Abstract—This Research-to-Practice Full Paper presents a reflective analysis of robotic literacy activities focused on children and teenagers. Robotic literacy is integrated or being integrated into the education system for children at an early age all around the world. Most of the teachers in charge of this education lack skills and are left to fend for themselves. This study proposes to focus on the discourses made by teachers and learners during such activities, and especially the metaphors used spontaneously. It takes shape through two robotic literacy activities. The first activity involved the robots BeeBot, BlueBot and Ozobot in seven classes of children from 3 to 10 years old. The second activity consisted of a five half-days training for 13 participants from 8 to 15 years old. They designed, built and programmed a robot. Young people’s representations and interactions with robots involved in educational activities are observed to contribute to the development of questions for critical technology education. Analyses are carried out using the conceptual metaphor theory of Lakoff and Johnson. Three roles are identified: the metaphor that helps to understand, the metaphor that makes tangible, and the metaphor that serves as a catchphrase. A metaphor can take more than one role and, whatever its role, can be classified as a living or non-living metaphor. Using living metaphors may hide aspects of the machine and raises ethical issues, inter alia. It is then essential to deconstruct young people’s representations of the machine. This can be achieved by analyzing robots as social constructions that reflect human intentions.

Index Terms—Digital Literacy, Robotics, Educational Robot, Computational thinking, Programming, Coding, Early childhood, Elementary Education, Secondary Education, Representations, Understanding, Conceptual Metaphor

I. INTRODUCTION

In French-speaking Belgium, computer science, including computational thinking, is almost missing from compulsory education, namely for 5 to 18 year-old students [1], [2]. The lack of teacher training [3] is often cited as a reason. Yet, in the near future, teachers may be required not only to integrate digital tools into their classrooms, but also to teach digital skills [4]. Indeed, Belgian education has been undergoing a major and complete reform that stipulates that “from primary school, an introduction to digital logic can be achieved by programming simple machines” and also evokes a “minimum mastery of tool logic - program or be programmed”1. A forthcoming polytechnic education curriculum between 3 and 15 years is also envisioned, including a digital theme. Despite the desire to develop digital skills from an early age, the content of such education has yet to be defined [5].

Coding education and robotic applications are integrated or being integrated into the education system for children at an early age all around the world [6]. These topics are widely promoted by the media, but also by funding plans. In the French community of Belgium, the “Ecole Numérique” plan proposes prize-winning schools “discovery of programming principles” packages including microcomputers (Arduino², Makeblock³) and robots (Thymio⁴). In addition, resources are multiplying on the Internet: testimonials, videos, turnkey activities (tested or not in a classroom), advice of all kinds, technical comparisons of robots, etc. Educational activities integrating robotics are being implemented in some schools, as well as in non-formal education places. However, there is a clear lack of didactic materials and resources that address the issue of assessing the skills developed through this type of activities. It’s not just a question of measuring whether an activity is successful or not, whether a robot comes out of a maze or not... The understanding of digital concepts and their societal stakes is particularly dependent on the discourses held during such activities. Naturally, metaphors were used in language; more particularly, to represent digital environments. It is therefore a question of reflecting about the discourse that a trainer should hold in front of his/her learners to ensure the best possible understanding of the concepts.

A study was conducted to develop a model of critical robotic literacy including technical, semiotic and social dimensions. Two robot literacy education activities focused on children and teenagers were observed and analyzed. In particular, it is a question of observing the conceptual metaphors mobilized in language. What do they bring to the understanding of how the robot works? Do they raise expectations or frustrations? Do they represent risks? Do they allow us to become aware of the place of robots in society, of the representations attached to them and of the stakes involved? So many questions to which this study attempts to provide some answers.

First of all, the notions of robots and metaphors are clarified in the context of the study. This one is defined in section

2https://www.arduino.cc/
3https://www.makeblock.com/
4https://www.thymio.org/
3 through the two case studies on which the research is based. Objective and methodology are then detailed. Extracts from discourses highlighting the metaphors used constitute the results presented in section 6 and discussed in section 7. Finally, some reflections conclude this paper and contribute to the formulation of issues that can be taken up in critical technology education.

II. RELATED WORK

A. The robots

According to Lambert [7], a robot is “a system formed by a complex and interactive network of sensors, processors, and actuators acting in a way that is partially or independent of the human” making use of it. He distinguishes two types of robots:

- The mechatronic robots are complex constructions of mechanical and electronic elements.
- The electronic robots, called bots, act on social networks, e-mails, or databases.

Moreover, the degree of autonomy of robots varies.

- Robots can be automatic systems. For example, robots whose instructions are ordered a priori by the programmer.

- Robots can be autonomous robots. For example, robots whose set of possible behaviors is not entirely ordered by the programmer.

Our study focuses on activities based on mechatronic robots, whose actions can be directly observed through their movements, and automatic robots “operating in perfectly determined and known environments, whose actions, totally predictable, are governed by the strict instructions of their software, implementing the programmers’ intentions” [7].

Introduced into education, robots are often associated with technologies that support learning [8], [9]. It is educational robotics [10], [11]. Robots are used as digital tools for pedagogical purposes in various subjects, particularly in mathematics, science, and engineering sciences, but also in more distant subjects [12], [13]. They also promote the development of meta-cognitive skills (soft skills) [9], [10], [14]. Different studies show that they encourage children’s motivation to learn, in particular through the storytelling [13], [15] or the use of competition [16]–[18].

But the robot is not only a means of learning, it can also be the object of learning. We talk about “robotic literacy”, a subset of digital education. Robots can be used to introduce learners to the fundamental concepts of computer science and computational thinking, to develop ICT/STEM sectors through specific training, or to train citizens about “digital literacy” [5]. The approach explained in this paper considers robotic literacy as part of a critical technology education discussing “technology’s role in societies and people’s everyday lives” [19].


- “Robots to use”, which is often humanoid (or animal) type, are “black boxes”. Their components are neither manipulable nor observable. Their internal technical functioning is not directly understandable.
- “Robots in kit to be built” are “robots to think with”. Their components are observable and manipulable. Their internal technical functioning is more easily understandable.

According to the authors, the second type is more favorable to educate children, giving them “the opportunity to become an author rather than a consumer of technology” [9]. Moreover, the first type favors perceptions and interactions with the machine close to those that individuals have with live beings. It can lead to certain frustrations due to the limited interaction capacities of robots with live beings [20]–[22].

Our study focuses on activities based on the two types of robots.

B. The Conceptual Metaphors

According to the theory of conceptual metaphor [23], the metaphors we naturally use in language are not linguistic artifacts, but indicators of our mental representations. They are cognitive processes that allow us to represent the world around us. “Our ordinary conceptual system, in terms of what we both think and act, is fundamentally metaphorical in nature” [23]. Metaphorical projections allow us to understand and experience something, often more abstract, in terms of something else, more concrete or physical. Metaphorical projection is not complete, in the sense that the intended concept does not quite become the metaphorical concept. However, it leads to focusing on certain aspects of the target concept, highlighted by the metaphorical concept mobilized, while hiding the other aspects. For example, when we say “your arguments are indefensible”, we consider the discussion to be partly a war. It, therefore, highlights aspects of the discussion that are similar to the war, such as having to defend oneself, while masking other aspects such as cooperating, for example.

Spatial metaphors are fundamental cognitive processes based on our physical and direct experience of our environment or objects. For example, we speak about happiness in terms of verticality (more happiness is on top). Web sites are often seen as boxes we open or close. Spatial metaphors are used without realizing it and it it why, as an observer, it is hard to identify them at first glance. Beside these metaphors which are fundamental but not very rich, there are structural metaphors. They consist of a structurally more complex metaphorical concept and they lead to particular understandings of the targeted conceptual domains, such as the war in the metaphor “discussion is war”.

Several works have highlighted the spontaneous use of metaphors to represent digital environments, in particular spatial metaphors [24], [25], but also structural metaphors that make these environments concrete or physical [26], [27]. These metaphors are not neutral regarding representations and interactions with digital environments. Collard has notably shown their influence on users’ understanding and navigational behaviors [28].
III. RESEARCH CONTEXT

Our study focuses on two cases: a first case using three robots to use (case study 1); the second one uses a robot in kit to be built (case study 2). All robots are mechatronic and automatic.

A. Case Study 1

In the first case study, a sequence of four 40-minute activities and a formative evaluation were set up with children aged 3 to 10 from the same school. A total of 140 children from seven different classes (one per level) participated in the study. The trainers were two researchers, a computer scientist and a pedagogue.

The first activity was to familiarise children with computer hardware and to dehumanize the robot. Children drew their representations of a robot and a computer. Then, children discovered the computer hardware thanks to Hello Ruby’s story\(^5\). At the same time, they build their own computer, with their components, in paper\(^6\) (Fig. 1). Finally, children manipulated real electronic components.

![Fig. 1: Building your own computer](image)

In the following three activities, Bee-bot, Blue-bot, and/or Ozobot were used, depending on the age of the children. These robots were selected for the various interaction modes they offer (buttons, programming bar, or mobile application on a tablet) and their popularity in education.

The second activity aimed at learning the programming language of the three robots, knowing that Bee-bot and Blue-Bot react to the same language. It is an unplugged activity. Children had a set of cards (Fig. 2) that reproduced the robots’ instructions. One child played the role of a robot in a giant maze. The others wrote, with the cards, a program to get the robot out of the maze. First, the solution was coded with the Bee-Bot language. Once verified, it was translated into the language of the Ozobot.

The objective of the third and fourth activities were to get children to write a program, test it by programming the robot and correct and/or optimize it (using the programming concepts of variable and loop). This drill was reproduced twice (2 * 40 minutes) so that the children could manipulate two robots with two different programming languages. Different mazes were proposed. The children wrote programs to make the robots move in these mazes.

![Fig. 2: Cards for programming](image)

The sequence of activities ended with formative evaluation. Individually, the children made drawings of a robot and a computer to compare them with their initial representations. They also had to correct on paper a program allowing the robot to exit a given maze. Then, in groups of three, the children discussed their productions, but also their understanding of basic programming concepts (variable and loop) with a trainer. Finally, a debriefing with the teachers was also organized to reflect on the materials used, the activities set up and how they felt about the children.

B. Case Study 2

The second case study concerns an introductory activity to robotics as part of a holiday course for children and teenagers. Five children aged 8-12 years and six teenagers aged 12-15 years participated in this activity. It consists of five half-days, supplemented by language learning. It involves a robot designed by the trainer, a robotics engineer.

The objectives of the activity were to design, build and program a “robot in kit”. Two levels were proposed according to the age of the participants.

- Children had to program the robot to move in a circuit, interacting with its environment.
• Teenagers had to program the robot to draw a design of their choice on a sheet of paper using a felt tip pen.

First, participants drew the robot’s elements on the 3D design software Tinkercad\(^7\) (Fig. 4). They then printed these elements on a 3D printer.

In the second step, participants assembled the different printed parts, an Arduino board, and various sensors to build the robot (Fig. 5).

Finally, the participants programmed the designed robot via the Blockly\(\textregistered\)Duino application\(^8\).

IV. RESEARCH OBJECTIVE

This study aims to identify the representations that learners and trainers use in two robot education activities. More specifically, it aims to identify the conceptual metaphors, especially structural and spatial metaphors, that are used in the language of learners and trainers and to analyze the role of these metaphors in these situations. By exploring these topics, the study seeks to understand the interactions between learners and trainers and those that are created with the robot, to contribute to the formulation of issues that can be taken up in critical technology education.

V. METHODOLOGY

A. Collecting Data

In the case study 1, several methods were used to collect the data. All the activities were filmed to observe children’s interactions (with each other, the trainer, the materials made available to them, and/or the robot) and listen again their verbalizations. The drawings, as well as all the programs written, were also collected. The discussions conducted during the formative evaluation were filmed. The debriefing with the teachers was audio recorded.

For case study 2, data were collected from both groups of participants (children and adolescents) for two days through ethnographic observation and noted in a notebook.

B. Analyzing Data

The metaphors used in the discourses of trainers and learners, and in their interactions with each other and with the machine, were recorded with attention to the spatial metaphors and the structural metaphors [23].

The different metaphors brought to light by this grid were then analyzed according to their role in interactions.

VI. RESULTS

A. Role Classification

Trainers and Learners’ discourse analysis allowed the metaphors used to be classified according to the role they play in the discourse. Three roles were identified.

- The metaphor that helps to understand. This first role is to popularize some computer science or electronic concepts and to understand the functioning of the computer, the robot or its components.
- The metaphor that makes tangible. This second role is to make some abstract concepts concrete and to relate some functions of the machine or interactions with the machine to the experience we have of our physical or social environment.
- The metaphor that serves as a catchphrase. This third role participates in the construction of a playful, affective and imaginary atmosphere, and intervenes at the level of “social” relations between the learners, the trainers, and the robot.

Note that these roles are not exclusive of each other: the same metaphor can take on several roles at once. However, for the sake of clarity and readability of the results, the metaphors used in the language of the trainers and the learners are classified according to the three roles identified.

Extracts from the discourses have been translated from French. The translations respect the pronouns used by the trainers, the children and teenagers when referring to people (female or male). The italic style emphasizes the keywords of the metaphor, the ones that justify its categorization into a role.

The Metaphor that Helps to Understand

In the Trainers’ Discourse

In case study 1, the trainers used the metaphor to help children understand the components of a computer. For example, to explain what random access memory is, they use the metaphor of the “deliverer who fetches information from the hard drive and brings it to the processor.” The cabinet

\(^7\)https://www.tinkercad.com/
\(^8\)http://www.techmania.fr/BlocklyDuino/
In the Trainers’ Discourse

The results show that trainers use metaphors in their discourse to support their understanding. In case study 1, the children questioned the components, sometimes using metaphors other than those used by the trainers. For example, they ask themselves about RAM using the metaphor of the “bus, but if she doesn’t have a wheel, how will she move?” Learners also use metaphors related to known behaviors and actions:

“Does she runs like us? At the same speed?”, “He doesn’t understand that, he just understands one square step ahead.”

In case study 2, the results are similar. On the one hand, learners use other metaphors than those of the instructors: “It’s like a jigsaw puzzle.” On the other hand, they also use verbs to express actions and behaviors that are specific to them:

“My robot, when I ask him to move, he doesn’t move”, “you have to tell him what to do when he meets obstacles”, “Turn, turn!” (and, because the robot doesn’t turn, the children says) “I have to program him to listen.”

The Metaphor that Serves as a Catchphrase

In the Trainers’ Discourse

The results show the construction of a playful, affective and imaginary framework through the use of metaphors in the trainers’ discourses in the two case studies. In case study 1, the trainers explain the labyrinth-solving activity to the children by engaging them in stories. For example, for a maze, the trainers explain:

“The little bee has to go on a colour hunt in the maze, looking for the colour green, then blue (...) and finish with the colour purple to get out.” “It’s a maze with a forest, a wolf and Little Red Riding Hood (...) you have to help the wolf run to Little Red Riding Hood get to her grandmother’s house faster than the wolf.”

In case study 2, the trainer also uses metaphors in their catchphrase role when guiding the children and teenagers in relation to their robot in kit.

“When you finish lining up, that’s when it’s magical...” “He’s doing what he has to do. We’ve programmed him to stop at the obstacle. He’d like to keep going, but he’s stopping. If you don’t want him to do that, you have to program him. You can tell him to “turn around”.”

In the Learners’ Discourse

The results show that learners use metaphors that refer to words and objects they know and encounter in their daily lives. For example, in case study 1, if the trainers used the deliveryman metaphor, the children said that the RAM “looks more like a postman”, “it’s as if he had little legs, how fast it goes.” “he carries cards, envelopes.”

In case study 2, the results point in the same direction. The children and teenagers talk about a jigsaw puzzle when they assemble their robot.

In case study 2, during the robotics course, the trainer uses metaphors to guide the children and teenagers in their assembly and discovery of the robot by allowing them to have a concrete image of the functioning or the material. For example, the trainer explains:

“There is one of the two eyes that sends vibration.” “This is the drawing table, the table where you come to deposit all your objects.” “Here you have several families of blocks, several libraries of blocks.”

The trainer even mimics with his body the way the robot acts to show the children and teenagers how the robot will turn and says to them “you’ll see, these are behaviors.”
This type of metaphor is also found in the trainer’s discourse when he refers to the functioning of his learners’ robots. For example, he says “I’m being attacked here!” referring to a robot circling around him, or “he’s nervous” about a robot that goes fast and spins around, or “we’re going to make a choir of robots” if all the robots sing at the same time.

In the Learners’ Discourse

In the discourse of the learners in case study 1, the results show that metaphors that elicit a relational framework and emotion are strongly present. The children cling to the family surrounding the “Little Red Riding Hood robot” by explaining, for example: “she’s at her mom’s and she’s walking in the forest to her grandmother’s.” They also use feelings to express the actions of the robots: “he’s crazy!”, ‘he’s a little rascal’ talking about the “wolf robot” running into the wall.

In the older children and adolescents in Case Study 2, many metaphors referring to emotions and feelings are found in discourses.

“The actions of the robots: “he’s happy.” “He’s not wise... Why does he stop?” “He’s learning fast.” “He doesn’t stop moving forward, that’s great. He’ll go around the world. (...) I swear he goes vroom vroom vroom vroom.”

We also see the creation of an emotional relationship, especially when learners talk to their robot or about their robot: “Mine likes to dance.” “Careful, you’re stepping on my robot, poor guy.” “I’m not happy (talking to the robot) You have to listen to me, I’m your daddy. And your mommy doesn’t exist.” “I’m happy with you little robot, you’ve done enough work for today.” “Look at my beautiful little robot. He’s spinning by himself in his little cage.” “Ha, he’s drawing now... That’s my little one.”

B. Type Classification

In addition to role classification in discourse, metaphorical concepts can be categorized according to their type. Three types of metaphorical concepts mobilized through the different roles were identified.

First, we identify the spatial metaphors that are commonly used to represent digital environments and that reveal the particular place of spatial concepts in our fundamental cognitive functioning, as shown by Lakoff and Johnson [23]. They make digital technology concrete and comprehensible, as talking about places, holes or boxes in applications.

Second, “non-living” metaphors, or comparisons with similar objects, are identified. For example, the assembly is “like a jigsaw puzzle”, the elements are “stored in a library”, a component is “a bus”, etc. These metaphors or comparisons often make it possible to understand a functioning, an environment or an element. They are not global, but rather focused on specific elements.

Thirdly, there are living metaphors both to make them understandable, tangible and catchphrases. They can be limited to some aspects of the robot (e.g., sonar works like a bat, the motherboard is a brain) or global (e.g., the robot is perceived as a small companion/pet, or as a bee).

VII. DISCUSSION

Unsurprisingly, the results are consistent with the theory of conceptual metaphor [23] regarding the roles of metaphors in discourse. Trainers help learners to understand the components of a computer or a robot, for example, use metaphorical projections. This understanding is measurable through the metaphors used by the learners. The abstract aspect of many computer science concepts leads trainers to use metaphors to tangibilize them.

The most interesting results come from this “catchphrase” role and from the types of metaphors. The results show that the machine is perceived as alive a priori, whether it is the computer or the different components of the robot. They have attributed an autonomous functioning (ex.: it can do something by itself) or certain feelings (ex.: it is happy). The moment the robot starts to move exacerbates the living metaphors, it really “comes to life” (ex.: it runs, dances, answers, refuses to do something, acts naughty, etc.). It becomes a character that people interact with. An empathy is developed towards the moving machine. We can observe the role that storytelling (metaphors used as a catchphrase) plays in reinforcing the perception of the robot as a character who “lives” a story. This phenomenon can be observed as much for “black box”/humanoid robots as for robots in kit. It is therefore more the movement than the appearance of the robot that seems to favour the “living” representation of the machine.

The risk of living metaphors is a misunderstanding of the nature of the interactions with the robot and the stakes involved. As Tisseron [29] points out, beyond a naturally developing attachment to objects, moving objects such as robots generate emotional and cognitive empathy. It leads to a transfer between man and machine: “the robot is like me and I am like the robot”. This “living” representation of the robot masks the fact that the machine has no intention of its own. A double shift in the location of intention takes place. The first shift makes us forget that the robot and the framework of the activity have been designed and set up by the trainers. The learners are in a creative process and appear as initiators (e.g. “you are going to create a robot yourself”, “you are going to help the bee”). The second shift moves the learners’ intention towards the machine. The robot acquires autonomy and goes from the status of an executor to that of an agent who performs a task according to its own will.

VIII. CONCLUSION AND FUTURE WORK

This paper presents a thoughtful analysis of robotic literacy activities for children and adolescents. It aims to observe young people’s representations of and interactions with robots involved in educational activities to contribute to the development of questions for critical technology education. Analyses are carried out using the conceptual metaphor theory [23]. While metaphors reflect the users’ understanding of how the
machine works, they may hide aspects of the machine [29]. They then create expectations, frustrations, and risks. This is what this study pays particular attention to.

It takes shape through two robotic literacy activities. The first activity involved the robots BeeBot, BlueBot and Ozobot in seven classes of children from 3 to 10 years old. The second activity consisted of a five half-days training for 13 participants from 8 to 15 years old. They designed, built and programmed a robot.

Three highlights are more memorable than others from this study. The first concerns the importance of “autonomous” movement and displacement, supported by the narrative that places the robot in the role of a character (metaphors used as a catchphrase). The movement reinforces an empathic relationship with the robot. Secondly, the living metaphor masks the specific aspects of the machine. It leads to erroneous representations of its functioning and to expectations of the “living” that are not realized. Thirdly, the living metaphor changes the location of intention from the learner where the robot is executing to the machine where the robot is an agent, by obscuring the intention of the robot trainer/producer as the designer of the activity or robot model.

Because of these results, there is a need to become aware of the living metaphor in robotic literacy activities. For this purpose, it is important to integrate robotics in education and critical education that would allow understanding the functioning of the robot while deconstructing the representations of the machine. The idea is not to eliminate the use of metaphors, which have their roles in education and cognitive processes but to be precise about the location of the intention and the nature of the machine’s autonomy. Recommendations could then be made for trainers to help them to speak about computer science and robot concepts with children. Moreover, it would be interesting to cross-reference this data with the roles and types of metaphors used. Recommendations could then be made as to what metaphors to be used at different ages.

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