Socio-enactive Systems: The Educational Scenario

Ricardo Caceffo *João d'Abreu* *Fabrício Matheus Gonçalves*
Olga Takinami *Roberto Romani* *Cecilia Baranauskas*

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INSTITUTO DE COMPUTAÇÃO

Socio-enactive Systems: The Educational Scenario

Ricardo Caceffo[1], João d'Abreu[2], Fabrício Matheus Gonçalves[1], Olga Takinami[3], Roberto Romani[4], Maria Cecília Calani Baranauskas[1]

Abstract. This work is a partial report of the multiannual FAPESP's thematic project "Socio-Enactive Systems: Investigating New Dimensions in the Design of Interaction Mediated by Information and Communication Technologies". Specifically, on this report we focus on the study, exploration and assessment of socio-enactive solutions in the educational environment. The methodology used was the bottom-up approach: initially we analyzed the related literature; then we created high-level socio-enactive work scenarios (*e.g.* inside or outside the classroom, considering K12 or undergraduate students, etc.); then we defined and expanded a more specific work scenario (children in the classroom environment). Finally we created a MVP (Minimum Viable Product) for the work scenario, developing and implementing a prototype through the MakeBlock platform (an arduino based robot vehicle), using Scratch as programming language. In the work scenario we propose the creation of an environment where children must use concepts of logic and computational thinking to position themselves on a stage in order to predict the robot's movement patterns. The goal is enable the kids, through their own movements, to guide the robot to a predefined location at the center of the stage. Proof of concept experiments indicate the need for prototype adjustments and adaptations. Next steps include the design and performance of workshops with the children, aiming at retrieving inloco information that will support further development of socio-enactive educational systems.

Keywords: Socio-enactive, Active Learning, Logic, Computational Thinking, HCI, K12, Educational, Classroom

[1] Institute of Computing, University of Campinas (UNICAMP) {caceffo, fmatheus, cecilia}@ic.unicamp.br
[2] Núcleo de Informática Aplicada à Educação, University of Campinas (UNICAMP) joao.vilhete@gmail.com
[3] Federal University of ABC olga.takinami@gmail.com
[4] University of Campinas (UNICAMP) romaniro@gmail.com

1. Introduction

This work is a partial report of the multiannual FAPESP's thematic project "Socio-Enactive Systems: Investigating New Dimensions in the Design of Interaction Mediated by Information and Communication Technologies".

As described in the project proposal[5]:

> *"Enactive systems have been defined as computer systems consisting of human and technological processes dynamically linked, i.e., forming feedback loops using sensors and data analysis, enabling a seamless interaction between human and computer. The presence of new technologies and new forms of interaction (tangible, wearable and natural interfaces), coupled with the ubiquity of computing and social networks, present challenges that require the consideration of new factors (emotional, physical and cultural) in the design of systems we are naming socio-enactive. Such systems represent a complex scenario for which there is still no theoretical and methodological basis (and not practical experiences) suitable for its design."*

Thus, the main goal of the project is to create a conceptual framework that consider the particularities and individual characteristics (like needs, limitations, cultural difference, learning styles and preferences) of their participants. The project focus on some specific contexts, like the interactions in museums, healthcare (*e.g.* hospitals) and educational environments.

Specifically, in this report we describe the study, exploration and assessment of socio-enactive solutions in the **educational environment**. The methodology used was the bottom-up approach (Crespi *et al., 2005)*. This report is organized in the following way:

- **Section 2:** analyzes the related literature;
- **Section 3:** describes the bottom-up (general to specifics) steps taken:
    - **Subsection 3.1:** presents 5 high-level socio-enactive educational scenarios (Children outside the classroom, College students outside the classroom, Children inside the classroom, College students inside the classroom and

[5] Available at: http://www.bv.fapesp.br/pt/auxilios/96114/sistemas-socio-enativos-investigando-novas-dimensoes-no-design-da-interacao-mediada-por-tecnologias/ Access: February 2018

Instructor’s room)

- **Subsection 3.2:** justifies the choice for the “Children inside the classroom” scenario;
- **Subsection 3.3:** presents three socio-enactive sub scenarios (*sub scenario 1*; *sub scenario 2* and; *sub scenario 3*) for the “Children inside the classroom” scenario
- **Subsection 3.4:** describes the choice for one of the sub scenarios (*sub scenario 2)* presented in subsection 3.3, named as work scenario.

  In the work scenario we propose the creation of an environment where children must use concepts of logic and computational thinking to position themselves on a stage in order to predict the robot’s movement patterns. The goal is to enable the kids, through their own movements, to guide the robot to a predefined location at the center of the stage.
- **Subsection 3.5:** presents the design and assessment of a MVP (Minimum Viable Product) for the work scenario. The MVP prototype was implemented through the MakeBlock[6] platform (an arduino based robot vehicle), using Scratch[7] as programming language.

  Proof of concept experiments indicate the need for prototype adjustments and adaptations. Next steps include the design and performance of workshops with the children, aiming at retrieving inloco information that will support further development of socio-enactive educational systems.

- **Section 4:** presents the ongoing work and next research steps.

[6] Available at: http://www.makeblock.com/ Access: February 2018
[7] Available at: https://scratch.mit.edu/ Access: February 2018

2. Background

This multidisciplinary work main goal is to study how to design and assess an educational socio-enactive system (see subsection 2.1). As this is not a explored (although promising) area, there are not related works in the educational environment, based in the socio-enactive view . Therefore in the following subsections we describe some **not yet socio-enactive** approaches related to Active Learning (see subsection 2.2), Pedagogical Robotics (see subsection 2.3) and Interactive Tactile Maps (see subsection 2.4). We understand these topics as having fundamental elements we could bring to the construction of socio-enactive educational scenarios.

In section 3 we describe a methodology to design a socio-enactive system supported by these **not yet socio-enactive** approaches.

2.1. Socio-Enactive Systems

Kaipainen *et al*. (2011) proposes a research agenda to study how the nature of interaction would change if:

- Interaction were not conscious, but instead driven by psycho-physiological reflections of a media experience;
- Experience modifies the content, constituting a self controlling system.

Figure 1, extracted from Kaipainen *et al.* (2011), exemplifies the interaction cycle in an enactive system:

Figure 1. Interaction cycle in an enactive system, as proposed by (Kaipainen *et al.*, 2011)

In this work, we propose a socio-enactive system, *i.e.*, an enactive system that **goes beyond** the individual interactive cycle proposed by Kaipainen *et al.* (Kaipainen *et al.*, 2011), considering also the social interactions among individuals.

Our context, the **educational environment**, is supported by the Active Learning Approach (see subsection 2.2), Pedagogical Robotics (see subsection 2.3), and Interactive Tactile Maps (see subsection 2.4).

2.2. Active Learning

The United States National Training Laboratories[8] proposed a learning pyramid, indicating the average retention rate for the most used learning practices. The pyramid, as Figure 2 shows, has on its top the instructional lecture (mostly based on passive learning practices, as reading and audio-visual presentations) and on its base active learning practices (Bonwell & Eison, 1991), like group discussion, practice by doing or writing and teaching others activities.

[8] Available at: http://www.ntl.org/ Access: February 2018

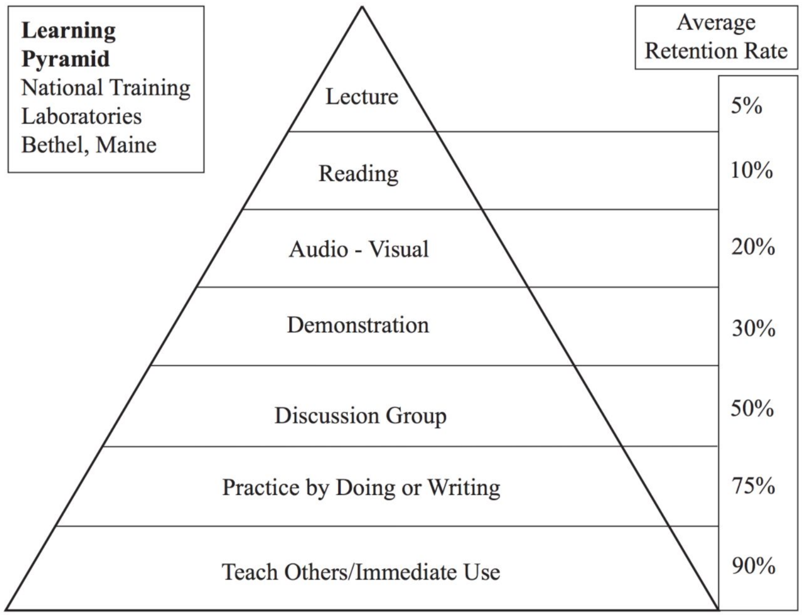

Figure 2. Learning pyramid, as proposed by The United States National Training Laboratories. Figure extracted from the Fashion Institute of Technology, State University of New York[9]

Our research hypothesis is that the pyramid base would have another layer, related to a socio-enactive educational approach, with a higher average retention rate than the other approaches.

2.3. Pedagogical Robotics

The idea of controlling "robots" devices which can contribute to the process of carrying out tasks goes back to old age. It came up, for the first time, in Egypt associated to myths and to mechanisms that gained life. As an interdisciplinary field of knowledge, the study and understanding of robotics crossed the Universities and entered other levels of teaching in

[9] Available from: https://www.fitnyc.edu/files/pdfs/CET_Pyramid.pdf Access: February 2018

Pedagogical Robotics. The Pedagogical Robotics, for more than three decades, has been enriching the way of teaching scientific and technological concepts.

Pedagogical Robotics can also be considered as an environment in which the learning process occurs in a growing spiral cycle (Resnick, 2007), for example in the form of project development of robotic devices to carry out certain tasks.

Maia *et al.* (Maia *et al.*, 2009) present a research whose objective is to provide an environment for open source programming through the use of robotics in education. Their aim is to help students to improve their programming skills and software engineering knowledge through the Lego Mindstorms Educational Kit[10].

On the other hand, Ribeiro *et. al.* (Ribeiro et al., 2011) proposes a methodology to conduct studies that provide ways to assess the impact of Pedagogical Robotics in the learning environment. The proposal has two distinct components: (i) the planning of a set of Pedagogical Robotics sessions to conduct with the students and; (ii) the validation of instruments that quantitatively and qualitatively evaluate the Pedagogical Robotics as an educational tool.

Also, Cho (Cho, 2011) describes the ways of introducing Pedagogical Robotics activities not only in extra-curricular programs but also in formal curricula, such as math, science, languages arts.

Trentin *et al. (Trentin et al., 2013)* states that the Pedagogical Robotics has relevant benefits to the students, increasing their interest in the areas of technology, also supporting the development of their responsibility, creativity and problem solving interdisciplinary abilities.

However, as explained by Venancio *et al.* (2013) for a school to develop activities in this area, it is necessary first to invest not only in instructor training, but also in an adequate space for the development of such activities, as well as the purchase of the required

[10] Available at: https://education.lego.com/en-us Access: February 2018

materials and devices (assembling kits, electronic components, specific software and so on).

Considering all those factors, it is possible to conclude that Pedagogical Robotics is an educational approach that gathers concrete and abstract problem solving features in a multidisciplinary way. Therefore, if correctly applied, the Pedagogical Robotics approach can not only support educational gains, but also expand the classroom possibilities beyond the traditional instructional lecture.

2.4. Interactive Tactile Maps

Brock and Jouffraiss (Brock and Jouffrais, 2015) explain that recent technological advances have enabled the design of interactive maps with the aim to overcome the limitations of classic (non-electronic) tactile maps. These maps, used mainly for accessibility, allows for example people with visual impairments to acquire geographic knowledge related to a city's or location configuration, helping their movement planning.

An example of this approach is the Accessible Route ("Rota Acessível")[11] an interactive tactile map designed to help students with visual impairments at the University of Campinas (Unicamp). Figure 3 shows a system prototype:

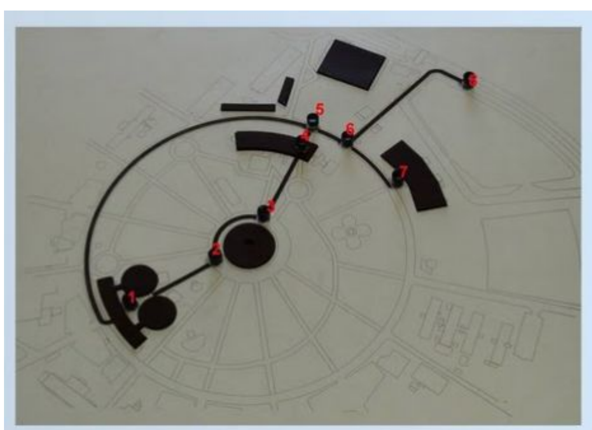

Figure 3. Prototype of the Accessible Route system, designed to help students localization at the university campus

[11] Available at: http://rotacessivel.blogspot.com.br/ Access: February 2018

However, not all tactile maps were created as accessibility tools. For example, the Tractos interactive tactile map[12] was designed focusing in the educational environment, helping children to understand their neighborhood geography particularites. Figure 4 shows a Tractos workshop, in which kids created a responsive tactile map (*e.g.* sounds are played when some location is touched) representing their neighborhood.

Figure 4. Children designing a Tractos responsive tactile map of their neighborhood. Figure retrieved from Tractos website[13]

3. Methodology

In this study we applied a bottom-up methodology, studying and developing possible scenarios from a general perspective (bottom) to a more specific and detailed view, resulting in a MVP (minimum viable product).

Following this approach in subsection 3.1 we present some general educational scenarios (inside and outside the classroom; K12 and undergraduate students); in

[12] Available at: http://tractos.fabiofon.com Access: February 2018
[13] Available at: http://tractos.fabiofon.com Access: February 2018

subsection 3.2 we present the definition of a more specific scenario, for K12 students inside the classroom; in subsection 3.3 we continue the specification of the previous scenario, designing the architecture for three socio-enactive situations (defined as Scenario 1, Scenario 2 and Scenario 3); next, in subsection 3.4, we present details of the Scenario 2 and; in Subsection 3.5 we describe the implementation and pilot test of a MVP related to it.

Figure 5 shows how the bottom-up methodology described in this section is organized:

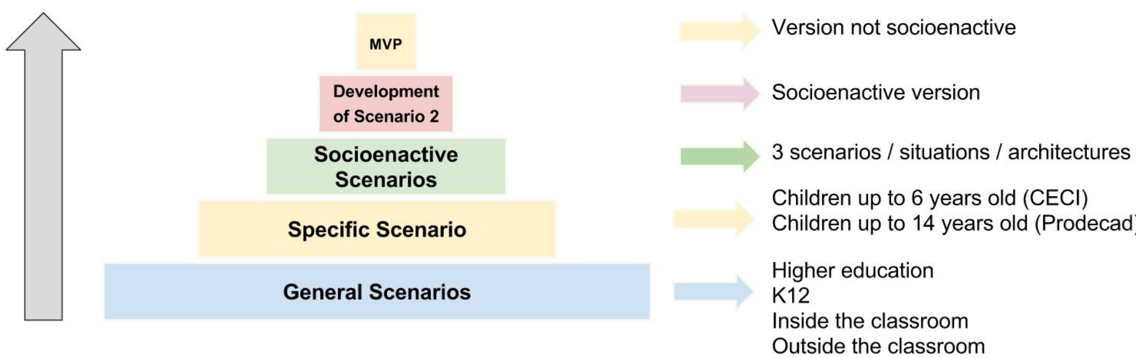

Figure 5. Bottom-up methodology

3.1. General Scenarios

Through internal discussions (brainstorm sessions) we debated about : a) which the **target public** of our study would be and; b) how the socio-enactive **educational environment** would be organized based in the socio-enactive view.

Related to the **target public,** we decided to focus on the students present in the university. Those students can be divided into two groups:

- **Undergraduate Students:** Unicamp has around 3500 undergraduate students.

- **Children:** The Division of Early Childhood and Complementary Education (DEDIC[14]) at Unicamp is the university department responsible to take care of the student's and employees offsprings. It is divided into:
    - CECI: Offers early childhood education to children aged 6 months to 6 years.
    - PRODECAD: offers *complementary* education to children aged 6 to 14 enrolled in the Sérgio Porto school.

Related to the **educational environment**, we deliberated that a socio-enactive system could be used inside (i.e during) or outside (i.e in a different time) the classes.

After the definition of the target public and educational environment, we built general scenarios to situate the research. Table 1 shows a brief description of each scenario, also pointing out to an Appendix in which the details are described.

Scenario Name	Description	Appendix
Children outside the classroom	A scenario, focused in child education, in which the socio-enactive system can be used by the students in the time between the classes (including the time at home). It supports the concept of Ubiquitous Learning[15].	A.1
College students outside the classroom	A scenario, focused in college education (undergraduate students), in which the socio-enactive system can be used by the students in the time between the classes (including the time at home). It supports the concept of Ubiquitous Learning.	A.2
Children inside the classroom	A scenario, focused in child education, in which the socio-enactive system is employed during the classes to promote an active learning environment. The teacher has a guide role in the process.	A.3
College students inside the classroom	A scenario, focused in college education (undergraduate students), in which the socio-enactive system is employed during the classes to promote an active learning environment. The instructor has a guide role in the process.	A.4

[14] Available at: http://www.dgrh.unicamp.br/dedic Access: February 2018
[15] Available at: http://ubi-learn.com/journal Access: February 2018

Instructor's room	A scenario focused in the teachers/instructors. The socio-enactive system is used by them to support collaboration and the design and assessment of new learning ideas and approaches.	A.5

Table 1. Scenarios explored in the target public brainstorm

3.2. Specific Scenario

Following the bottom-up methodology, in this section we describe the decision to choose the following scenario: Children inside the classroom. This scenario was chosen as the research group (InterHAD[16]) has relevant research experience working with children at the DEDIC. Specifically, Figure 5 shows some workshops (*e.g. CPES* relates to storytelling workshops; *Tan2Talk* relates to alternative and increasing communication initiatives; *TaPrEC* relates to tangible computing; *Wearable* relates to wearable and tangible computing and Sphero relates to visual programming and pedagogical robotics):

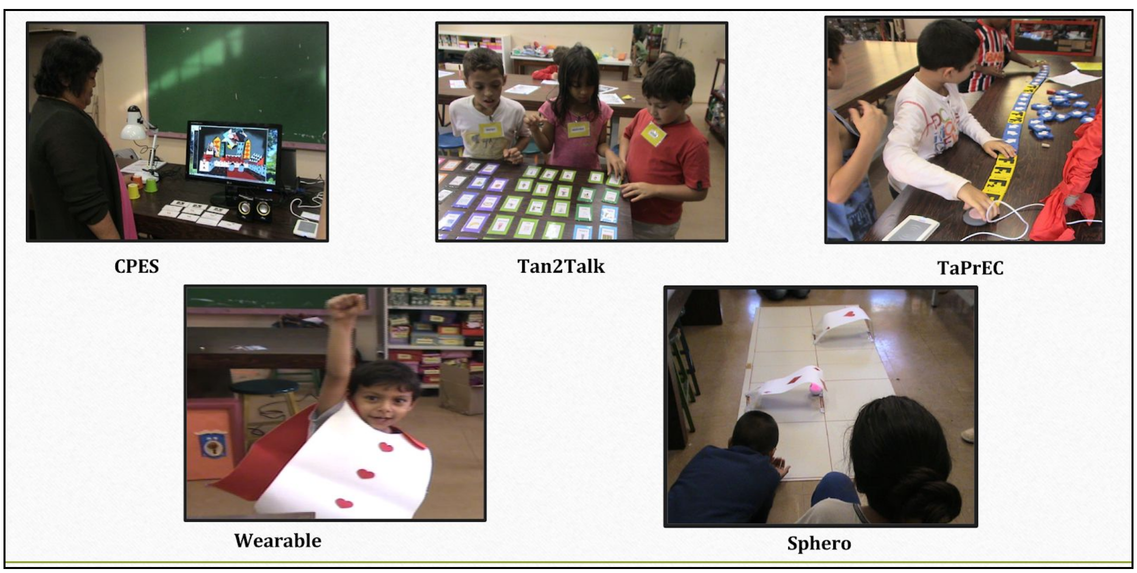

Figure 5. Example of some research projects and workshops developed by InterHAD at DEDIC.

In turn, Figure 6 shows the scheme related to this scenario:

[16] Available at: http://interhad.nied.unicamp.br/ Access: February 5th, 2018

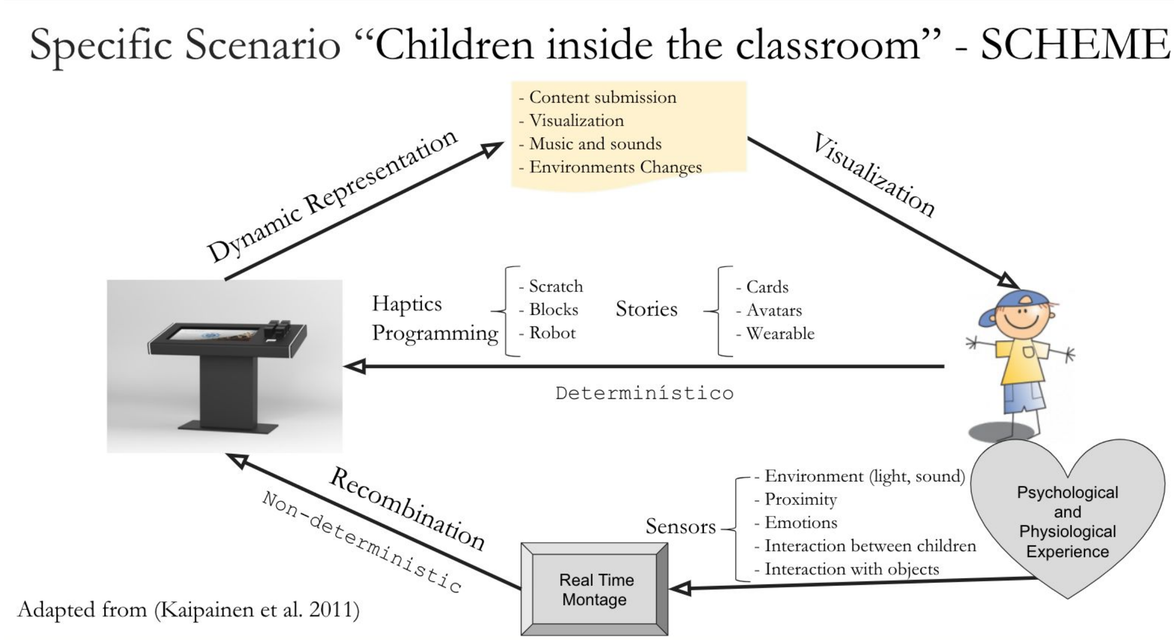

Figure 6. Socio-enactive scheme of the specific Scenario "Children inside the classroom". Adapted from Kaipainen *et al.* (2011).

Although this is the initial scenario of this research (also approved by the Ethics Committee) the other scenarios were not discarded. In fact, we believe the findings on the current research will provide relevant insights and information that will allow the further development of the other scenarios.

3.3. Socio-enactive Specific Scenarios

Following the bottom-up approach, three specific scenarios (named Scenario 1, Scenario 2 and Scenario 3) were created within the Children Inside Classroom scenario. Table 2 briefly describes these scenarios, also mapping them to appendixes with more detailed information:

Scenario Name	Description	Appendix
Scenario 1	A scenario focused in child education and based on tangible computing (specifically the TaPrEC approach - see subsection 3.2). Children are encouraged to program and interact with the mBot.	A.6
Scenario 2	A scenario focused in child education and pedagogical robotics. The children interact with the mBot to solve a computational thinking challenge.	A.7
Scenario 3	A scenario focused in child education in which the mBot reacts to the children's actions and behaviour.	A.8

Table 2. Scenarios explored in the brainstorm.

3.3.1. Scenario 1

In this scenario children use the TaPrEC system (see subsection 3.2) to create problems and/or an interactive environment to support the mBot's activities. At the start of the activity children are divided into two groups: G1 and G2. The main steps are:

- **Problem design:** in a collective work, the G1 team discuss (brainstorm) how the robot's behaviour would be.
- **Problem programming:** the G1 team uses the TaPreC to input the robot's programming.
- **Problem explanation:** the G1 team explains to the G2 the problem to be solved.
- **Problem solution:** the G2 has to interact with the robot to solve the proposed problem.

This scenario focus is to use the Pedagogical Robotics to promote the Computational Thinking through the Active Learning (cooperation vs competition approaches). Figure 7, adapted from Kaipainen *et al.* (2011), shows the socio-enactive scheme for this scenario:

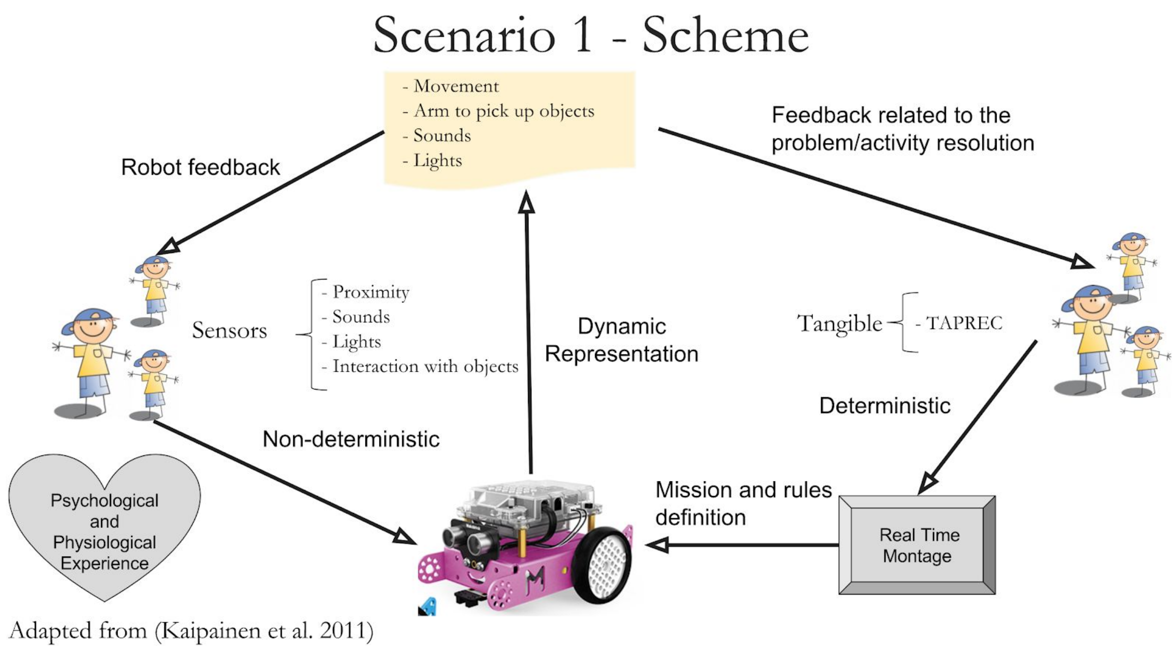

Figure 7. Socio-enactive scheme for the Scenario 1. Scheme adapted from Kaipainen *et al.* (2011).

3.3.2. Scenario 2

In this scenario children have the goal to imprison the robot, who escapes from them. The robot uses distance sensors to escape (run off) from each child. Also, it reacts to environmental stimuli (lanterns, palms, noise, *etc.*). The robot wins if it is able to leave the bounded area. Figure 8 illustrates how the scenario would be organized:

Figure 8. Scenario 2 organization: children guiding a robot in a bounded area. This Figure is an adaptation of a kids image[17] and a mBot picture[18].

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[17] Available at: https://thenewageparents.com/wp-content/uploads/2014/08/Singapore-multi-cultural-society.jpg Access: February 2018

In their turn, children must organize themselves spatially in order to guide the robot's movement. To accomplish this goal, it is required:

- A cooperation among the children (related to Active Learning practices)
- Children's perception and understanding of the algebraic algorithm (pattern) that guides the robot's movement (related to Computational Thinking knowledge)

Children win if they are able to guide the robot to a specific area. Figure 9, adapted from Kaipainen *et al.* (2011), shows the socio-enactive scheme for this scenario:

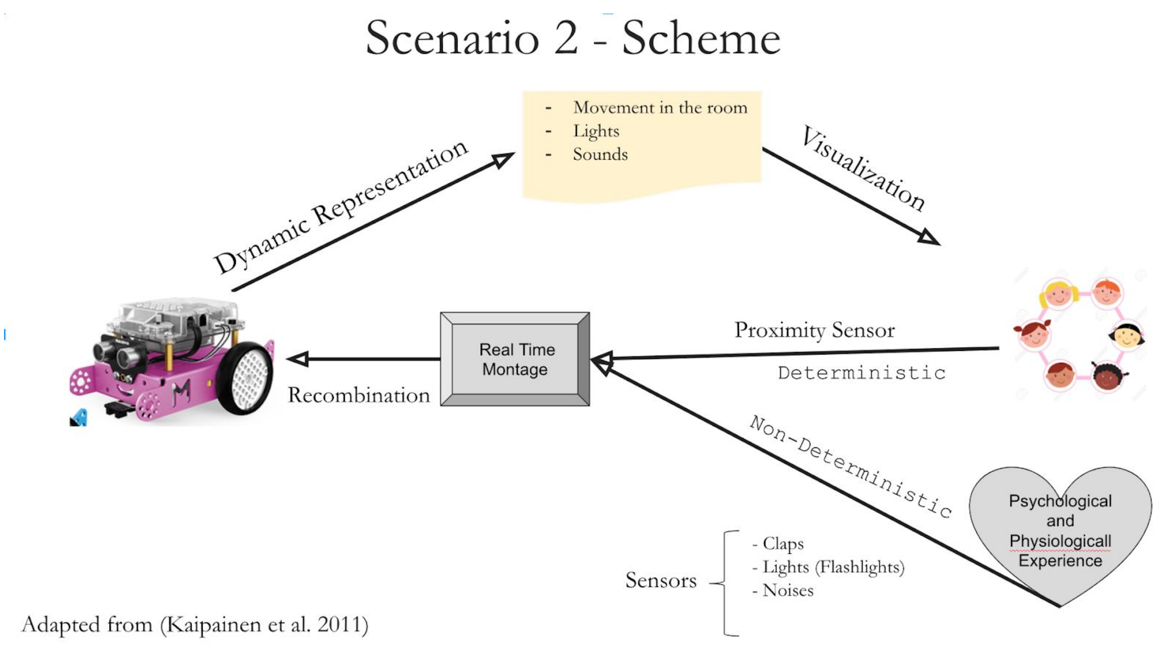

Figure 9. Socio-enactive scheme for the Scenario 1. Scheme was adapted from Kaipainen *et al.* (2011).

[18] Available at: http://store.makeblock.com/product/mbot-robot-kit Access: February 2018

3.3.3. Scenario 3

In this scenario the robot is programmed to react to the behaviour of children. For example, if the children are agitated, the robot could also become agitated (or in similar scenarios, the opposing).

This could be achieved through sensors (*e.g.* proximity, movement, health monitoring, etc.). Figure 10, adapted from Kaipainen *et al.* (2011), shows the socio-enactive scheme for this scenario:

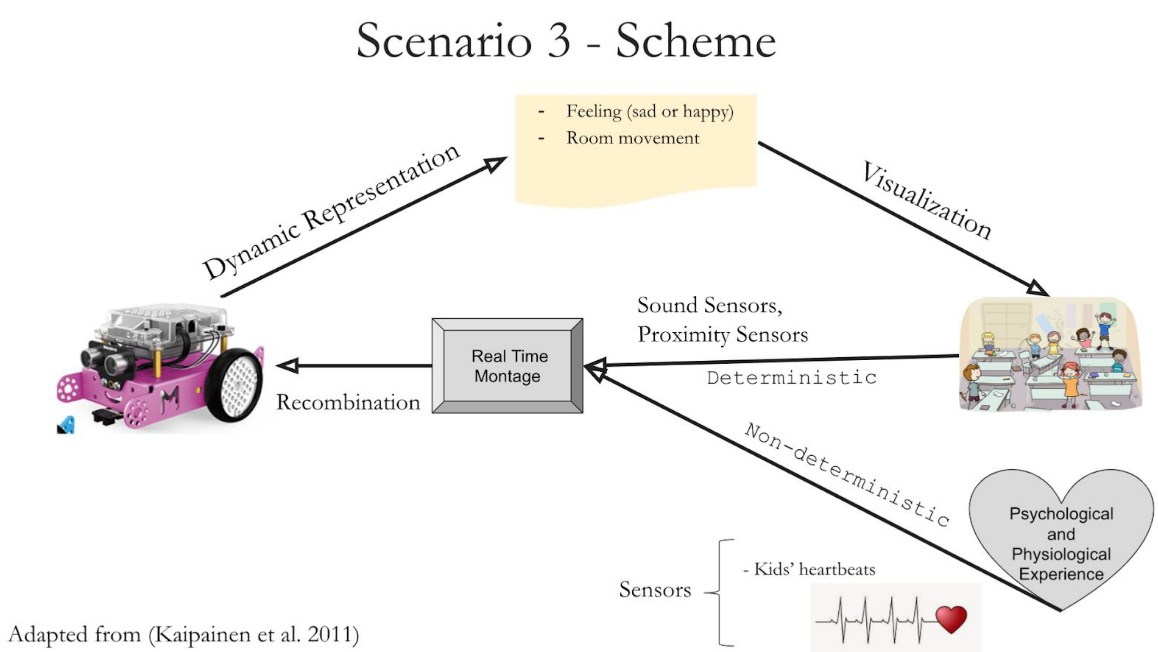

Figure 10. Socio-enactive scheme for the Scenario 1. Scheme was adapted from Kaipainen *et al.* (2011).

3.4. Development of Scenario 2

Following the bottom-up approach, in order to support the creation of MVP (minimum viable product), the scenarios described in the previous sections were analysed through the following criteria:

- The feasibility to support the creation of a MVP (minimum viable product).

- The current hardware availability

There, we chose Scenario 2 because: a) it has the minimum MVP development time and; b) it is the only scenario that does not need additional hardware to be purchased (the sensors provided natively with the mBot are sufficient to support the prototype implementation). Next section describes the MVP development.

However, as the Scenario 2 full implementation (with the socio-enactive features) would take a considerable time to be developed (also requiring additional hardware) we decided to simplify the Scenario 2, implementing an enactive, but **not yet socio-enactive MVP**. This implementation is described in details in the following section.

3.5. MVP

MVP stands for **M**inimum **V**iable **P**roduct approach. It is part of the Lean Startup concept, allowing the developers to early receive feedback from users, helping them to identify and correct design issues as soon as possible.

Figure 11 shows the MVP interactive cycle:

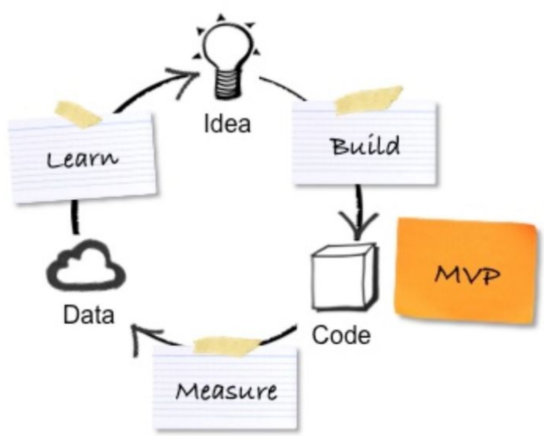

Figure 11. MVP interactive cycle. Figure extracted from Research Gate website[19].

[19] Available at: https://www.researchgate.net/profile/Eduardo_Oliveira_21/publication/277143597/figure/fig5/AS:325105726050347@1454522653510/Minimum-viable-product-feedback-loop-51.png Access: February 2018

The Scenario 2 MVP implementation consisted of the following steps:

- **Main algorithm definition**: three versions of the algorithm were discussed, implemented and tested (see subsection 3.5.1)
- **Classroom Environment and Winning condition details:** two versions of possible environments and winning conditions were discussed, implemented and tested (see subsection 3.5.2).
- **Concept proofs:** The final algorithm and winning condition versions were tested in the defined classroom environment.
- **Programming issues documentation:** The issues identified in the previous steps were documented and an action plan was developed to address them.

3.5.1. Main Algorithm Definition

Table 3 presents the pseudo-code versions designed for the algorithm:

Version	Algorithm
Version 1	● Go forward ● Rotate X degrees according to environmental stimulus ● Victory Condition? ● Losing Condition?

Version 2	● ***Direction*** = random (right, left)
	● Rotate 45 degrees in ***Direction***
	● Go forward
	● If sensor detected obstacle
	    ○ Walk backwards
	● Victory Condition:
	    ○ Robot is positioned at the boundary area center
	● Defeat Condition:
	    ○ Robot exits the boundary area

Version 3	● Repeat:
	    ○ Walk forward continuously
	    ○ If sensor detected obstacle:
	        ■ Walk back X steps
	        ■ ***Direction*** = random (right, left)
	        ■ Rotate 45 degrees in ***Direction***

	○ Check Victory Condition: ■ Robot is positioned at the boundary area center ○ Check Defeat Condition: ■ Robot exits the boundary area

Table 3. The Scenario 2 MVP algorithm (in pseudo-code) evolution.

Figure 11 illustrates a possible use case for the algorithm Version 3. It relates to the situation of children guiding the robot to avoid that it leaves the boundaries:

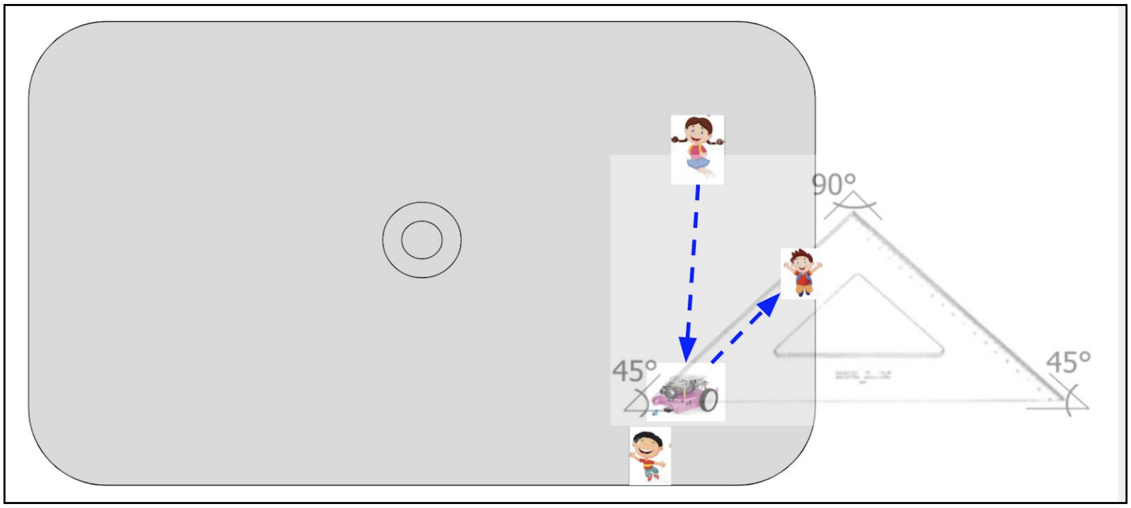

Figure 11. Algorithm Version 3 diagram: children guiding the robot to avoid it leaves the boundaries.

In turn, Figure 12 illustrates another a possible use case for the algorithm Version 3. It relates to children guiding the robot to the boundary center:

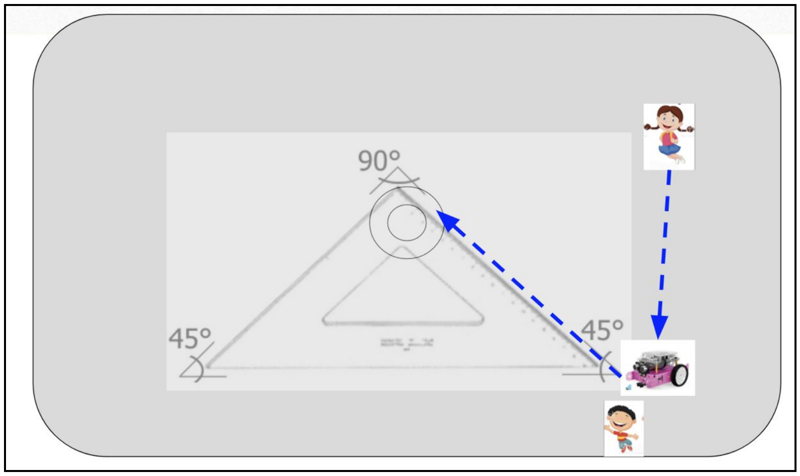

Figure 12. Algorithm Version 3 diagram: children guiding the robot to the boundary center.

3.5.2. Classroom Environment and Winning condition

The **first environment** defined was the classroom floor surrounded by a black line (floor black belt) and with a black circle at the center (center black belt). The children winning condition was defined if the robot was placed at the center and the children losing condition was defined if the robot somehow reached the floor black belt. Figure 13 illustrates this environment:

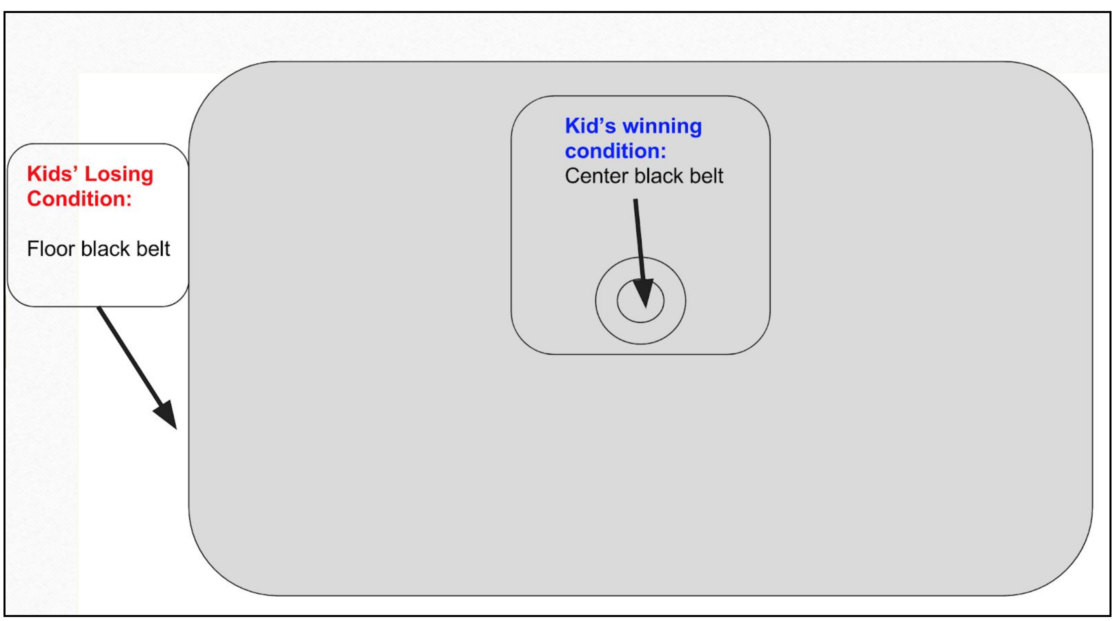

Figure 13. Children winning and losing environment and conditions (first version).

In this version, if the winning condition is achieved, the robot starts turning while playing a happy music. Otherwise, if the losing condition was achieved, the robot would walk through the floor black belt, not reacting to the children movements anymore.

Through initial tests we identified the following issues regarding this approach:

1. The algorithm to "walk in the line" was not easy to implement (the robot was not able to correctly follow the line, wrongly changing its course);
2. The robot's sound processor was too slow for the winning condition. So the robot continued walking (thus passing the center black belt) only starting the music some distance after the center circle;
3. It was not possible to distinguish between the winning and the losing condition (**both** conditions were represented by lines on the floor!).

In order to solve these issues a second version of the environment and winning conditions were designed . It was defined that if the robot reaches the floor blackbelt, the kid's losing condition is executed, leading to a robot full stop.

Also, in this version the black center was replaced by a fully filled circle. This allows the robot to identify the differences between the kid's losing condition (floor blackbelt) and kid's winning condition (fully filled circle). Finally, to avoid delays in the robot movimentation, it was decided the robot would not play music anymore. Instead, the music will be played by an external bluetooth device (e.g. a computer or bluetooth box).

3.5.3. Concept Proof

We used the final prototype version, related to the final algorithm version (see subsection 3.5.1) and final classroom environment and winning condition version (see subsection 3.5.2), to run some concept proof experiments.

Figure 14 shows the concept proof experiment to validate the children’s winning condition. The floor black belt (losing condition) was replaced by books.

Figure 14. Concept proof experiment to validate the children’s winning condition.

In turn, Figure 15 shows the concept proof experiment to validate the children’s losing condition. In this experiment some books were replaced by the black belt line (insulation tape).

Figure 15. Concept proof experiment to validate the children’s winning and losing condition.

3.5.4. Technical Issues

In the Classroom Environment and Winning condition (see subsection 3.5.2) and Concept Proof (see subsection 3.5.3) some technical issues were identified. These issues were milestones in the MVP development, and some of the approaches employed to solve them lead to new steps in the interaction cycle.

The main issues were:

- **Weak Battery:** During the tests, it was sometimes identified a weird and anomalous robot's behaviour, like unexpected changes in its speed, rotation and sensor sensitivity. After some research, we identified the issue was caused by a weak battery (AA batteries). As a rule of further development we decided to always have a spare battery kit at hand for similar situations.

- **Robot's sensor is highly sensitive:** In the concept proof tests it was identified the robot's sensor are highly sensitive when identifying the current surface (the surface the robot is above) color. Therefore, for a real situation (a real floor) the algorithm developed does not work, as the robot identifies small details in the floor as they were black lines, thus wrongly executing the winning and losing conditions.

  In order to avoid this, the concept proof testes were executed in a table surface. However, for the real workshops (see section 4) the experiment environment must consist of a plan, smooth and monochromatic surface.

- **Missing Emergency key:** As the main tests were done in a surface of a table, it was required that always a team member was ready to save the robot from accidents, like an unexpected fall. In order to increase security, it was implemented a emergency key, that fully stops the robot movement.

- **Line Following algorithm needs improvement:** The first children losing condition described a situation where the robot should keep running indefinitely in the floor black belt. Figure 16 shows the first algorithm pseudo-code for the line following algorithm:

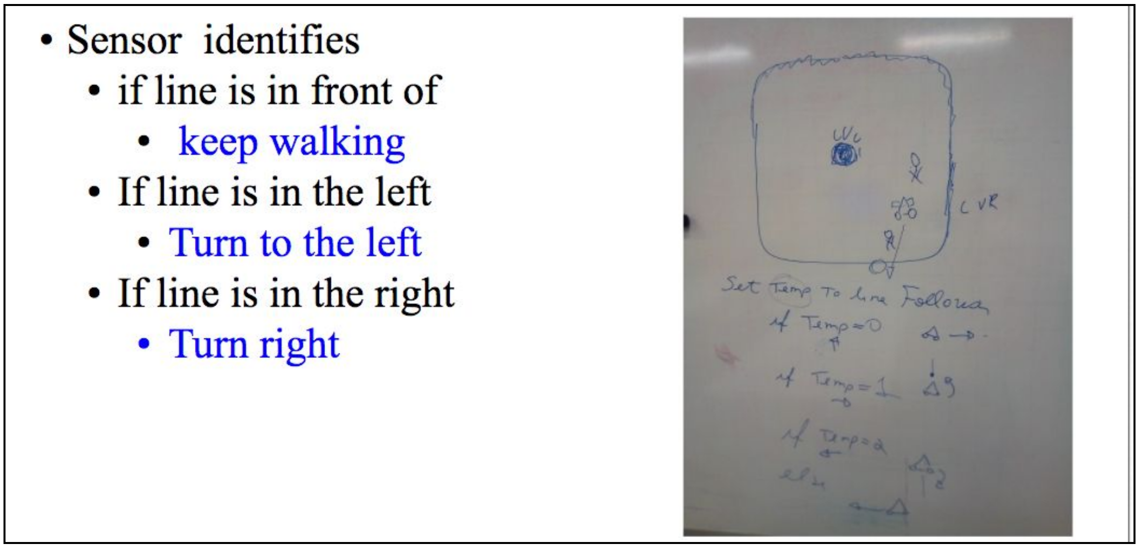

Figure 16. Line following algorithm, first try.

However, as the tests with this algorithm was unsuccessful, the team decided to implement the "official" line following algorithm recommended to the mBot. Figure 17 illustrates this approach:

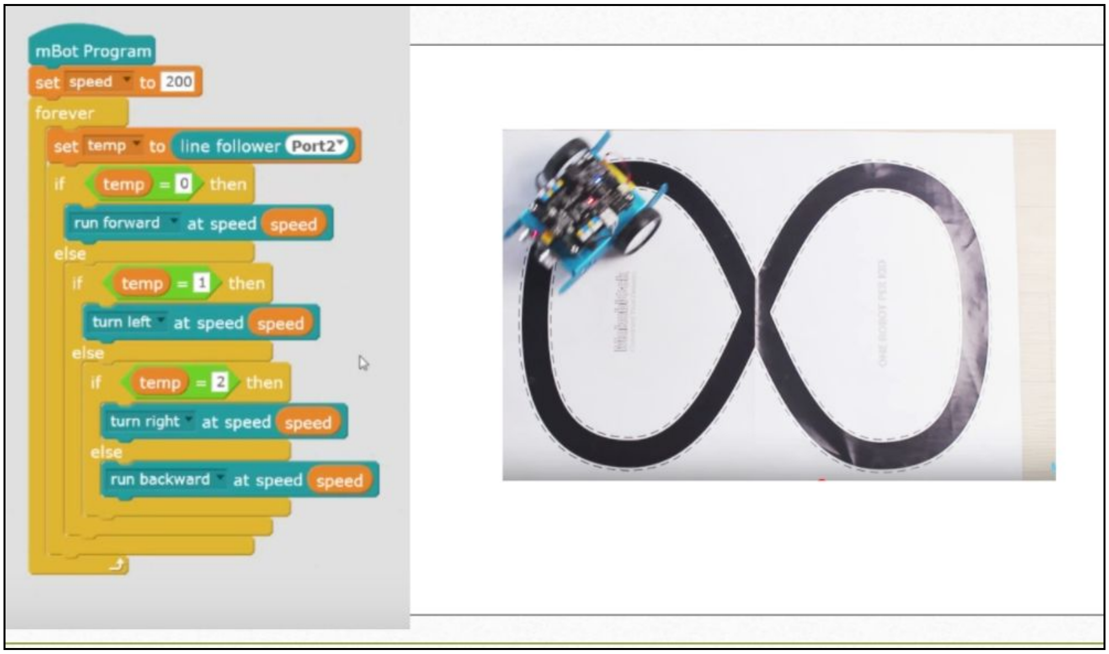

Figure 17. Second line following algorithm.Figure retrieved from "Line - following robot - mBot controlled using mBlock software" YouTube video[20].

Also, the second line following algorithm implementation still did not work. This lead to the design decision to change de children's losing condition to a full stop of the robot, instead of the line following approach.

- **Issue distinguishing the winning and losing conditions:** If the robot enters in parallel on the floor black belt (a not common, yet possible situation), then the robot considers this as a children's winning situation instead of a losing situation.

  This happens as the algorithm identifies the winning situation (when the robot walks by the center fully filled circle) in the following way: if the sensor identifies that the robot has entered a black area and 2 seconds after the robot is still in a black area, then it concludes the robot is in the fully filled circle at the center.

  It was identified that when entering in parallel on the floor black belt this situation happens, therefore the robots behaviour as the children have win, not the

[20] Available at: https://www.youtube.com/watch?v=k6Kn0bBxzdk Access: February 2018

opposite. The proposed solution is to use as floor black belt a circle (as shown by Figure 18) and not straight lines (as shown for example in Figure 15).

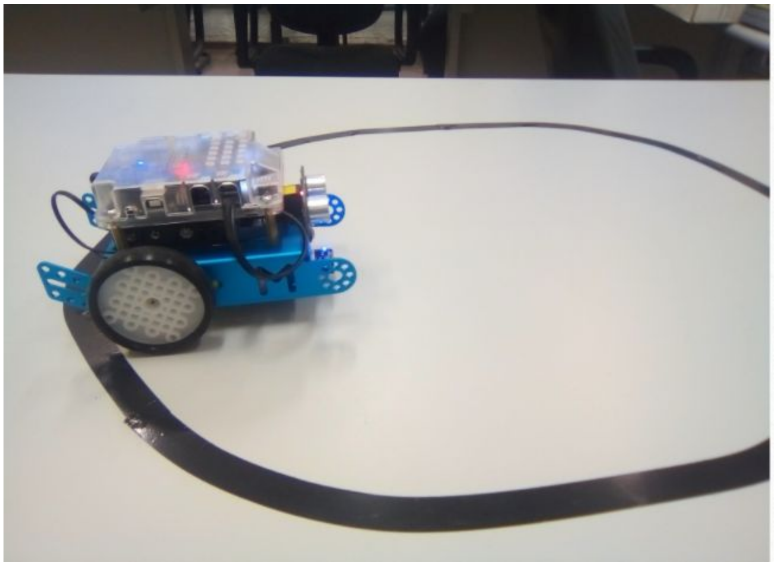

Figure 18. A floor black belt a circle is used to enhance the algorithm efficiency.

- **Children losing condition accuracy:** During the tests it was identified that sometimes the robot was able to cross the floor black belt (either in its straight and circular version) **without** considering it as a children losing condition.

  We identified this happens as the insulating tape used as floor black belt **reflects light**, as shown in Figure 19:

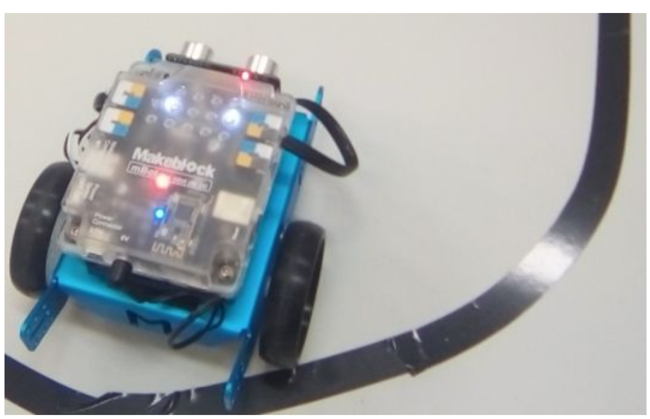

Figure 19. Insulating tape reflecting light.

In order to avoid this issue we plan to use as floor black belt materials that don't reflect light. This issue does not happens in the fully filled circle at the center (children' winning condition) as the material used was a plain printed sheet (laser printed).

4. Ongoing Work

The research next steps were designed in a top-down approach: starting from the MVP, the next step will be its validation through workshops (real classroom). In this step we plan also to assess a Scenario 2 variation approach, dividing the children into groups. Each group will have its own winning condition (an independent fully filled circle), and they will **compete** to guide the robot to it. Also, the groups will have to **cooperate** to each other, avoiding the robot to reach the floor black belt (losing condition). If the robot wins, all kids, regards its group, lose!

The next step will be the development of a **socio-enactive version** of Scenario 2 and its subsequent validation. Finally, we plan to explore the other scenarios described in this document. Figure 20 illustrates the proposed top-down approach:

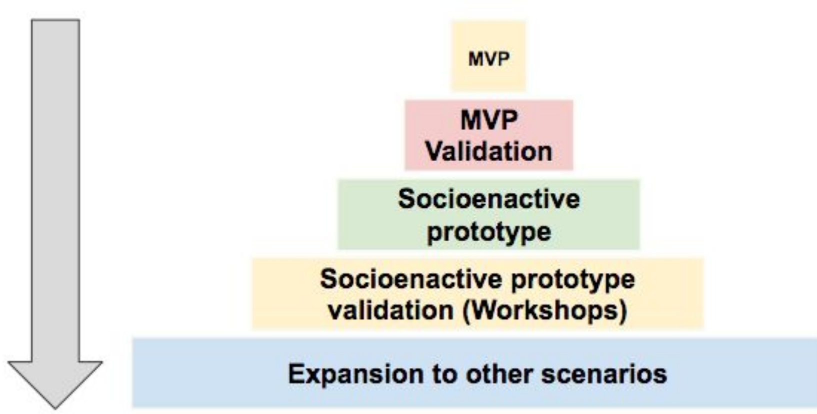

Figure 20. Top-down approach, starting from the current MVP assessment and leading to a socio-enactive prototype version and its expansion to other educational scenarios.

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Appendix A - Scenarios

This Appendix describes in detail the scenarios proposed in earlier sections. Table 4 maps each scenario to its corresponding section or subsection in which it was referred to. Some scenarios are available only in Portuguese language.

Appendix	Scenario's Name	Section it was referred	Language
A.1	Children outside the classroom	3.1	English
A.2	College students outside the classroom	3.1	English
A.3	Children inside the classroom	3.1	Portuguese
A.4	College students inside the classroom	3.1	Portuguese
A.5	Instructor's room	3.1	Portuguese
A.6	Scenario 1	3.3	Portuguese
A.7	Scenario 2	3.3	Portuguese
A.8	Scenario 3	3.3	Portuguese

Table 4. Scenarios mapping through the Appendix A subsections and report sections

A.1. Children outside the classroom

When John comes to school in the morning, he always walks past the table in the yard before entering the classroom. Today he meets Lucas and Nicolas, two classmates, along with others:

"Hey there, what's up?" he greets.

"Not so bad!" Lucas replies.

As John approaches the table, a picture of John's face appears on the table surface. The device also presents other photos, pictures, drawings and avatars of the other students. The photo of Matheus, who is in the afternoon class, appears.

"This Matheus ..." thinks John *"is already online to vote!"*

At the center the table shows today's Top 20 hits containing the album cover, the music's name and a hyperlink to the music's lyrics.. John finds his favorite song, the new one of Lady Gaga. He opens his backpack and picks up an Iron Man toy - his favorite superhero right now. The toy has a sticker on the bottom with an RFID chip and QR code. He puts the code over the photo of Lady Gaga and sees that the number of votes increased, rising her in the rank. Gladly, he continues the conversation with his colleagues.

Later, in the first interval, he returns to the table, where already appear several others of all the series.

"Let me see, let me see!" he exclaims when approaching the table.

"I do not believe! Fourth place! Again! OMG!!!"

He returns to look for his friends and convince them to vote for Lady Gaga, but today everyone has already voted.

"Tomorrow I'm going to be smarter and ask Ana and her gang not to vote again for that boring Justin Bieber song" he planned.

At that moment the table starts to play the Justin Bieber's song. It also displays the avatars of the afternoon students that are watching online the pool. Also, lights on the table and around begin to glow in different colors, synchronized to the music. The immersion is completed with panels vibrating around the table, vibrating in music's rhythm.

Next to the panels is Paula, a John's deaf colleague. She enjoys the video that accompanies the music and the vibrations of the panels. Everyone starts to dance. As the kids get agitated, the sound and intensity of the lights and vibrations increase proportionally. Everyone knows that great part of the afternoon students are watching online, as the number of online students displayed on the table is continuously increasing.

The crowd gets more excited and gives a good show their online friends. The second song played is the one of Justin Bieber. Everyone stops.

"What is this?" they ask.

"Oh...lol, you don't like Justin?!"

That was a joke from the afternoon students, which combined to vote for the Canadian singer. The crowd starts whistling and booing, and the table starts playing the next music on the list.

"I'm going to listen to Lady Gaga today" rejoices John.

A.2. College students outside the classroom

It was a rainy afternoon. John was in the living room of his house and remembered the next week he would make an evaluation of the discipline MC102 - Algorithms and Programming of Computers.

John called a voice command from his television: "Study MC102". The application accessed his online diary, identifying the content of his classes and a simulation. From this, he began the presentation of a video lesson on the topic of declaration and scope of variables.

It turns out the video because it was very boring. John indicated in the application the option "Boring Video" and turned the television off. After that, he opened his notebook (which he was already on, just hibernating) and the application automatically identified whats John's current context was to study MC102, and that he had not been successful with the study through videos.

The application began to display a brief explanation of the topics of the discipline, followed by a quiz. John earned points with every right answer. This score was shared with classmates from his class - at that moment, another 4 students were online doing the same quiz. John was excited about the competition, since the student who scored more points could share a trophy on social networks.

After an hour of study, John shut down the notebook and went to dinner. He was tired, he went to his room and turned on his iPod. The application identified that John was studying for the MC102 exam, but he also knew it out to John would not like to learn new content because it was late. In this way, the application selected some review audios that he had studied in this day, focusing exercises that he missed in online competition.

A.3. Children inside the classroom

Os alunos da Escola Curiosa tem um mascote, Wally.

Wally é um aluno virtual que participa das aulas por meio de multimídia, geralmente exibida em uma janela também virtual (monitor com som 3d e câmera), mas de vez em quando invade inclusive os slides dos professores.

Wally, um androide com voz sintética que veio do futuro, gosta muito de viajar e aprender, ele pode se teleportar e lembrar de tudo que vê ou ouve. Wally gosta de interagir com os outros alunos, principalmente enviando fotos (selfies) dos lugares interessantes que visita ou frases famosas relacionadas a suas experiências fantásticas, que incluem visitas ao país da matemática e vários contos de fadas.

Geralmente essas fotos servem de ponto de partida para uma viagem com a turma toda para encontrar Wally! :)

Para isso, os colegas de Wally devem exercitar o pensamento computacional além de propor e resolver enigmas relacionados a temática do local onde Wally pode estar. Wally tentará responder os enigmas dos colegas, e propor novos em um jogo cooperativo de aprendizado e diversão. Algumas vezes, os colegas de Wally podem se teleportar para a história (*cromaqui do Julian*).

Mas nem sempre Wally tem créditos para trocar mensagens com os colegas. Dependendo de moedas mágicas (rfid) que são usados para controlar a cadência de interação através da janela virtual.

Wally às vezes também é visto na mesa da parada musical, no pátio da escola, e também já participou de visitas a museus e hospitais.

A.4. College students inside the classroom

João é aluno da disciplina MC102, de Algoritmos e Programação de Computadores. O tópico da aula são laços, e o professor está explicando neste momento como um **for** funciona. João não está entendendo muita coisa, mas é muito tímido para levantar a mão e perguntar - afinal, a classe tem 80 alunos! Então João aperta um botão em seu clicker (um pequeno controle remoto ligado ao sistema da sala de aula), indicando que está com dúvidas naquela parte da aula. Imediatamente após isso, as bordas do slide do professor mudam gradualmente de cor, ficando levemente vermelhas. O professor continua sua explicação sobre o funcionamento do **for**, e para surpresa de João, o vermelho das bordas do slide se intensifica. João olha ao redor e vê que seus colegas também estão com os clickers em mãos.

O professor nota a mudança de cor do slide e para a aula: “OK, acho que é hora de explicar o funcionamento do **for** de outra forma. Vou dar um exemplo diferente para ver se as coisas fazem mais sentido assim”.

Durante a explicação do professor, João finalmente consegue entender como um laço funciona. Ele então aperta em seu clicker a opção correspondente ao entendimento, e o vermelho das bordas do slide fica mais tênue. Os demais alunos seguem procedimento igual. O vermelho do slide vai aos poucos desaparecendo, dando lugar a uma borda verde. O professor, satisfeito com a explicação, passa para o próximo tópico da aula.

A.5. Instructor’s room

Sistema sócio-enativo para estimular o desenvolvimento de habilidades com os conceitos e capacidades do pensamento computacional.

Um sistema que vai interagindo com os professores na criação de um problema a ser apresentado aos alunos. Seria “o desafio do mês”, criado por todos os professores de forma colaborativa. Os professores vão interagindo entre eles e com o sistema em busca de uma situação problema, que seja propícia a ser resolvida através da aplicação do pensamento computacional. A resolução da situação problema deve ser baseada no desenvolvimento de habilidades nos conceitos: 1) coleta de dados; 2) análise de dados; 3) representação de dados; 4) decomposição de problemas; 5) abstração; 6) algoritmos e procedimentos; 7) automação; 8) paralelização; 9) simulação; 10) colaboração e 11) engajamento.

O “desafio do mês” deve ter o caráter multidisciplinar e a própria criação do desafio pelos professores pode seguir a metodologia do pensamento computacional proposta no cenário “dentro da sala de aula e com crianças”.

A.6. Scenario 1

Cláudio é professor de Matemática numa escola de ensino fundamental. Hoje os alunos vão trabalhar com lógica. Ele trouxe o TaPrEC e o robô para a sala, o que deixou os alunos ansiosos. Metade da turma tinha a tarefa de criar restrições no movimento do robô e definir um ponto da sala onde o robô deveria chegar. Leila estava nesse grupo, e sugeriu para a equipe fazer com que o robô só andasse em “L”. Juntando os **blocos de movimento**, eles definiram isso.

Com o problema criado, a outra metade dos alunos teve que descobrir o que o robô tinha que fazer. Eles foram fazendo perguntas para o robô a fim de descobrir o que ele queria; logo perceberam que era fazer com que ele chegasse em algum lugar. Juntos, os alunos perceberam que para mover o robô, deviam se acumular em um lado, direita ou esquerda, e ele se movia em “L” na direção que eles ficavam. Com isso, a turma foi se organizando até conseguir chegar no ponto da sala, que o robô foi indicando a proximidade por “estar frio” (longe - cor azul) ou “estar quente” (próximo - cor vermelha).

A.7. Scenario 2

A professora colocou no centro da sala uma pequena cesta, uma bolinha colorida e o robô Toby, que possuía uma pá robótica, similar à de um trator. O grupo de 7 crianças se aproximou, curioso. A professora disse: “O objetivo de vocês é fazer com que Toby pegue a bola e jogue dentro da cesta!”

João se aproximou de Toby. Para seu espanto, conforme se aproximava, o robô se afastava cada vez mais, na direção oposta. As demais crianças também tentaram, em vão, se aproximar do robô. Foi então que Maria teve uma ideia: “Pessoal, vamos fazer uma roda e dar as mãos!”

As crianças fizeram isso e Toby ficou parado ao centro, numa posição equidistante de todos. A bolinha estava um pouco atrás do robô. Então Maria teve uma ideia: “Vou dar um passo à frente!” Sem soltar as mãos dos colegas, Maria se deslocou um pouco na direção do robô. Isso fez com que ele fosse para trás, ficando bem ao lado da bolinha.

“Muito bem!” disse João “Mas como vamos fazer Toby pegar a bolinha?”

A professora orientou os alunos: “Para que Toby levante sua pá robótica, vocês devem assoviar. Para que ele abaixe a pá, vocês devem bater palmas!” Então as crianças se organizaram. Mantendo-se de mãos dadas, alguns deles assoviaram, enquanto outros se deslocaram para frente e para trás, forçando Toby a pequenos movimentos.

Após algumas tentativas frustradas, finalmente Toby pegou a bola! Já acostumados ao funcionamento de Toby, os alunos seguiram procedimento similar para fazer o robô ficar com a bola acima da cesta.

No final, bateram palmas. “Legal! A bola caiu dentro da cesta!”, disse Maria. Todos bateram mais palmas, mas dessa vez de satisfação pela tarefa cumprida!

A.8. Scenario 3

Em uma determinada escola as(os) alunas(os) acabaram de chegar, trazidos pelos seus pais que durante o percurso de casa até a escola, haviam recebido mensagens de que neste dia haveria uma atividade diferente para ser realizada. As(os) alunas(os)os alunos sabiam portanto, que iriam brincar com um robô que reagia ao estado de ânimo na sala de aula. Ao chegarem na sala, enquanto aguardavam a professora, o robô que já estava lá, e que usava sensores de som e proximidade para reagir à agitação das crianças, começou a conversar com elas. Nesse instante chegou a professora que também entrou no clima e todos foram se aproximando do robô, e perceberem que este ficava mais alegre e até dançava, quando chegavam bem perto dele.

Ao perceberem que ele dançava, passaram a inventar movimentos diferentes de dança para que o robô as acompanhasse. Nisso, o ambiente da sala de aula foi se transformando em uma pista de dança e, as crianças que já estavam usando uma pulseira que media seus batimentos cardíacos descobriram que seus batimentos cardíacos eram sentidos pelo robô. Notaram que quanto mais os seus batimentos aumentavam mais agitado ficava o robô. Com isso, passaram boa parte da aula, daquele dia, dançando, tentando fazer o robô se cansar. Advinha que se cansou primeiro.