An Experience Report on Teaching Programming and Computational Thinking to Elementary Level Children using Lego Robotics Education Kit

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Abstract—We present our approach and experiences in teaching computational thinking, problem solving, team-work and project management skills to several elementary level children using Lego Mindstorms EV3 robotics education kit. We taught students how to design, construct and program robots using components such as motors, sensors, wheels, axles, beams, connectors and gears. Students also gained knowledge on basic programming constructs such as control flow, loops, branches and conditions using a visual programming environment. We carefully observed how students performed various tasks and solved problems. We present experimental results which demonstrates that our teaching methodology consisting of both the course content and pedagogy was useful in imparting the desired skills and knowledge to elementary level children.

Index Terms—Computational Thinking and Programming, Elementary Level Children, Lego Mindstorms EV3, Robotics Education Kit, Technology for Education

I. RESEARCH MOTIVATION AND AIM

Robotics construction and programming using robotics education kit for teaching computational thinking, problem solving, programming and engineering skills to elementary school level kids (who fall in the broad range of 4th to 7th grade and about 8 to 13 years old) is a teaching methodology which is gaining popularity in several school curriculum all over the world [1][2][3][4][5][6]. Lego Mindstorms EV3 is one of the most popular and widely used robotics education kit in the world. Lego Mindstorms EV3 Education Kit provides several types of parts like the controller (called as brick), motors and sensors (like color, ultrasonic and touch sensors) as well as a visual programming system required for building and programming a variety of robots. Our research motivation is to investigate the application and effectiveness of Lego Mindstorms EV3 for teaching computational thinking, problem solving, programming, team-work and project management to elementary level kids.

II. RELATED WORK AND RESEARCH CONTRIBUTIONS

Karp et al. present their experiences on the implementation and development of a LEGO robotics engineering outreach program for elementary school students in West Texas [1]. Kim et al. present their approach on educating C language to students using Robotic Invention System 2.0, a system that helps students to understand the technology of both robot and programming language [2]. Garcia-Cerezo et al. report on their experience of the 2008 international summer school on mechatronics based on the LEGO Mindstorms NXT Set [3]. Karp et al. describe the evaluation results from an annual LEGO robotics competition for students in elementary and middle schools held at Lubbock, Texas, that aims at increasing interest in science, technology, engineering, and math [5]. Varney et al. describe a program implemented in diverse schools which has been developed for in-school sessions focused around LEGO robotics to foster interest in STEM topics at a young age [6].

Research Contributions To the best of our knowledge, the study presented in this paper is the first experience report and case-study from India on using the robot as a metaphor and using Lego Mindstorms EV3 education kit to teach various skills to elementary school students such as computational thinking, team-work, problem solving and programming. We believe that case studies and experience reports from diverse and heterogeneous countries are important and our work is a contribution to the body of knowledge in application of technology for primary education in developing countries like India.

While there has been several experience reports on the impact of implementing robotics curriculum as a course in schools, there is a lack of experience reports on summer camps. Summer camps provide a different learning environment and platform than standard courses in schools. Summer camps are of 7 to 14 days intense training on a specific topic consisting of students of varying ages but similar interest. Our experimental study is specifically intended to examine the value of robotics summer camp for elementary level children and examine the effectiveness of a short-term course (7 to 14 days) in comparison to a longer duration course.

III. RESEARCH FRAMEWORK AND METHODOLOGY

Figure [1] shows our research framework and methodology consisting of several steps from curriculum design, surveying students about their expectations, understanding their demographics and prior experience, monitoring their learning, behavior and reactions and finally evaluating the results of the learning process. Each of the steps in Figure [1] are covered
in detail in the following sections. We create an alignment between the learning environments and the desired skills and knowledge which we want to impart to the students. We create educational indicators and evaluation systems to understand and get feedback about learning outcomes of students and refine the content accordingly as the course progresses. Finally, we acquire data on the overall effectiveness of the summer camp across various parameters.

IV. EXPERIMENTAL DESIGN AND SETUP

A. Student Demographics and Robotics Background

We organized a summer camp on teaching robotics using Lego Mindstorms EV3 for elementary level children from 8 May 2016 to 17 May 2016 in Bangalore (India). We created a small batch of 9 students only so that the instructor can give individual and personalized attention to every student. Diversity in terms of age, gender and school was one of our goals as we wanted students from diverse backgrounds, cultures and experiences to work together. We first (Step 1 in Figure 1) collected information about student demographics and robotics background. The youngest student in the batch was 7 years old and eldest was 13 years old. There was one 7 year old student, two students of age 10, two of age 11, one of age 12 and three of age 13. The average age of the students was 11.12. The number of male students were twice the number of female students, varying from 2nd grade to 8th grade in their respective schools.

Fig. 1: Research Framework and Methodology

Fig. 2: Bar Chart showing the Assessment Results of Students in-terms of Level Achieved and Number of Hints Provided

B. Competency and Skill Assessment before Camp

Step 2 (refer to Figure 1) of our research study was to conduct an assessment of the computational and logical thinking skills of the students before the summer camp. We asked students to play an online game which is based on the application of computational thinking. The game comprises of 14 levels in the increasing level of difficulty. We asked the students to progress one level at a time and qualify as much level as possible. The game is based on the Scratch visual programming language. In the game, there is a zombie, zero

https://scratch.mit.edu
or more chompers and a sunflower. The objective of the game is that the zombie should eat all the sunflowers in order to cross the level without coming on the way of chompers. The game has 3 blocks: move forward, turn left and turn right. In addition to these 3 basic blocks, there is a block of repeat statement. The difficulty level of the game increases with the level number, with more chompers being introduced after a level is crossed. The game requires students to think logically and create a control flow which requires a set of instructions (such as move, turn and repeat) to be executed. The game used a visual programming language which has similarity to the Lego Mindstorms EV3 programming language. While playing the game, some students were facing difficulties on how to enter instructions. In particular, we observed that some students had difficulty in understanding the concept of direction and the number of steps required to move to get to the sunflower. We notice that many of them were unable to give 5 instructions simultaneously or make use of repeat statements. To encourage students to help them qualify the different levels, we provided hints as well. At the end of each student’s game, we collected their assessment data. Out of the 9 students who played the game, 3 students could not exceed Level 4, 2 students crossed all the levels without any hints and the rest landed up some-where in the range of 5 – 8. The bar graph in Figure 2 displays the summary of the assessment results. Our observation and assessment result shows that the computational thinking and programming skills of students required training and improvement which was one the major objectives of the summer camp.

C. Course Curriculum, Objectives and Structure

We conducted a total of 9 classes in our summer camp. Our objective was to teach 6 skills to students: CPT- Computational Thinking, PRG - Programming, HCD - Handling Complexity & Divide Task into Sub-tasks, PRM - Project Management, TMW - Team Work, RBT - Robotics.

In the first class, we introduced students to basics of LEGO Mindstorms EV3 kit, motors, sensors and bricks. The 2nd class introduced students to programming using the LEGO EV3 Mindstorms software. The next class was on robot construction. Students did hands-on on programming and constructed basic models of EV3 robots and also wrote simple programs on how to move a robot. After practicing the basic programming, the objective of the next lesson was to train students on how to command the robot and provide instructions to move in forward and backward direction using tank steering. After completing several robotics programming exercises, the next 5 classes were dedicated to advanced programming. In 6th class, our aim was to teach students how to turn robot using tank steering and different types of curve movements. In 7th class, we taught students the construction of the rotor arm to grab and move objects. 8th class was to explain them about light sensors and write programs to stop the robot at a line of a given color. In next class, we explained about gyro sensors and using this, we asked students to write a program to stop robot at a certain angle. The last class was on ultrasonic sensors using which students wrote a program to make a robot stop at a certain distance from an object. Worksheets were given to students to examine their understanding of concepts taught in each class.

V. Educational Program Learning Outcome

We evaluate the 6 competencies of all the 9 students using a 5 point or letter grade system: A (Excellent), B (Good), C (Average or Acceptable), D (Below Average or Poor) and E (Unacceptable or Fail). The A grade is the highest grade and E grade is the lowest grade. The 9 students and 6 competencies constitutes a 9X6 data or grade matrix. Figure 3 shows the Bertin plot representing the grades of 9 students across 6 competencies. Figure 4 reveals the grades based on a grey level palette corresponding to the 5 grades. Figure 5 reveals that only two students had a B grade on computational thinking and rest everybody had a D grade. The programming skills and knowledge of the students were also below average as they did not have any prior exposure to computer programming. The ability to work effectively in team of 3 – 4 members and solving a complex task requiring engagement of more than 30 – 45 minutes consisting of designing, constructing and programming robots clearly needed improvement based on our assessment of the students. Issues like difficulty in coming to a consensus or decision, unequal contribution from members, dominance by one member, aggression and negation was visible and the group dynamics certainly needed improvement. Figure 4 displays evaluation of the 9 students across 6 competencies after the completion of the program. Figure 5 reveals a substantial improvement in the knowledge and skills of the students. One of the major aims of our educational program was to impart team skills and improve the ability of students to get along with their coworkers while working towards a goal. Figure 6 reveals substantial improvement in collaboration skills of 7 out of 9 students. However, we observe that 2 out of 9 students were not effective group members and were facing challenges in working in groups. We gauge the team skills of students by observing their interaction with each-other and engagement level towards solving the given task. Figure 5 reveals that the computational thinking and programming skills of 6 out of 9 students showed substantial improvements. Our assessment shows that 6 out of 9 students scored an A or B grade in programming after the completion of the program. We notice that few students learnt how to examine and test if the program is able to perform the given task. They were able to identify and fix errors and were able to write correct programs. Our assessment and experience shows that the experience and exposure received by students through the program improved their computational thinking and programming skills. Our assessment shows that 3 out of 9 students scored an A grade on the competency of project and time management. We could clearly notice that some of the students were better in time management and were able to organize themselves better in comparison to other students. Ability to remain focused and not getting distracted and interrupted from the main goal is a skill that required...
training and we taught students how to stay attentive to their given task.

VI. STUDENT’S COURSE FEEDBACK AND INPUTS

Table I shows student’s course feedback. Table II reveals that 78% of students said working in team is actually helpful to solve the problem effectively while 22% students said it is better to work individually. 100% students said they found the instructor extremely helpful and they learnt a lot during the camp. While asking about key challenges faced during the summer camp, 89% of students mentioned that they found computer programming quite challenging as it was their first hands-on experience. 11% students felt robot construction was more challenging in comparison to programming. When we asked them about their takeaways from the camp, 56% students said they learnt and experienced computer programming which was new to them, 33% students said they learnt robotics concept very nicely and it was a nice exposure on robotics kit, and 11% students mentioned that they learnt and enjoyed robot construction a lot (assembly and joining of parts). Finally, 89% students said they would like to participate in a follow-up advanced robotics summer camp while 11% students mentioned that they would not like to participate in the advanced robotics camp.

VII. CONCLUSION

We observe that designing, constructing and programming robots is exciting for students and increases their engagement level. Hands-on assignment and tasks makes the learning both fun and challenging. We conclude that teaching system integration, creative and innovative design from components, parts and connectors is easier and more effective for instructors with a robotics education kit than lecture based approach.

REFERENCES