Designing for Children
- With a focus on 'Play + Learn'

Evaluating the effectiveness of using programmable toys to develop CT skills
An industry perspective

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Abstract: The purpose of this study is to measure the effectiveness of teaching children using MEER a programmable toy robot, with a micro-bit processor that runs on a code written using a visual programming language. The study is designed to examine MEER's potential to promote the development of CT in middle school children.

Keywords- Computational Thinking; robotics; effectiveness; problem solving; creative thinking

1. Introduction

Founded in 2007, XYZ Pvt. Limited is a fast-growing, technology-driven company revolutionizing the education system in India. Every day, our innovative products and solutions transform the lives of 10% of India's private-school-going children. More than 12,000,000 children from various socio-cultural backgrounds study in 12,000 partner schools across the country. Our vision is to provide optimal solutions for all K-12 stakeholders. As part of our curriculum offering, we have launched a new series on robotics for middle school and high school children. This study report findings from a pilot study conducted to gauge the effectiveness of robotic activities to develop Computational Thinking (CT) in children. We first conducted a survey to understand the children's existing knowledge and skills. Our assessment of the target population's familiarity revealed certain shocking facts. Although robotics education and coding have seeped into today's educational scene and most schools are adopting it, it's still not a level playing field. The participants in our pilot were children from CBSE schools, grades 5-7. All of them come from backgrounds with educated and employed parents who do not own a computer at home. None of the children have heard about robotics or attended any robotics/coding workshops or activities in school or outside. However they had computer labs in their schools and had regular sessions where they learnt basics of using a computer and its features and utilities. However, robotics wasn't part of their curriculum at school. Our survey also revealed that schools are reluctant in implementing a full-fledged curriculum for the want of qualified and trained teachers and time commitment challenges.

In this context, we conducted a pilot with our programmable toy robot to understand its effectiveness in developing CT and an interest in learning more about robotics.

2. Related Work

Computational Thinking (CT) has been an increasingly popular topic for computer science educators. However, CT has also gained traction amongst other experts and the need to include CT across subject areas in the K-12 domain has been part of curricular reforms ((Barr, D., Harrison, J., & Conery, L., 2011), (Barr, V., & Stephenson, C. (2011), (Lu, J. J., & Fletcher, G. H. (2009), (Maeda, J., 2013)). Research has focused on what constitutes CT, making these concepts accessible to educators, assessment of CT as well as tools that can be used to teach CT. These proponents cite work with educational robots as a means of engaging students in CT (Bers, M. U.,2008). This trend is examined from the robotic educator's perspective in this study. Research using educational robots reports that robots promote creativity, problem-solving abilities, a sense of inquiry and collaboration ((Bers, M. U., 2008), (Bers, M. U., 2010), (Resnick, M., 2003), (Wang, X. C., & Carter Ching, C., 2003)). Since the robots are programmable toys, children learn to create computer programs that allow robots to move, to sense, and respond to their environment. Such training in programming is shown to have developed visual memory ability, logical skills, problem-solving skills and even the way children think ((Bers, M. U., 2008), (Bers, M. U., 2010), (Clements, D. H., 1999), (Resnick, M.,et.al, 2009)). These are all components of CT.

Now, the coding of a robot itself is an exercise in problem-solving. To make a robot do a particular task, coders will go through a process of trial and error until the correct code is written. This process inculcates perseverance and critical thinking. Besides this, by working together to make the robot perform children also develop collaborative skills.

This study adopted the Computational Thinking Language (CTL) framework from (Grover, 2011) and focuses on the spoken words of children in response to questions posed to them and examines the development of CT and CTL through verbal descriptions provided by the children.

3. Methodology

The research question this study aims to look at is children's knowledge, use, development and expression of ideas of computational thinking while and after working with a programmable toy robot. Hence, structured interviews conducted before and after the workshop were the main measures collected and report as data.

The workshop was designed for middle school children of classes 5-7. The workshop was for a total duration of 10 hours. 8 children (avg age: 11 years) who were enrolled in CBSE schools participated in the workshop.

The workshop introduced the coding interface, the robot toy and its components to make the children familiar with it. The robot consists of a chip inserted inside a car shaped toy which can move in all directions and has sound and light sensors. The program is to be written on a computer and copied to the robot using a USB cord. After familiarizing children with the interface and components they would be engaging with during the workshop, the children were shown how to write a code to draw a basic shape, transfer it to the toy and make it draw the shape. This was followed by more complex tasks such as achieving right-angle turns to drawing a path with repeated turns as well as conditional acts involving obstacles as well as sound and light sensors.

At the end of the workshop the objective was to develop an interest in children on the process of coding and its possibilities; to be able to write effective codes given certain conditions and to be able to think stepwise manner to arrive at code or a solution.

Data reported in this paper was collected through pre and post-workshop interviews and a simple written task to demonstrate CT skills. Children's perception and about robotics and coding were assessed in the pre-workshop survey. In the post-workshop survey, they were asked questions to gauge the change in perception as revealed through the pre-workshop survey. In the written task children had to describe a simple everyday task as a sequence of steps and another task that included a certain if-else condition. The same task was asked to be rewritten after the workshop to measure any observable difference in their approach.

4. Results

In this section, we present the results of the effectiveness of our workshop in terms of the development of CTL and engagement measured through interview responses and the writing task

4.1 Pre/Post interview

Prior to the beginning of the workshop, and at the end of it, each participant was a set of questions as in Appendix B. Children's verbal responses in these interviews were recorded and form the data that has been analyzed for this paper. After transcribing the pre and post interviews, coding and analysis were based on a coding scheme in (Grover, 2011). Table 1 describes these categories of Computational Thinking with example snippets from children's responses from this study.

Categories	Description	Examples
CT Concepts	Programming/Automation/Storage	Using our program we make our Robot think like us do things automatically…because our program is stored in MEER.
CT Procedural	Turn the power switch on/off; download a program from the computer to the robotic controller via a USB cable	Then we use those blocks to write the program. Then this program we burn into MEER brain using the USB cord. After that MEER does the action according to our program ;
CT Technical Terms	the processor chip is the "brain" of the robot	It has a brain as a chip but only our program can make it work; We used the blocks in the computer to write our program. Then we burned that into the brain of our robot.
CT Principles	If-then conditional; stepwise thinking; error checking;	When you enter a command into the brain of the robot-like if you say if you use the blocks move forward and turn right if you see an obstacle else turn left it will do exactly the same. Like this many ways, we can control the robot using our program.

Table 1. CT components adapted from Grover

Findings indicate a substantial qualitative increase in Computational Thinking Language (CTL) as communicated by children in response to the same question before and after the robotics workshop. Pre-workshop has zero to few instances of CTL. Post-workshop responses, by contrast, made a large number of mentions of CTL See Table 2 for a few examples. These responses were richer not only in more specific notions and principles of computing but vocabulary as well (*burn, test, commands, program* etc.) thus signifying development of CTL along various dimensions.

Participant	Pre Workshop	Post Workshop
Child 1	It is about robots	We can use blocks as commands to write step by step what we want MEER my robot to do. (…) if it senses an

		obstacle then it will make a noise or it can blink lights. We can choose any sensor.
Child 2	using computers we can make things	we can write programs in computer and burn it in MEER's brain to make it perform. In the program, we must write perfect instructions in a step by step manner so that MEER understands easily.
Child 3	like code language something we tell in computers	First, we think and write what we want MEER to do. Then In the computer, we select the blocks (…) use those blocks to write the program. Then this program we burn into MEER's brain (…). If anything goes wrong we change (…)and copy the program again and test again (…) many times till MEER does what we want exactly without errors.

Table 2. Examples of responses to a question about what robotics and writing a program means before and after the workshop

As the analysis and results show from Fig 2, with the robotics workshop, children's computational thinking as expressed in response to the same question not only increased but also had various categories of ideas in the domain of computer science.

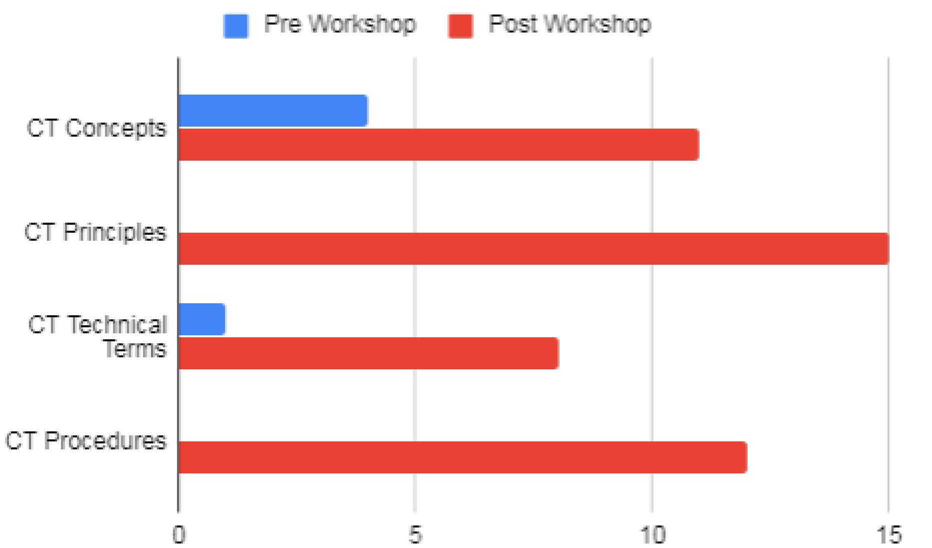

Figure 1. Total occurrences of CTL for all subjects and CT categories in pre-post responses

4.1 Written Task

In the written task, children were first asked to describe a simple everyday process in English (pseudocode). The children wrote about how to make a simple sandwich with toasted bread, jam and butter. The objective of this test was in line with the belief that CT is not only about computers and an important objective of building CT skills is facilitating transferable skills that find application in other domains and everyday life also (Fletcher, G.H. and Lu, J.J., 2009). Discourse analysis of written responses was done to analyse the use of transition words and phrases that signal step by step thinking as well as phrases that reveal conditional logic that links action and consequence. Findings in Fig 2 reveal that there was a significant increase in the discourse post-workshop than the pre-workshop responses.

Figure 2. Total occurrences of CT categories in pre-post responses

4.3 Other observations

The workshop was also observed using a non standardised observation protocol to gauge instances of collaborative learning. Three silent researchers monitored and counted instances according to the following categories to measure collaborative practices.

Categories	Description
Peer Assistance	Participants offering proactively to help a struggling peer and working together
Peer Interaction	Asking each other queries and questions
Peer discussion	Participants discussing each others outputs and sharing experiences
CT Principles	If-then conditional; stepwise

	thinking; error checking;

Table 3. Categories used for observing collaborative practices

Findings indicate that over 67 instances of collaborative interactions were observed between the participants over the 10 hour period. This corroborates the findings in existing research ((Bers, M. U., 2008), (Wang, X. C., & Carter Ching, C., 2003)).

5. Conclusions

In spite of Computational Thinking having achieved a status as a welcome domain in most parts of the world, it is yet to been seen effectively integrated into the mainstream curriculum. As (Grover, 2011) points out there is a consensus on how CT can be taught or assessed in practice. This pilot was to gauge children's attitude towards robotics lessons and its effectiveness in imparting CT skills to them via the workshop.

The results have been satisfying and we plan to build a full-fledged curriculum with activities that can be integrated with other subjects. We envision a product that is cost-effective and academically sound.

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