a passive role.

4.2 RoleBot Design

In this subsection, we will go through the steps we took in the design process of our system. We started by selecting a computational kit that would fit an age range of elementary school with features that would allow us to design an accessible system adapting the computational kit.
Having our hardware decisions made, we proceed to make our decisions on the robot behavior, deciding how the robot would talk and interact with children and which roles it would play. Next, we designed different robot roles and how the robot would behave when playing each of the roles.

4.2.1 Selection of the Computational kit

To choose a robot that would fit our needs we explored the existing computational kits. We divided these kits into physical kits with electronics and hybrid kits with virtual/tangible programming blocks. Our analysis focused on some characteristics such as age target and features that allow the computational kit to support accessible activities. Since we are interested in developing an activity for primary children, we are mainly interested in robots that target children aged 6-11. There were several specifications on which we focused on to infer the level of accessibility of the computational kit, such as the type of input and output, buttons distinguishable by touch, and supporting different types of output.
Having in mind all these considerations, we decided to use Dash, which falls into our category of hybrid kit with virtual programming blocks. Dash´s recommended age range is more than 6 years old and although its factory settings only limit the manipulation of the robot using their app on a smartphone or tablet, the robot has built-in functions allowing programming it, for people who want to change and manipulate the robot features. Therefore, although this robot isn´t straightforwardly accessible, it provides some materials to enable people to use it for accessibility means.

Figure 4.2: Dash Robot

4.2.2 Adaptation of the Computational Kit

To guarantee the accessibility of the computational kits, there were some requirements that we considered essential based on our related work and our interview findings. Having audio feedback enables the robot to be used by blind children, especially when the audio feedback is detailed and specific. There are some things to have in mind when producing audio feedback for VI people such as the content, the diction, and the volume. It is crucial to have audio verbalizing actions that the robot performs and describing the state of the activity and if the task was successful or not. The voice of the audio needs to speak calmly and clearly to be completely perceptible. The volume needs to be high enough to be heard and ideally, the audio should be in the robot so that the child can perceive its relative location to the robot, based on the distance of the sound. Dash has an audio recording function that changes the voice, which we used. However, we had to consider the speed of the speech when recording, since the voice changes fasten the speech.

We also took into consideration the lights of the robot. It is very common for visual impairments to be associated with other medical conditions such as epilepsy. Therefore, we decided not to have many lights, and not to have a lot of blinks, since that could be overstimulating for some children.

4.2.3 Setup

Although we had already decided on the computational kit we would use, Dash, there were still some decisions to be made. Dash´s built-in input is through a Wonder app, using an android phone or a tablet. Since using screen readers on programming apps can increase the cognitive load for VI children due to accessing all the information via audio, we decided to use physical programming instead. Tangible pieces consist of physical blocks that allow abstraction, reducing the cognitive load inherent to text-based programming or audio input. It also enables a hands-on experience that facilitates the process of giving instructions to the robot.

Hereby, we decided to use tangible pieces with tactile and visual cues. The pieces are composed of a visual and tactile cue matching the action the robot performs and a topcode to be readable by a camera and recognized on a system that commands the robot.

To organize the pieces and keep them aligned we used a LEGO green baseplate where the child would place the pieces. To fit the baseplate, the pieces have the shape of a LEGO block underneath so that they can be fitted into a LEGO base plate. LEGOs are widely known and enjoyed by children and are instantly associated with the idea of playing. Therefore, we believe that by using these, we might be adding a layer of engagement.

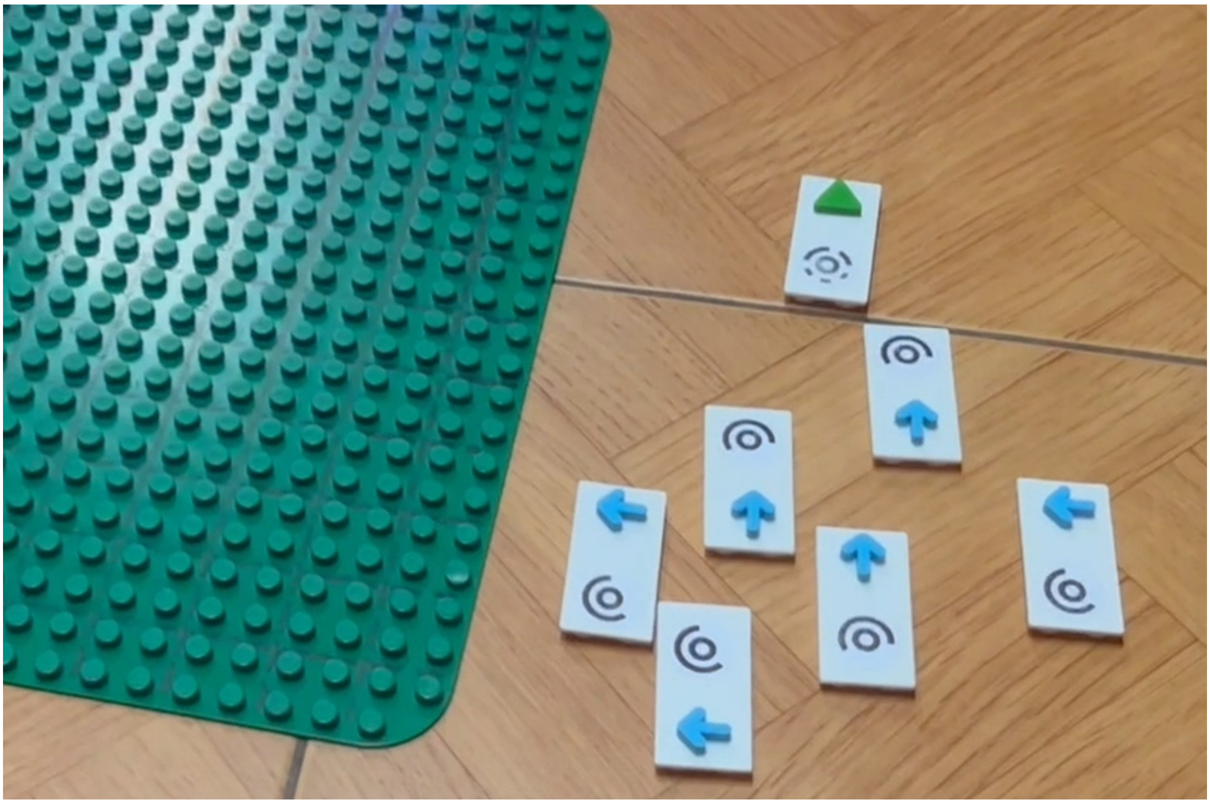

Figure 4.3: LEGO baseplate and tangible pieces

4.2.4 Robot

Since we wanted to make the system accessible for everyone regardless of any impairment, we considered it important to consider frustration in both conditions. Children with cognitive disorders usually have low cognitive control which might result in a lower tolerance for frustration [62], therefore when the child takes more than 10 seconds to choose the next piece, the robot interacts with the child to try to help. Regarding the robot´s speech, we tried to make it as enthusiastic as possible, by speaking with a playful and encouraging tone of voice, expressively depending on what the robot is communicating.

4.2.5 Components

Our system, Rolebot, consists of the robot, the pieces with the topcods and the interface to input the pieces, and the system to recognize the pieces and pass the instructions to the robot. We used 3D pieces that were already designed and printed out by members of Lasige who had previously worked with similar systems. The pieces had a touchable cue of the matching instruction so that regardless of the level of vision, children could recognize each piece and a sticker with the topcode of that instruction.

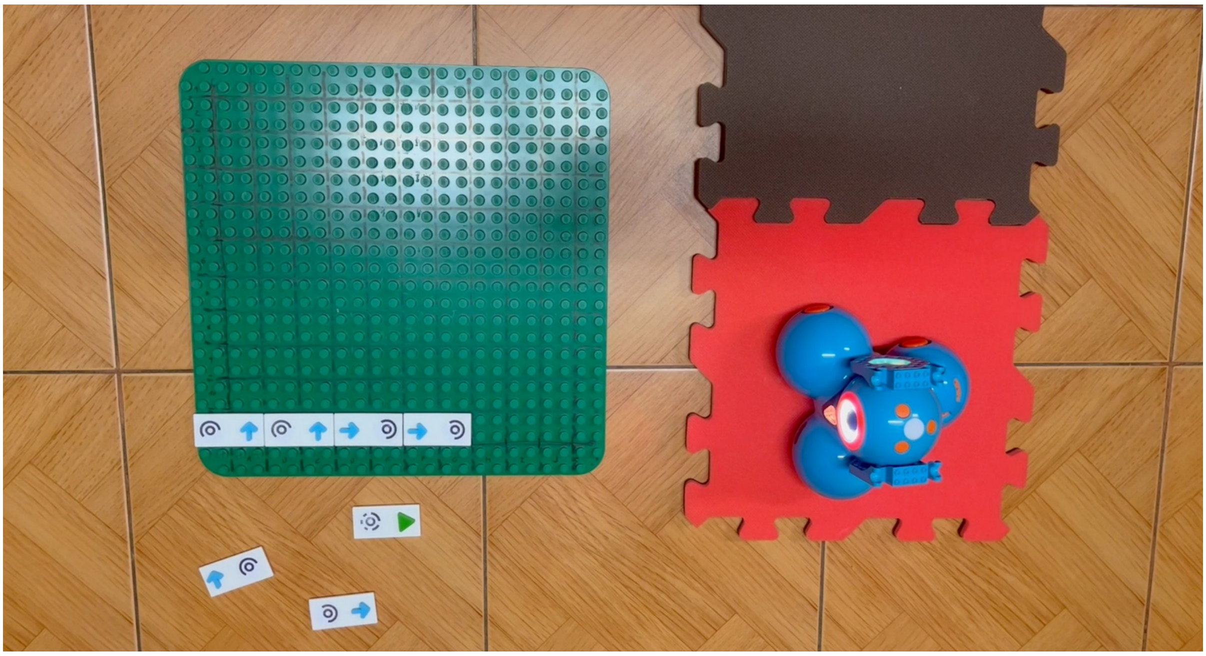

Figure 4.4: RoleBot Setup

4.2.6 Roles: Tutor and Peer

Collaboration [63] is the concept of having different individuals working together for a common purpose. In schools, collaboration is used as part of cooperative learning teaching techniques to allow children to learn and grow together and it is known for helping children develop their thinking skills and build their confidence and self-esteem. Since we wanted to explore collaboration, we decided to assume that when collaborating, children can assume different roles based on their knowledge and confidence. When a child feels confident about their knowledge, they tend to help their peers and teach them, whereas if the child feels unconfident about their knowledge or does not have much knowledge they tend to learn and absorb their peers' knowledge. If the children within the group have a similar level of knowledge on the topic they are working on, they seem to help each other and none of them takes the role of teaching or being taught, instead, they assume a peer role where they learn together.

In a collaboration context, there is usually some complementarity between different roles, therefore the idea is to use the robot in the tutor condition when the child is not confident on the topic or does not have much knowledge, and the robot as a peer when the child already has some knowledge and does not need much help.

While the tutor robot acts almost as a teacher, guiding the child through the activity, helping, explaining, and giving detailed feedback on each decision the child makes; the peer robot goes along with the child on the activity, giving only basic feedback on the child's actions with some degree of uncertainty. In both conditions, the robot introduces and explains the activity at the beginning, reacts after each child interaction, such as the child choosing a piece for the sequence, and gives the final feedback on the task.

Whereas the robot on the tutor condition gives instant correct feedback on each piece, giving a small explanation when the piece is wrong and suggesting; the peer robot only gives feedback regarding the piece being correctly recognized, not making any comment on the piece being right or wrong or, if the piece is not the right one, asks the child to explain why they chose that piece.

In our system, we decided to explore two of these three roles. Based on the related work [55] and the findings of the interview with the special education teacher, we decided to consider the following two conditions: robot assuming tutor and peer roles. The difference between the two roles relies on the knowledge of the robot. We defined the robot´s behavior for several case scenarios:

Dealing with doubt

If the child takes more than 10s to choose a piece, we consider that the child is uncertain about the piece to choose. In these cases, the robot interacts with the child. While the tutor robot suggests about the action that needs to be executed, the peer robot just asks the child which piece could be used next.

Dealing with error

When the child chooses a wrong tangible piece, the tutor robot suggests using another piece, explaining why. The peer robot, instead of suggesting choosing another piece, asks the child for tutoring, using a comment such as “Hum… Why did you choose this piece? Are you sure?”

Dealing with multiple errors

If the child chooses a wrong piece and after the robot intervention, they choose the same piece or another wrong piece, in both conditions the robot accepts the instruction, making a comment about not understanding why that was the chosen piece.

Dealing with success

In the tutor role, when a child chooses the right piece, the robot congratulates the child. In the peer robot, after a child chooses the right piece, the robot only gives audio feedback validating the piece, saying something like “Yeey! Another piece!”.

On the overall sequence feedback, for both roles, when the robot successfully finishes the execution of the sequence it congratulates the child and performs a happiness dance while making happy sounds.

Dealing with unsuccess

If the child chooses the wrong piece, the tutor robot lets him know he does not agree with that piece and explains why. When the robot finishes the execution and the sequence is wrong, the tutor robot says it couldn't reach the objective and explains what that was wrong and why happened.

The peer robot just validates the input of a new piece when a piece is added to the sequence. When the child finishes an input sequence which is not right, the robot says they were not successful and invites the child to play again.

4.3 RoleBot Implementation

After designing the system, we decided to implement the solution. In this section we will focus on the used technologies, the background workflow and the design of the activity which will serve as a use case of our system.

4.3.1 System and Used Technologies

Our system consists of the robot, 4 colored block play mats, the tangible pieces, the LEGO baseplate, and the web application, developed in JS on a computer. The computer allows the connection between the input and the robot which produces the output. Our web application consists of the interface that provides the camera which scans the tangible pieces and allows the Bluetooth connection to the robot; and the system that provides the Bluetooth connection and handles the tangible pieces recognition by converting the tangible piece to the matching instruction. After the scanning of the tangible piece, and matching it to the instruction, the computer sends it to the robot, which executes it. The instructions executed by the robot after placing each piece are audio instant feedback on the input piece. The sequence is only executed by the robot at the end, when the input piece is play.

After analyzing the libraries provided by Wonder and having in mind our prior experience on programming languages, we decided to use JavaScript as the main programming language.
Wonder consists of a brand that belongs to the startup Wonder Workshop, which produces tools, such as open-source computational kits and libraries to code on their products.
Our project front end makes use of HTML5 to structure the webpage and present the page contents which are styled by the use of CSS. The elements shown in the webpage are manipulated by using JQuery.

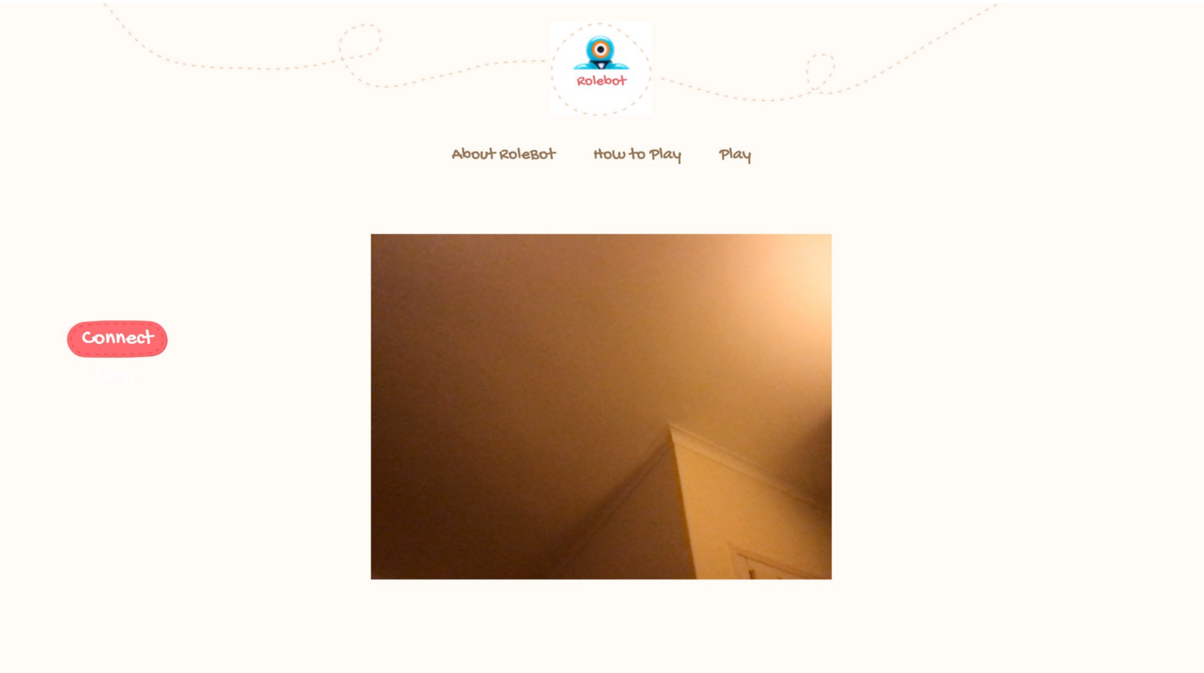

Figure 4.5: RoleBot Interface – Scanning pieces page

The backend consists of JavaScript. We used a library, from TIDAL-Lab, called Tangible Object Placement Codes which converts each topcode to a corresponding number. To convert each piece ID to an action for the robot to execute, we used the WonderJS library from Wonder Workshop, which provides some functions to connect the system to the robot and make the robot execute the instructions.

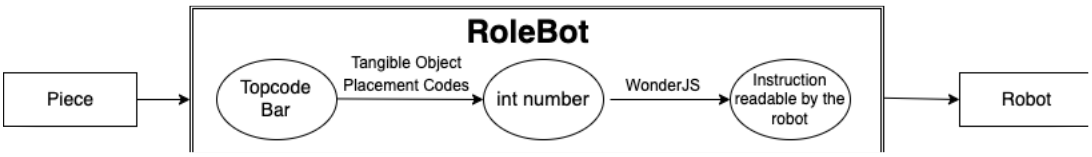

Figure 4.6: System flow

4.3.2 Background Workflow

Our user interface consists of a local website in a localhost. When the user enters the website, they can connect the robot to the system and choose the mode of robot they want to play with, which can be the tutor or the peer. After connecting the robot and choosing the role of the robot, the user needs to allow the website to use the camera, and afterwards the camera opens. The robot starts to introduce himself and the activity, inviting the child to play and how to interact with the system, using the pieces. The pieces are placed in the baseplate, underneath a camera connected to the computer.
When the user introduces a new piece, the system recognizes it and using the Tangible Object Placement Codes library, converts it to its ID. Our JavaScript module makes the robot play an audio feedback based on the used piece, depending on if the piece was the correct one or not. When the user completes the sequence and uses the play piece, the robot informs it that it will execute and perform the sequence. At the end of executing it, the robot gives audio feedback, letting know if the goal was achieved or not.

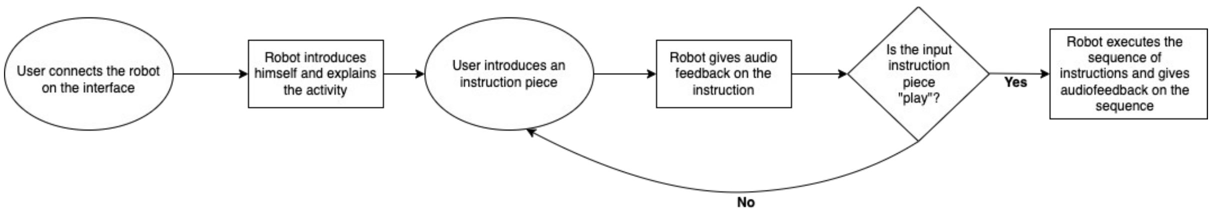

Figure 4.7: Background Workflow of RoleBot

In figure 4.6 we can visualize the activity cycle. Assuming the robot is already turned on, the user starts by connecting the robot to the interface, using the “Connect” button. The robot proceeds introducing himself and explaining the activity, inviting the child to play. The child places the first instruction piece and the robots give audio feedback on the piece. Until the instruction piece used is the “play”, the user keeps placing pieces on which the robot gives audio feedback. When the instruction piece used is the “play” one, the robot lets the user know that it is going to execute the sequence and starts executing it. At the end of executing the sequence, the robot gives the final audio feedback, letting the child know if the activity goal was achieved or not.

4.3.3 Interface

On our interface, the user starts by connecting the robot to the interface, by using the “Connect” button. Afterwards, the user can choose from one of our system modes: tutor and peer. After clicking on the chosen mode button, the user goes to the second page in which they have to allow the camera permission. Then, the camera opens and the user can start the activity, by inputting each piece on the baseplate, which will be scanned by the camera and recognized by our system.

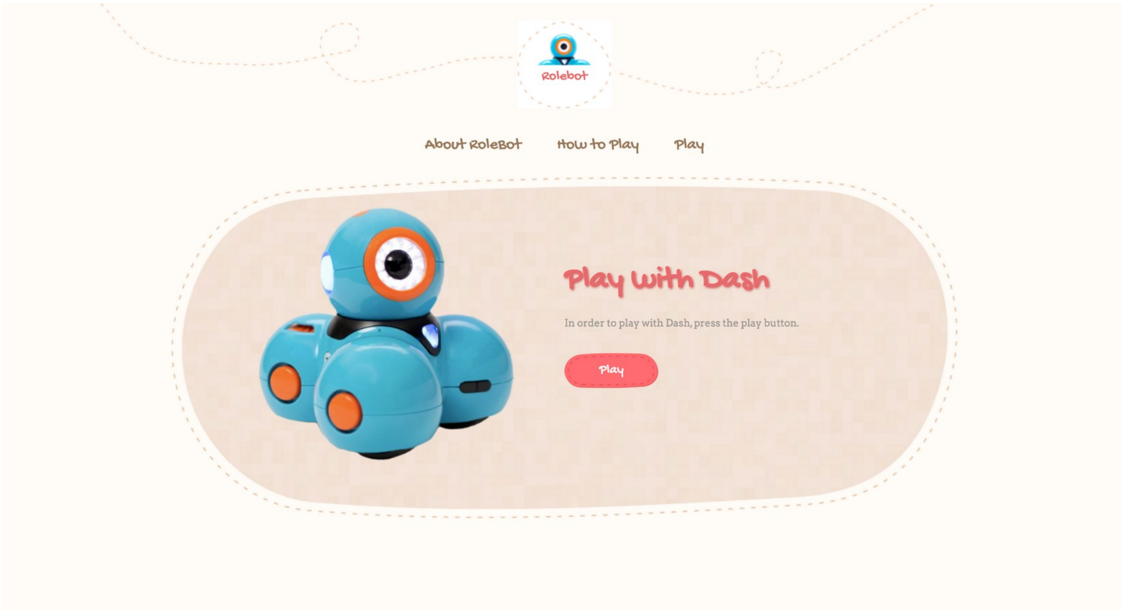

Figure 4.8: RoleBot Interface – Main Page

4.4 Activity Design

Having in mind the suggestion of the special educational teacher, we decided to design a one-to-one activity approaching directions. Having an activity with only a child and the robot allows us to fix some variables and focus on the child's behavior, performance, and difficulties. Analyzing these factors allows us to evaluate if the activity has potential and therefore explore this activity with more than one child.

Directions have been a difficulty that children have, especially when it comes to command of the robot on previous studies [38]. This is especially important for VI children, since it does not come easy for them to learn directions which are very important for someone not sighted, as pointed out by the special education teacher on the interview.

Therefore, our activity consists of tasks in which the child needs to help the robot get from point A to B. Depending on the child's performance, the task can be challenging, having tasks of different levels. To help the child, visualize the way the robot needs to go through, we used colored block mats, which indicates the way the robot needs to follow.

To make the task more engaging we added a context on the sequence which consisted of the robot feeling thirsty at point A and asking the child to help it get to point B, where the bottle of water is.

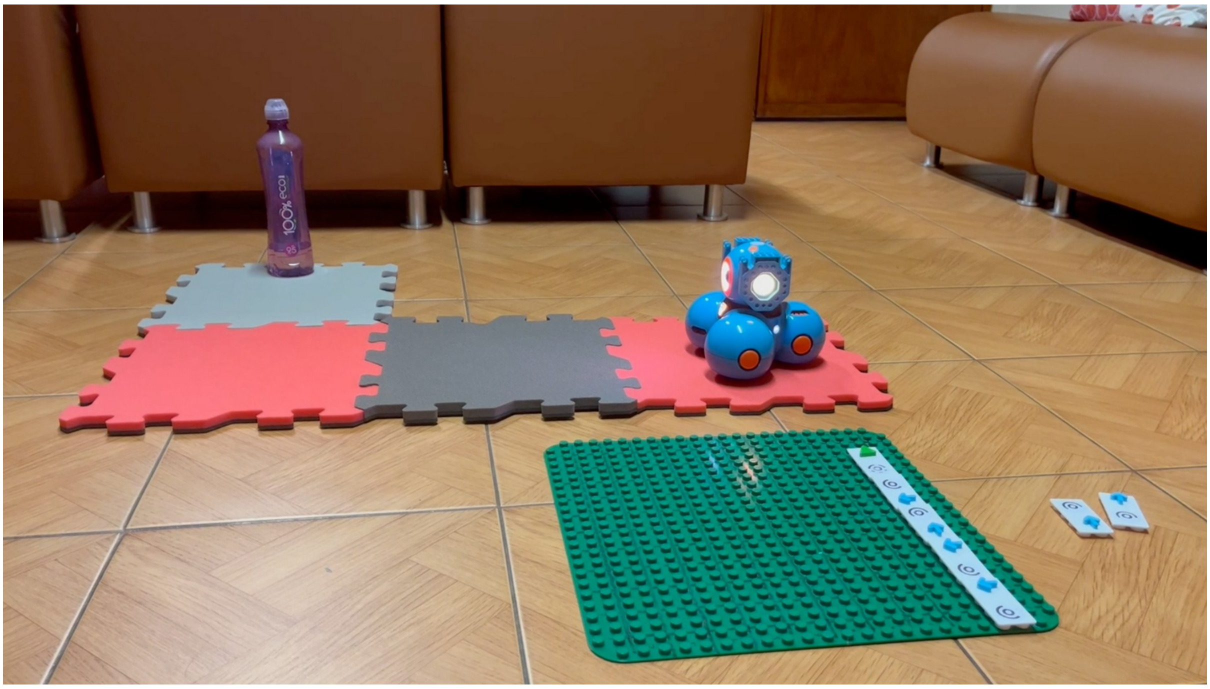

Figure 4.9: Activity Setup

Chapter 5

User Study

To get some feedback and evaluate our solution, we decided to conduct an in-person focus group involving 3 teachers that work in a school with visual mixed-ability classes. The analysis of this user study will allow us to understand if RoleBot and the roles we designed could possibly be used in the context of teaching computational thinking to VI and sighted children. Our user study will also provide us some feedback on our system, giving us some ideas on how to improve it.

5.1 Method

5.1.1 Participants

The session took one hour, and the participants were 2 female and 1 male, which we will refer to as P1, P2 and P3, noting that these don´t correspond to the participants we refer to in chapter 3. During the focus group, teachers made references to specific students which we refer to S - Student. The participants have varying experience in teaching sighted and VI children in a mixed-ability environment.

5.1.2 Procedure

To facilitate the focus group, we recorded and edited previously a video of a simulation of a child using the system. We started by making an introduction, and asking for permission to record, followed by some general questions about collaboration and roles. In the second part of the focus group, we provided an introduction about the activity and showed the video of the activity simulation. Afterwards, there was a time for discussion and feedback on the activity, with some brainstorming followed by some questions and themes we put on the table. The protocol followed on the focus group is available in Appendix B at the end of this document.

5.1.2.1 Video Simulation

We decided to simulate some case scenarios of a child interacting with the system and record them and use these videos in our study to have a more controlled environment. Although we implemented the system, there were some points at which it could be unstable. Therefore, to prevent undesirable situations, we preferred using the videos on the study.
In the simulation we performed for the video, we used one of the sequences we planned for the activity and used for each condition (tutor and peer) three different case scenarios. The case scenarios we considered include the child choosing the wrong piece, the child choosing the wrong piece and

correcting it after the robot intervention, the child being unsure about the piece, and the child choosing the right piece. We also simulated the two possible activity outcomes: the child making the right sequence and succeeding on the task and the child making the wrong sequence and failing on the task. We chose these scenarios because we believe they can summarize the possible scenarios on the interaction between the child and the robot.
For each condition the robot starts by presenting itself and introducing the activity. Afterwards the child should explore the robot, becoming comfortable around it and confident enough to start the activity. Then, the children start choosing the pieces by placing them in the baseplate, interacting with the robot until the play piece is placed in the baseplate and the robot proceeds to execute the sequence.

5.1.2.2 Data Analysis

After the focus group we proceeded to analyze the data we had collected, by using the method of thematic analysis [58,59] which resulted in the following findings.

5.2 Findings

5.2.1 Collaboration

Regarding collaboration, participants stated that they consider that "in general I feel that they try to help, collaborate (...) normally sighted peers really like to help blind people"[P2] in the context of classes with students of mixed visual abilities educators mentioned that they "do not need to promote help, they often help themselves (...) they have that initiative."[P1].
This idea was illustrated by exemplifying the interaction between two students in the school, one blind and one sighted, in which the sighted child, in a self-directed and spontaneous way prepares the necessary tools for his colleague to attend the class, before the class begins.
"I have a blind boy who left his wheelchair last year, C1. And I have a boy in my class, C2, every day C2 comes into class and without anybody telling him, he gets C1's Perkins machine, puts it on the table and puts the paper on the machine, and nobody ever taught him how to put the paper on the machine. He saw me putting the paper in the machine, he learned, from his place he saw how I did it, and then he goes into the room, gets the machine, puts it on the table, and puts the paper in the machine. So, I think this is a delight, because the way he must help his classmate without anyone asking him, in an autonomous way. So, he knows that he needs help because he does not know how to put the sheet in... and he does that to the classmate."[P1]
In addition to this spontaneous collaboration, in group activities, in which collaboration is promoted, various strategies are used in defining the groups, depending on the teacher. These strategies vary between affinities between students and peer technique with different levels of knowledge, since they try to group them "with whom they feel more affinities (...) Try to balance the thing as much as possible, for example a student who knows a little more with a more average one" [P2].
Regarding mixed visual abilities, there is a concern with inclusion, and the groups are made to include sighted and blind or low vision children, in order to promote collaboration between children of mixed visual abilities. Some techniques are used, namely, "the blind child choosing the classmates (...). We include blind children, or children with more difficulties and we try to integrate them in a group"[P2] and "groups with only blind or groups only with low vision are not an option (...) We try to at least put one in each group"[P1]

Although in general there is a general tendency to help each other among students, sometimes some difficulties arise in the formation of specific groups, with the guidance of teachers, namely with more competitive students, who do not want to form a group with students with less knowledge, or with students who have a specific temper, incompatible with that of the colleagues of the potential group. One of the participants claimed: "What I notice is that when there are more competitive children is that..."[P2], and P1 continued saying that it also happened with children "a specific temperament (...) Temperament issues that they do not want to be part of the group" [P1].

Although the teachers considered the collaboration between children of mixed visual abilities to be beneficial, there were some aspects to which they pointed out that attention should be paid, so that the results of this interaction are as beneficial as possible for everyone. The main difficulty was that "sometimes they help too much, they see him and think he can not do it and they start doing it for them" [P2], and "the VI children tend to do... almost do the whole task.... They do not give them that space that..that they need to understand it and to accomplish it"[P3].

Another difficulty in teaching blind children, mentioned by teachers, relates to students who have a more peculiar temperament and who refuse to do some tasks, despite their ability to complete them, giving the example of a student whose "intelligence is as good as bad. And he refuses to learn to read and write. "[P1]

5.2.2 Use of Roles

Concerning the use of role play, teachers said that although it depended on the personality of the children, "there are children who from their personality really like to help and to, to be there guiding" [P2].

Teachers also tried to promote role use and inclusion by doing awareness actions in which blind children teach their normal sighted peers how to use the Perkins machine and suggesting students who have already finished the task to help their peers.

"Awareness actions in the class and for example children want to use the Perkins machine and C3 or C4 are explaining it to them"[P2]

"sometimes C3 will hurry up early doing something "and now you tell C4 there, and you guys get your bearings"... I really give freedom"[P2]

Some of the advantages of role exploration pointed out were that role playing "helps them feel more competent, more confident in what they know. It's positive"[P2]. Still, they mentioned the need for some care in the application of these roles, so that the children's perception is not the difference in levels of knowledge between them and peers, "for a question of self-esteem, because this level of self-esteem also messes with them. Because one knows and the other does not, because I understood and you did not understand."[P2]

Although the teachers admitted the use of role plays as an advantageous teaching strategy for student learning, they expressed some difficulties when the technique is applied to children with mixed visual abilities, being that "there are things that they just do not explain as much, because it's like this, blind children is not as easy to help as a non-blind child who is in the same abilities (...) even if they want to, sometimes they may not know how to help."[P2]

After a brief general introduction on the application of the use of roles in an activity with the robot, when asked how the roles and their evolution should be thought out and constructed, regarding how active and participatory the robot should ideally be, the participants felt that ideally "there should be a certain balance here. The robot plays the tutor role but leaves room for the child to be a tutor as well. Leave something here for the child to also give of himself."[P1]

5.2.3 Interaction between the robot and the child

After showing the videos, the teachers were optimistic about the application of the demonstrated activity simulation. Still, there were some points that were made. [P1] pointed out the voice of the robot as a point for improvement, considering it "a very robotic voice", stating "it's a kind of voice that would not work for me".

In general, the comments were very positive, with the participants considering that "It's much more interactive than what we're used to, it's really... And there it is, it draws attention to what is not correct but in a nice way" [P2], referring to what had been one of the concerns previously pointed out in the use of roles.

Regarding the application of the robot as a peer, the participant [P2] considered as a positive point the fact that the robot "did not give the child the idea that the robot knew so much more than her, it was almost like a mutual collaboration"

The participants were enthusiastic about the robot taking a more active and participatory role, considering it more "stimulating" and "attractive" [P1], stating that "children are really looking for this interaction with the robots and this need for the robots to interact with them, so the more they interact, the more they will want to" [P2]. They also referred to previously observed interactions in which "the children themselves try to communicate with the robot, talking to the robot... And if there was an interaction like that between the robot and the child it would still be ideal"[P3]. The teachers consider that "the bigger the interaction the better"[P1]. The way the interaction is done between the robot and the child, in the video was considered "nice"[P1].

5.2.4 Potential of the use of Robots in class

Several interaction suggestions were made by the teachers, namely "a robot that talks to them, and asks them questions about school contents, for example, something. And they have to answer and interact with the robot and there "Oh no, that one there... that's right, good". But based on these dialogues and so, there will be this interaction and there is the oral part that is the basis of... (...) any blind child can then use" [P2], "And that plays songs for example..."[P3].

Regarding suggestions to be applied in the presented activity, the importance of contextualization of the activity was stressed, for example, " be thematic presentations, like you did [in the past], started by doing, talk about pollution in the oceans, the planet earth, for them to have that level of objectives and be guided by that..."[P3], it was suggested, for the activity to be more challenging and less difficult to execute "to move forward you have to answer right, do those things like that (. ...) I walk as you get it right, add that challenge" [P2], and that "thinking about the whole sequence before and then he does it all at once, I found it very complicated" [P2]. It was also suggested that there should be "a previous work, as if the child were the robot (...) she herself worked as a robot, then she could feel like the robot's tutor in the directions "it's not like this, it's like this" [P2]. To keep the child's attention, it was suggested "in moments when the child is less interested, give some information "you knew this and that..." [P3] and "quiz, of... the children like those things too... Use the robot to participate and have that interaction too..." [P2].

In group activities it was suggested the robot "ask the names and then in the activities remember the children's names"[P3], "Associate the voice to the name"[P1], in order to "help the children to be more focused"[P3] and mediate the activity if it is done in group, "give each one a turn and they have to respect the robot to get the interaction (...) establish there an interaction time"[P2] "It would help them to manage a little bit that anxiety and also manage their behavior so that afterwards they can speak and give their turn to the other, to the colleague"[P3], referring to the challenges most felt by teachers in

group activities, namely keeping students quiet and waiting for their turn "Be quiet (...) Wait to speak"[P1].
Some ideas for activities emerged, such as "For blind children it would be interesting to have models, for example models of certain, certain objects (...) certain constructions... So that blind children can better acquire knowledge and achieve their objectives"[P3], "it could be interesting to use as a plan of some space, of spaces that they know well, try to guide the robot... It was also interesting (...) Group work with a robot (...) builds information together, then must program it"[P2].
Teachers proposed "using this of the directions as another thematic idea, I do not know, to learn for example other school content using this..."[P2], "For example for drawing, I do not know. Instead of straight ahead, right, left, triangle, triangle, square, rectangle, for example, the geometric shapes."[P1], " for them to work the areas, I do not know if it will also give them to make a map for them to calculate the areas with the robots"[P3]. It was also suggested the use of the robot for activities related to language learning, "Word games, phonetic games, phonological part that is a part that they all sin... Take advantage of the robot voice (that I love) to work all the phonological parts and the phonation system, that the children unfortunately, each time is worse..."[P1]. Another suggestion made was in relation to how the interaction is done, being based on a game "do a kind of glory game, 'you answered right': go forward, you got it wrong, go backwards."[P1]

5.2.5 Robot deceiving

The robot getting some suggestions wrong was considered a good teaching strategy, but "it requires some greater knowledge of the child for the activity (...)Because sometimes he does not realize that there was the robot that got it wrong. And then, he gets confused, and that's when it has to be a more advanced level. (...) But I think at a more advanced level, yes. It's even funny. Then you see how the child interacts with a robot that makes mistakes. Another participant suggested that this is a strategy used to "test the child's attention. The robot says a wrong information and the child has to figure it out."[P3]
One of the teachers referred to an interactive teaching tool they use, making an analogy in relation to the robot "There's an interactive globe. We have one in the classroom that says, "look for the Taj Mahal" and then they have to go there with a little plane and figure out where it is and then they position it and it says some trivia about it. And... and they like that interaction and... but there you go, it has the audio part", "And the knowledge that it transmits" [P1]" yes, because then they repeat a lot of what they've learned. Because they repeat some things repeatedly, they also listen to it again and then they systematize the knowledge. Okay, and it's something that can have various levels of knowledge, and they'll... you can adapt it to different children and everything... and they like that kind of thing. They really look for that."[P2]

5.2.6 General Considerations

According to the teachers, the assignment of tutor/collaborator roles to the student should be done according to each one's "competencies. Let's be realistic. There are children who have higher skill levels than others"[P1], which should be gauged through "simpler tests"[P2].

There are some considerations that were mentioned as important to be taken into account during the activity, in order to make it quicker, namely, "to always have an adult present, to mediate any kind of conflict that there is between the two of them, is not it, the robot and the child"[P1] and in cases of frustration of the child, where he "cannot give in we would have to be adults, with a lot of diplomacy turn the child around to be the one to give in."[P1]

For teachers it would be interesting to explore an evolution of roles, in which the robot starts with a role "of tutor. Then as a colleague, it's the next level up" [P2], that is, "it starts at a lower level, it will feel confident to go to the next level and then it can stay at that level, but there can be levels to adapt to different children and their skills."[P2] It was also concluded that it would make sense to have a regression of roles, i.e., the child and the robot could alternate between being a tutor and a colleague "the children learn more and know more and sometimes for it to remain interesting for the child..."[P2], and an analogy was made with real life "there is an inversion of roles throughout our lives, I am a daughter and I am a mother, I am a mother and I am a daughter" [P1], in order to constitute a challenge, because what they like is a challenge [P1].

According to the teachers, all children like to teach. But the modeling of behaviors is also very much missed and the coping, dealing with frustration is also very good"[P1], and for them, this activity could help children learn to "know how to deal with frustration, know how to lose, know how to deal with their emotions"[P1].

When the topic of the design of the robot and the activity's accessories was brought up, the participants reinforced the idea of concern for accessibility, suggesting some adaptations that could be made on the pieces, such as "a little piece of a different color, or a different texture…" . Regarding the robot they also suggested using textures and colors in robot's ears "one on the right and a different one [texture] on the left. At least at the beginning, to help, but later take away, for example"[P2]. One participant suggested a robot with a screen for students who have low vision and braille for blind students, in which students would walk behind the robot in order to "interact with the robot itself": "The robot itself could have like a screen[...]for students with low vision to be able to for example pair images, hit images. And, maybe... this now, this is me here having some ideas having some ideas... (...) if the robot itself besides the screen had... for example, in the front part it could have a screen for low vision students to observe some images, those that are possible for them... And in the back, there could be a braille line and that could... that the dots themselves could draw for example, geometric shapes" [P3]. Another participant replied, thinking that it would be a better idea for this braille line not to be associated to the robot, but to be connected to it by Bluetooth "it is better for him to have the braille line in his hand and maybe be remotely connected to the robot, then yes, than being attached to the robot. In terms of movement, the blind person is much freer. And the robot, well, it walks there autonomously. It's important that the blind person knows what circuit he's going to do.

Some forms for the robot were suggested, for example, "have a humanoid shape"[P3], "It can be a tower"[P1] and the robot having different voices, assuming different emotions or personalities "the robot having different voices, a more generous voice of an old lady, almost like a theater (...) different voices, that also stimulates the attention of the children"[P2], "Or an angry voice, they also have an angry voice"[P1].

Regarding the possibility of the activity being done in groups and not in a child-robot pair, the teachers considered it a good idea, thinking that "if there are more children there is more interaction, I am sure they will learn something more among themselves... and that's good, they socialize and everything... knowing how to wait their turn"[P2] and suggesting that it would be interesting "If the robot could question, ask the names and then in the activities remember the children's names"[P3] and "Associate the voice with the name"[P1], that would help "the children stay more focused"[P3]. It was pointed out as a potential difficulty to the execution of the group activity, "knowing how to wait their turn...That is really a difficulty they have", and it was suggested to overcome this difficulty, the robot "give each one a turn and they have to respect the robot to get the interaction (....) establish an interaction time" [P2], that is, the robot acting as a mediator, managing the interaction of each student with it, as follows: "The robot itself could define the time... A child would talk for a certain amount of time, then

the time would pass, and the robot would say "look, the time is up, now you'll pass it to another child". It also helped them to manage a little bit that anxiety and to manage their behavior so that they could then speak and give their turn to the other, to the colleague."[P3]
In regard to teaching Braille using the robot, it was suggested "the robot explaining that that piece is that letter and he forming words and saying if it is right or not... having an instant feedback and him being able to play independently without other people being there" [P2], "The robot itself could also correct, in the Lego Braille itself having codes to read and recognize the pieces" [P3]. However, preferably with the robot on the tutor role "I think it would have more results, or more interested children if it is the other way around"[P2].

5.3 Discussion

Participants believe collaboration as a teaching technique can have several benefits, namely collaboration with use of roles which according to them happens often in class since some students take initiative to help colleagues with more difficulties. They believe that using roles in the context of collaboration, helps children feel more competent and confident about their knowledge. However, when the use of roles is promoted by teachers, there are some things that should be taken into account, so that children do not perceive the difference in their level of knowledge as something bad, affecting their self-esteem. Regarding an activity exploring roles using a robot, their main concern was about the way the robot would interact with the child when correcting them, claiming that if the robot was too incisive it could affect the child's self-esteem.
RoleBot had very positive feedback from the teachers. They found the system and the activity very promising in terms of potential, since it is much more interactive than what they are used to. There was one complaint about the system, made several times by one of the participants, regarding the voice of the robot, stating that the robot had a “very robotic voice”. The participant who expressed her concern about the robot lines was relieved after she saw the videos, pointing out that the robot corrected the child but in a nice way. Participants expressed excitement and enthusiasm about RoleBot, considering it very stimulating and attractive. For them, the interactiveness of the system was one of the main points of the system and suggested some activity contexts in which we could use RoleBot. Some suggestions of considerations to have on the activity were made, such as accessible design ideas and how to conduct the activity. According to teachers, behavior modeling and dealing with frustration and their emotions are skills that are very important to acquire in these ages, especially for children with impairments and believe that activities using RoleBot could help develop these.
Participants also saw potential in the use of Rolebot in a group context with two or more children interacting with the system at the same time. One of the ideas that came up regarding group activities was having the robot mediating the interactions, asking for children to interact with it on turns by saying whose turn it was at each time.
Generally, the comments and feedback on RoleBot were very positive, which makes us believe in the potential of our system.

Chapter 6

Conclusions

This section will address the goals and the objectives set out in the first chapter of this thesis. It is crucial to point out how important our related work and analysis of our initial interviews were the great drivers for a good start and definition of what this project was. In addition, they validated the importance of teaching computational thinking in early ages and how crucial it was to design and produce engaging and captivating activities to improve children's learning ability. More than confirming that the current teaching techniques do not have in mind accessibility, the perspective of a VI special education teacher validated the importance of having visually mixed-ability classes to achieve inclusion. Our findings on these interviews made it very clear that to design activities for visually mixed-ability children it is crucial to have in mind not only accessibility but the interactiveness and engagement of the activity, captivating the attention of children.

Our preliminary analysis gave us the motivation to develop RoleBot, a system that allows children to play with an accessible computational kit in an interactive way, increasing the levels of engagement.

While designing RoleBot we had in mind all the accessibility and general considerations we gathered from our related work and interviews, to provide a solution that could be used by any child regardless of any impairments.

With that being said, the result of this project is a system that can be used in activities to increase children's knowledge on any topic, namely computational thinking. We also provide a case activity in which our system can be used.

The results suggest that our solution is viable, although it can further be improved. RoleBot was appreciated by the participants who saw potential in our solution, showing enthusiasm about the interactiveness and benefits for children, such as personal growth along with developing their knowledge on some topic.

Analyzing our initial goals and the work accomplished, along with the conclusions drawn from our exploratory analysis, we defined a list of limitations on our solution and some suggestions from which we can improve our system in our future work.

6.1 Limitations

Due to the pandemic context, we had some restrictions during our research which represented some challenges that we managed to overcome. At first, it was not easy to find teachers who were available for interviews which we considered to be a crucial part of our project. Regarding the design of RoleBot, the focus group provided us some important feedback and suggestions which would be interesting to be looked at and improve the system. The voice of the robot and some small adaptations such as the robot asking the child to put it down if the child lifts it, was one of the interesting ideas that came up after the focus group.

The implementation of our solution wasn´t 100% reliable since sometimes, unpredictably, the robot would take more time than expected to execute an instruction. This is related to the WonderJS library used. Therefore, re-structuring the code to be in a different programming language such as Java could improve the reliability of the system since colleagues working with this library did not report any of these problems in their implementation.
In addition, after working on these limitations, performing user testing with VI and sighted children would provide important feedback on the system and validate its usability, which was not possible to perform due to time restrictions.

6.2 Future Work

In our future work, we plan not only to improve the points described in our limitations but also to adapt the robot to be used in an activity in a group context, instead of a one-one environment.

Appendix A

Appendix - Computational Kits' Table

A1 Computational Kits' Table - Physical kits with electronics






			Bee Bot	Cellulo robot	Cubetto	CurlyRobot	Dr Wagon	Microbit *
Resume	Type of computational kit		phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics
	Programming	Type of input	buttons on the robot	haptic (move the robot)	tangible blocks	move the robot while pressing button	tangible blocks	buttons / light sensors/ APP
		Supported programming languages	N/A	N/A	N/A	N/A	N/A	Python, swift
	Recommended age range		4-7	6 +	3-6	4-7	6-12	8-14
	Advantages		Allows early age kids learning CT	Promotes collaboration and inclusive learning	Includes several maps and a storybook to promote criativity; blocks with visual feedback	Its size, weight and shape make it easy and intuitive to manipulate. Supports feedback loops	Possibility of changing the robot´s appearence easily; blocks with haptic feedback	Output is the microbit´s LED screen
	Disadvantages		No audio or haptic feedback	External speaker	No audio or haptic feedback	-	Basic audio feedback	-
	Open Source Software		No	No		No	No	Yes
Specifications	Hardware	Dimensions	125 x 100 x 75 mm	7.5cm diameter	27(w) x 26(h) x 15(d)cm	-	-	43 mm × 52 mm
		Weight	-	-	1.5 kg (whole kit)	-	-	8g
		Battery autonomy	-	1h-2h	6h (Batteries)	Batteries	-	Batteries
		Memory card slot	-	No	No	No	No	-
	Conectivity	Bluetooth	No	Yes	Yes	No	No	-
		Conectivity	No	-	-	No	-	-
	Sensors	Microphone	Yes	No	No	No	No	Yes
		Touch sensor	No	Yes	No	No	No	No
		Distance sensor	No	No	No	No	Yes	No
		Object detection	No	No	No	No	Yes	No
		Accelerometer	No	Yes	No	Yes	-	Yes
		Gyroscope	No	-	No	Yes	-	No
		IR emmiters/transmitors	No	No	No	No	No	-
		Color sensor	No	No	No	No	Yes	-
		Camera	No	Yes	No	No	No	No
		Others	-	-	-	-	-	Light sensor
	Control	Volume control	-	N/A	N/A	No	-	-
		Audio recording	Yes	No	No	No	-	Yes
	Output	Speaker	Yes	Yes (not bulit-in)	No	No	Yes	Yes
		LEDs (programmable?)	Not programmable	Not programmable	No	Not programmable	Not programmable	Yes
	Accessibility	Touch distinguishable buttons	Yes	N/A	Yes	Yes	Yes	No distinguiveis
		Audio, visual, haptic feedback	Audio and visual	Audio, visual and haptic	Visual	Visual	Audio and visual	Audio and visual
		Accessible programming	Yes	Yes	Yes	Yes	-	-
		Accessible for blind/low vision people	Yes	Yes	Yes	Yes	-	-
		Others	-	-	Tangible blocks with visual feedback	-	Tangible blocks with visual and haptic feedback	-





			Ozobot Evo *	Kibo	Robot mouse	Robotito	Sphero*
Resume	Type of computational kit		phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics	phisical kit with eletronics
	Programming	Type of input	environment manipulation (lines and colors) / APP	tangible blocks	buttons on the robot	environment manipulation (color and/or objects)	environment manipulation (lines and colors) / APP with virtual blocks and text programming
		Supported programming languages	Blockly	N/A	N/A	N/A	N/A
	Recommended age range		6-12	4-7	4-7	4-7	8 +
	Advantages		Allows two types of interaction: virtual blocks on touchscreen and environment manipulation	-	Kit includes mat and accessories for different difficulty levels	Programming through environment manipulation	A lot of online material and information regarding the use of the robot, ideas of activities using to learn specific CT concepts
	Disadvantages		Basic audio feedback	Indistinguishable touch blocks	Audio feedback only when goal is reached	No audio feedback	-
	Open Source Software		No	No	No	Yes	Yes
Specifications	Hardware	Dimensions	-	-	-	-	7.28 x 7.27 x 7.28 cm
		Weight	-	-	-		200g
		Battery autonomy	1h	-	Batteries	-	2h
		Memory card slot	No	No	No	No	Yes
	Conectivity	Bluetooth	Yes	No	No	No	Yes
		Conectivity	-	-	No	No	-
	Sensors	Microphone	No	Yes (1)	No	No	Can be added as accessory
		Touch sensor	No	No	No	Yes	No
		Distance sensor	Yes	Yes	No	Yes	No
		Object detection	No	No	No	Yes	No
		Accelerometer	-	No	No	-	Yes
		Gyroscope	-	No	No	-	Yes
		IR emmiters/transmitors	Yes	No	No	No	Yes
		Color sensor	Yes	No	No	Yes	Yes
		Camera	Yes	No	No	No	No
		Others	Line sensor	Light sensor , code scanner	-	Touchless gesture sensing	Light sensor, Light sensor, Collision detection
	Control	Volume control	-	-	No	No	N/A
		Audio recording	No	Yes	No	No	No
	Output	Speaker	Yes	Yes	Yes	No	Can be added as accessory
		LEDs (programmable?)	Yes	Programmable	Not programmable	Not programmable	Yes
	Accessibility	Touch distinguishable buttons	N/A	Yes	Yes	N/A	N/A
		Audio, visual, haptic feedback	Audio and visual	Audio and visual	Audio and visual	Visual	Visual
		Accessible programming	-	No	Yes	-	
		Accessible for blind/low vision people	-	No	Yes	No	
		Others	-	-	-	-	

A2 Computational Kits Table - Hybrid kits with virtual/tangible programming block




			Coji	Cue	Dash	Thymio

Appendix B

Appendix - Focus Group Protocol

1. Introduction **- 2 min**

Hello, first of all we would like to thank you for your willingness to participate in this study. I am Marta, a master's student and I am doing my dissertation, which is framed in studying the roles that the robot can adopt in an interaction with VI children.

Before we begin, we would like to ask to make the audio recording, which will not be released but will facilitate our later analysis of the data collected.

Before we start talking about robots, we wanted to understand a little better how collaboration and the use of different roles currently works in the classroom.

2. General questions about collaboration and roles **- 5 min**

1. In the classroom, you often use collaboration between students. In what ways do you usually promote collaboration between students? How are the groups defined? (gender, knowledge level, visual ability)

2. (**If they have not talked about roles**): In collaboration often roles are assigned, such as when you form pairs of peers who have different levels of knowledge and one teaches the other, being their tutor. What kinds of roles do you explore in class and in what ways?
    a. **If they have talked about roles**. For example:
        i. (You mentioned tutoring...), what other roles do you usually explore as teaching methods? In what ways?

3. Introduction about the activity **- 2 min**

Just to help us discuss this issue further, we developed an activity that explores the interaction between a child and a robot using the roles of tutor and peer. The activity consists in helping the robot to make a route from A to B, where in the tutor condition the robot is aware and actively participates in helping the child. While in the colleague condition, the robot assumes a role identical to that of the child, in which they will have similar levels of knowledge.

4. Screening of the videos - **30 min**

Introduction
Robots are beginning to be used more and more in classroom settings, which may bring some potential for role exploration. What potential do you see for this role exploration using a robot that takes a more active and participatory role?

- What roles can you imagine in this scenario?

We made a simulation of this activity for each of these roles, in which we explored three possible scenarios, from the child getting the sequence wrong, to the child getting it right. We recorded this simulation in order to facilitate discussion and would like to show it to you so that you could suggest possible interactions of the robot.

Let's watch the first video, starting with Robot Tutor

1. Video presentation - 2 videos of **10 min**
2. Space between each condition to comment **- 5 min**
3. Space between videos for general comments **- 5 min**

Questions after each video:

1. What did you think of the interaction between the child and the robot? What changes or additions would you make?
2. What other interventions would you suggest for a robot (tutor/colleague)?
3. The robot intervened before an error, when the child was undecided, or after an error, to prompt the child to reflect. Can you imagine other ways to help the child considering a robot (tutor/colleague)

5. Final comments **- 10 min**

Looking at the two videos now, we wanted to ask some more general questions:

- What did you think of the differences in the robot's behavior between the two videos?
- In what other ways could a robot with these two roles be used in computational thinking activities?
- How do you think roles should be assigned to the robot for each child?
    - Follow up: Personality or knowledge level of the child? fixed roles over time?
- We saw a fellow robot and a tutor. What if it was the other way around-the robot being tutored in the activity? Do you see potential in this role reversal? In which ways could it be supported?
- Here we talked about child-robot pairs. Can you see other options that consider larger groups?
- Do you have any other suggestions, or other types of interactions or activities that could make use of these roles?

References

1. HSU, Ting-Chia; CHANG, Shao-Chen; HUNG, Yu-Ting. How to learn and how to teach computational thinking: Suggestions based on a review of the literature. Computers & Education, 2018, 126: 296-310.
2. .ISNAINI, Ratih; BUDIYANTO, Cucuk; WIDIASTUTI, Indah. Robotics-based learning to support computational thinking skills in early childhood. In: AIP Conference Proceedings. AIP Publishing LLC, 2019. p. 020044.
3. ASSELBORN, Thibault, et al. Bringing letters to life: handwriting with haptic-enabled tangible robots. In: Proceedings of the 17th ACM Conference on Interaction Design and Children. 2018. p. 219-230.
4. HAMM, Mary; ADAMS, Dennis. Collaborative inquiry: Working toward shared goals. Kappa Delta Pi Record, 2002, 38.3: 115-118.
5. CATLIN, Dave; WOOLLARD, John. Educational robots and computational thinking. In: Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education. 2014. p. 144-151

6. Team, L. (2022, June 1). *Definitions of computational thinking, Algorithmic Thinking & Design thinking*. Learning. Retrieved July 30, 2022, from https://www.learning.com/blog/defining-computational-algorithmic-design-thinking/
7. SALEH, Mohammad; LAZONDER, Ard W.; DE JONG, Ton. Structuring collaboration in mixed-ability groups to promote verbal interaction, learning, and motivation of average-ability students. *Contemporary Educational Psychology*, 2007, 32.3: 314-331.
8. THIEME, Anja, et al. Enabling collaboration in learning computer programing inclusive of children with vision impairments. In: *Proceedings of the 2017 Conference on Designing Interactive Systems*. 2017. p. 739-752.
9. MORRISON, Cecily, et al. Torino: A tangible programming language inclusive of children with visual disabilities. *Human–Computer Interaction*, 2020, 35.3: 191-239.
10. SALLNAS, Eva-Lotta; MOLL, Jonas; SEVERINSON-EKLUNDH, Kerstin. Group work about geometrical concepts among blind and sighted pupils using haptic interfaces. In: *Second Joint EuroHaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems (WHC'07)*. IEEE, 2007. p. 330-335.
11. Cooper, M., Keating, D., Harwin, W. and Dautenhahn, K. 1999. Robots in the Classroom - Tools for Accessible Education. In Proceedings of the 5th European Conference for the Advancement of Assistive Technology, (Düsseldorf, Germany, November, 1999) IOS Press, pp. 448--452
12. FREY, Carl Benedikt; OSBORNE, Michael. The future of employment. 2013.
13. F. Buitrago Flórez, R. Casallas, M. Hernández, A. Reyes, S. Restrepo, and G. Danies, "Changing a Generation's Way of Thinking: Teaching Computational Thinking Through Programming," Review of Educational Research, vol. 87, no. 4. American Educational Research Association (AERA), pp. 834–860, May 23, 2017
14. Mubin, O.; Stevens, C.J.; Shahid, S.; Al Mahmud, A.; Dong, J.J. A Review of the Applicability of Robots in Education. Technol. Educ. Learn. 2013,1, 13
15. G. Andruseac, R. Iacob, "Exploring the potential of using educational robotics as an effective tool to support collaborative learning", E-Health and Bioengineering Conference (EHB2013), Romania, 2013

16. CHING, Yu-Hui; HSU, Yu-Chang; BALDWIN, Sally. Developing computational thinking with educational technologies for young learners. *TechTrends*, 2018, 62.6: 563-573.
17. YU, Junnan; ROQUE, Ricarose. A review of computational toys and kits for young children. *International Journal of Child-Computer Interaction*, 2019, 21: 17-36.
18. ÖZGÜR, Ayberk, et al. Cellulo: Versatile handheld robots for education. In: *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI*. IEEE, 2017. p. 119-127.
19. OZGUR, Arzu Guneysu, et al. Can Tangible Robots Support Children in Learning Handwriting?. *Educational Technology*, 2020, 20.
20. KABÁTOVÁ, Martina, et al. Robotic activities for visually impaired secondary school children. In: *3rd International Workshop, Teaching Robotics, Teaching with Robotics*. 2012. p. 22-31
21. Learning Resources. Robot Mouse. Retrieved from https://www.learningresources.com/stem-robot-mouse
22. BAKAŁA, Ewelina, et al. Designing child-robot interaction with Robotito. In: *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 2019. p. 1-6.
23. TEJERA, Gonzalo, et al. Robotito: programming robots from preschool to undergraduate school level. In: *2019 19th International Conference on Advanced Robotics (ICAR)*. IEEE, 2019. p. 296-301.
24. CHAWLA, Kunal, et al. Dr. Wagon: a'stretchable'toolkit for tangible computer programming. In: *Proceedings of the 12th international conference on interaction design and children*. 2013. p. 561-564.
25. SULLIVAN, Amanda; ELKIN, Mollie; BERS, Marina Umaschi. KIBO robot demo: engaging young children in programming and engineering. In: *Proceedings of the 14th international conference on interaction design and children*. 2015. p. 418-421.
26. ELKIN, Mollie; SULLIVAN, Amanda; BERS, Marina Umaschi. Programming with the KIBO robotics kit in preschool classrooms. *Computers in the Schools*, 2016, 33.3: 169-186.
27. AUSTIN, Jonny, et al. The BBC micro: bit: from the UK to the world. *Communications of the ACM*, 2020, 63.3: 62-69.
28. SENTANCE, Sue, et al. " Creating Cool Stuff" Pupils' Experience of the BBC micro: bit. In: *Proceedings of the 2017 ACM SIGCSE technical symposium on computer science education*. 2017. p. 531-536.
29. BALATON, M. C.; DA SILVA, L. F.; CARVALHO, P. S. Teaching kinematics with OZOBOT: a proposal to help improve student's graph interpretation skills. *Physics Education*, 2020, 55.5: 055009.
30. KÖRBER, Nina, et al. An Experience of Introducing Primary School Children to Programming using Ozobots. *arXiv preprint arXiv:2008.13566*, 2020.
31. ŽÁČEK, Martin; SMOLKA, Pavel. Development of Computational Thinking: Student Motivation Using Ozobot. In: *Proceedings of the 2019 3rd International Conference on Education and E-Learning*. 2019. p. 36-40.
32. Sphero. Retrieved from https://sphero.com/
33. Ioannou M and Bratitsis T, "Utilizing Sphero for a speed related STEM activity in Kindergarten," in Hellenic Conference on Innovating STEM Education, 2016.
34. V. Robles-Bykbaev, C. Contreras-Alvarado, L. Matute-Sanchez, E. Lema-Condo, Y. Robles-Bykbaev and P. Suquilanda-Cuesta, "An educational environment based on stuffed toy robots

mobile apps and expert systems to provide support in the early development of children", *Proc. IEEE Colombian Conf. Commun. Comput. (COLCOM)*, pp. 1-6, Jun. 2019.

35. J. F. Roscoe, S. Fearn and E. Posey, "Teaching computational thinking by playing games and building robots", *Interactive Technologies and Games (iTAG) 2014 International Conference on*, pp. 9-12, 2014.
36. WowWee. Coji. Retrieved from https://wowwee.com/coji
37. MakeWonder. Cue Robot. Retrieved from https://www.makewonder.com/robots/cue/
38. PIRES, Ana Cristina, et al. Exploring accessible programming with educators and visually impaired children. In: *Proceedings of the Interaction Design and Children Conference*. 2020. p. 148-160.
39. MONDADA, Francesco, et al. Bringing robotics to formal education: The thymio open-source hardware robot. *IEEE Robotics & Automation Magazine*, 2017, 24.1: 77-85.
40. RIEDO, Fanny, et al. Thymio II, a robot that grows wiser with children. In: *2013 IEEE Workshop on Advanced Robotics and its Social Impacts*. IEEE, 2013. p. 187-193.
41. SHIN, Jiwon; SIEGWART, Roland; MAGNENAT, Stéphane. Visual programming language for Thymio II robot. In: *Conference on Interaction Design and Children (IDC'14)*. ETH Zürich, 2014.
42. CHEVALIER, Morgane; RIEDO, Fanny; MONDADA, Francesco. Pedagogical uses of thymio II: How do teachers perceive educational robots in formal education?. *IEEE Robotics & Automation Magazine*, 2016, 23.2: 16-23.
43. MAGNENAT, Stéphane, et al. A programming workshop using the robot “Thymio II”: The effect on the understanding by children. In: *2012 IEEE Workshop on Advanced Robotics and Its Social Impacts (ARSO)*. IEEE, 2012. p. 24-29.
44. UNGAR, Simon; BLADES, Mark; SPENCER, Christopher. The construction of cognitive maps by children with visual impairments. In: *The construction of cognitive maps*. Springer, Dordrecht, 1996. p. 247-273.
45. NETO, Isabel, et al. Using tabletop robots to promote inclusive classroom experiences. In: *Proceedings of the Interaction Design and Children Conference*. 2020. p. 281-292.
46. METATLA, Oussama, et al. Robots for Inclusive Play: Co-designing an Educational Game With Visually Impaired and sighted Children. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020. p. 1-13.
47. Antunes, Cristiana & Neto, Isabel & Correia, Filipa & Paiva, Ana & Nicolau, Hugo. (2022). Inclusive'R'Stories: An Inclusive Storytelling Activity with an Emotional Robot.
48. MILNE, Lauren R. Blocks4All: making block programming languages accessible for blind children. *ACM SIGACCESS Accessibility and Computing*, 2017, 117: 26-29.
49. MUTTAQIN, Tatang. *Cooperative learning and students’ self-esteem*. Working Paper. Available at file:///C:/Users/12923079/Downloads/CooperativeLearningand StudentSelf-Esteem% 20 (2). pdf. Accessed on 1 June, 2019.
50. HAMM, Mary; ADAMS, Dennis. Collaborative inquiry: Working toward shared goals. *Kappa Delta Pi Record*, 2002, 38.3: 115-118.
51. Taba H. *Teaching Strategies and Cognitive Functioning in Elementary School Children*. San Francisco: San Francisco State College; 1966.

52. *Teaching strategies: Cooperative learning*. Annenberg Learner. (2019, December 18). Retrieved July 30, 2022, from https://www.learner.org/series/insights-into-algebra-1-

teaching-for-learning-2/variables-and-patterns-of-change/teaching-strategies-cooperative-learning/

53. How People Learn: Brain, Mind, Experience, and School; Bransford, J.; Brown, A. L.; Cocking, R. R., Eds.; National Academy: Washington, DC, 2000; http://www.nap.edu/books/0309070368/html/ (accessed October 6, 2006).
54. A. Zaraki, M. Khamassi, L. Wood, G. Lakatos, C. Tzafestas, B. Robins, and K. Dautenhahn, “A novel paradigm for children as teachers to the kaspar robot learner,” in BAILAR workshop at the 27th international symposium on robot and human interactive communication (RO-MAN 2018). Nanjing, China, 2018.
55. H. Chen, H. W. Park, and C. Breazeal, “Teaching and learning with children: Impact of reciprocal peer learning with a social robot on children’s learning and emotive engagement,” Computers & Education, vol. 150. Elsevier BV, p. 103836, Jun. 2020. doi: 10.1016/j.compedu.2020.103836.
56. S. Chandra, R. Paradeda, H. Yin, P. Dillenbourg, R. Prada, and A. Paiva, “Do Children Perceive Whether a Robotic Peer is Learning or Not?,” Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction. ACM, Feb. 26, 2018. doi: 10.1145/3171221.3171274.
57. F. Tanaka and S. Matsuzoe, “Children Teach a Care-Receiving Robot to Promote Their Learning: Field Experiments in a Classroom for Vocabulary Learning,” Journal of Human-Robot Interaction. Journal of Human-Robot Interaction, pp. 78–95, Aug. 01, 2012. doi: 10.5898/jhri.1.1.tanaka.
58. Maguire M , Delahunt B. Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars.AISHE-J.2017;3(11);8:3351-3354.

59. Mortensen, D. H. (n.d.). *How to do a thematic analysis of user interviews*. The Interaction Design Foundation. Retrieved May 15, 2022, from https://www.interaction-design.org/literature/article/how-to-do-a-thematic-analysis-of-user-interviews
60. Marta Carvalho, Filipa Rocha, João Guerreiro, Hugo Nicolau, Tiago Guerreiro, and Ana C. Pires. 2022. “*Current Practices in Teaching Computational Thinking to Children: Accessibility is an AfterThought*”, ACM IDC’22 workshop on Co-designing with Mixed-ability Groups of Children to Promote Inclusive Education
61. S. Evripidou, A. Amanatiadis, K. Christodoulou and S. A. Chatzichristofis, "Introducing Algorithmic Thinking and Sequencing Using Tangible Robots," in IEEE Transactions on Learning Technologies, vol. 14, no. 1, pp. 93-105, Feb. 2021, doi: 10.1109/TLT.2021.3058060.
62. Jiménez-Soto, Annabel & Lorente-Loza, Joaquín & Vargas, Juan Pedro & Diaz, Estrella & López, Juan. (2022). Beach balls: Assessing frustration tolerance in young children using a computerized task. Acta Psychologica. 224. 103528. 10.1016/j.actpsy.2022.103528.

63. Gates, S. (n.d.). *Benefits of collaboration*. NEA. Retrieved August 15, 2022, from https://www.nea.org/professional-excellence/student-engagement/tools-tips/benefits-collaboration