Benefits and Introduction to Python Programming for Freshmore Students Using Inexpensive Robots

Yoong Cheah Huei

Information System and Technology Design
Singapore University Technology and Design, Singapore
andrew_yoong@sutd.edu.sg

Abstract—**Robots were used for teaching at various levels of education. Many research papers reported positive results of using robots to aid students in understanding of programming concepts and writing programs. In this paper, the investigation results had shown that mini-projects using the Finch robot not only enhanced creativity, problem solving skills, and research capability of students but also had helped understood Python programming concepts and writing programs in a collaborative teaching environment at Singapore University of Technology and Design (SUTD). The pedagogical activities of this research were described. Then the experiences and results of findings were shared. The shared knowledge will be beneficial to academics or educators who wish to integrate robots into their programming course, especially in a course of more than 250 students, students with numerous interests, and students with different learning abilities.**

Keywords—*robot, creativity, problem solving, research, Python programming*

I. INTRODUCTION

Many researchers had reported the using of robots to teach computer programming at different levels of education. The use of LEGO NXT robots to teach K-12 teachers in computer programming and then from the teachers to their students were documented in [1]. The LEGO NXT robot was used to help senior high students understand programming concepts in Taiwan [2]. Research was carried out to introduce programming for 9th and 10th grades Greek secondary school students using LEGO Mindstorms [3]. LEGO RCX robots were used to teach programming basics at West Point [4]. The LEGO Mindstorms was also used to help students understand programming concepts and learn programming in university [5-9]. The use of CSbots program on iRobot Create platform to teach computer programming was reported in [10]. Another robot, Scribbler 2, was used to introduce programming to first year engineering majors [11-13].

Robots were not only used to introduce computer programming to students but also employed to assist in English lesson [14], fuzzy logic class [15], artificial intelligence [6,16,17], distance learning environment [18], embedded systems class [19] and advanced software engineering class [20].

In this paper, the exploration of mini-projects using a very low cost robot had exhibited that students not only understood Python programming concepts and writing programs but enhanced their creativity, research skill, and problem solving ability in a collaborative teaching environment at SUTD as well.

Section two describes the background of the research. Section three explains the implementation and discusses the findings. Section four tabulates survey results and summarizes student comments. Section five concludes this paper.

II. BACKGROUND

A. Finch robot

The Finch robot [21] was the result of four year study at CREATE lab, Carnegie Mellon university. The robot could run on many programming languages like Python, Java, C, Visual Basic, and C++ and different platforms. Each Finch had the following features: Light sensor, temperature sensor, obstacle sensors, three-axis accelerometer, speaker, full-colour beak Light Emitting Diode (LED), and pen mount for the purpose of drawing. The Finch required no batteries and could be connected directly to a computer using a USB. The Finch was purchased at USD$79 each including an extended warranty.

The Finch robot was chosen for mini-projects because it was inexpensive. For this reason, one robot was shared by two students instead of four or five students to share one robot. Hence, better chances for students to get hands on experience. Moreover, the Finch had features that promote creativity and problem solving. Consequently, students could do research of what problems they wished to solve in mini-project four. After that, they could write programs for the problem and create a setting to demonstrate their solution.

B. Student profile and cohort class

Most students had no computer programming experience. There were more than 250 students who took the Digital World (DW) module. The student interests were information system technology design, architecture, engineering product design, and engineering system design majors. Students came from many different countries like China, Malaysia, Thailand, Korea, Myanmar, Vietnam, and Singapore.

There were six cohorts and each cohort had more than 40 students. Each team consisted of two students. If there was odd number of students in a cohort, one team was made of three students. Each team was allocated one Finch robot from week one to week seven. In week seven, the robots were returned to the technician.

C. Pedagogical and research methods

Students were engaged in activities through active learning method. Problem-based learning and team-based learning were used to promote active learning. In collaboration teaching of DW module, there were three instructors including the lead instructor for each cohort. Students may ask questions to clarify their doubts with any of the instructors during class. Qualitative research methods such as demonstration of projects in cohort classrooms and observations of students working with the robot were used. A quantitative research method called student survey was carried out.

III. IMPLEMENTATION AND FINDINGS

Generally, students in SUTD learnt the first computer programming language in DW course. The DW course was taught in term three for Freshmore (Freshman plus sophomore first half) students. In DW, the first five weeks (Table I) was used to impart the Python programming language concepts to students. Python was chosen because it was one of the easiest programming languages to learn, in particular for students who have no prior knowledge of computer programs. In addition to main collaborating teaching lessons and solving problem sets, the Finch mini-projects were used to reinforce the Python concepts, solve given problems, exhibit creativity and research ability of students. Students could download the mini-projects handouts from Moodle (an open-source course management software). All teams had demonstrated the four mini-projects. Thus, 100% participation rate was achieved in mini-projects.

TABLE I. Topics

Week	Content
1	Using Idle, operator types, complex numbers, type conversion, variables, operators precedence, formatting, input, output, mathematical functions, comments
2	Functions definitions and arguments, boolean expression, if-else branching, while and for loops, list and basic operations, debugging
3	Nested list, traversing sublists, Monte Carlo simulation, matrix as a list, matrix operations
4	String, dictionaries, file input/output, numerical integration, differentiation
5	Objects, classes, inheritance, examples in numerical integration and differentiation

A. First mini-project

The first mini-project objectives were to get students familiarized with the Finch function calls, buzzer, sensors on the Finch like temperature sensor, obstacle sensors, and light sensors, and apply basic Python commands (week 1) to control the robot movements such as forward, clockwise and backward in a timely manner, create sound and activate some sensors.

Since there were six cohorts and the class schedules for five cohorts varied, the mini-project deliverables for cohorts of different schedules was not the same. In this way, code duplication was discouraged. The identical strategy was applied for mini-project one to three.

As collaboration teaching was practised in DW module, each team was to demonstrate the required robots movements and sensors activation to one of the three instructors during class in week 2.

One important observation was the actual use of robot which constituted motivation for students. At the cognitive level, students were able to understand the functions of each component of the robot and the components application. The initial time spent, including reading about the robot from the Internet to familiarize with the robot and its system was short. Some students were excited to see the movement and noise made by the robot during demonstration and testing.

B. Second and third mini-projects

The second mini-project objectives were mainly to use if-else branching (week 2), loops (week 2) and other Python commands to control the movements of the robot in a timely fashion. Similar to mini-project one, a different problem was given to cohort of dissimilar schedule. Each team had shown the solution using the robot to any of the three instructors during class in week 3.

The third mini-project covered two-dimensional lists (week 3), extracting data from sublists (week 3) and other Python commands from weeks 1 and 2. There were five problem sets for six cohorts depending on the cohort schedule. Analogous to week 1, each team was supposed to display the solution during class in week 4.

Both mini-projects were problem based and required students to work together in a team. A crucial observation was that most students were able to complete the mini-projects in a short time. Students were able to comprehend the given tasks and had minimum difficulty in writing and testing the programs. A variety of solutions was seen. One solution used for loop instead of the while loop in mini-project two. In mini-project two, some codes were more complex than others to achieve the same results. In mini-project three, the number and size of lists may not be the same. This caused the use of different repetitive construct and if-branching.

During this time, an interesting view was noticed. Some students took time to decorate the robots. Fig. 1 and Fig. 2 displayed two samples. They took Finch as a personal toy and were emotional attached to it. Some creative work was seen in the decoration. Furthermore, students had committed to spend time in the robot and wanted to play with the robot as a personal toy where they could touch, see, and hear.
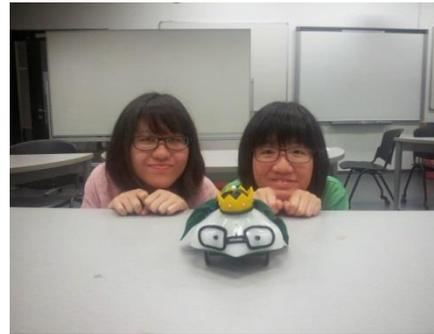

Fig. 1. Tree Finch

Fig. 2. King Finch

C. Final mini-project

The final mini-project had two parts. Part one was an open problem. Students were to display useful tasks using at least the accelerometer, light sensors and light emitting diodes of the robot. As for part two, a restricted problem was given. Students were to navigate the robot to each side of the rectangle box. Each team was to create their own box and bring the box during demonstration in week 6.

As for part one, each team needed to do research of what problems that could use the Finch to solve by using at least two required built-in functions. The next step was to write Python programs and provide a creative setting to solve the chosen problem. For part two, creative thinking was displayed during the demonstration, for example robot movement in a virtual rectangle box.

During the demonstration of part one, many solutions were presented by students. Many students told short stories about their solutions of the given problem before demonstration. Very active student participation at this session was noticed. Below were two examples (Fig. 3 and Fig 4.). Two of the many interesting stories done by SUTD students for part one were described in the next few paragraphs.

The first very short story was the simulation of earthquake environment. In the picture shown in Fig. 5, the team depicted falling rubbles from the nearby buildings, similar to what could happen in an earthquake scenario. The Finch accelerometer was used to control the robot movement because of the board movement. The robot beak changes colour if large movement was detected. After going through the tough terrains due to the disaster, the Finch decided to detect and head back to its own house for safety! (Fig. 6). In order to do this, the light sensor had to be activated for the robot to halt in the house.

The team commented "The Finch project was an interactive and intriguing activity that stimulated our creativity and practicality."

Fig. 3. Finch game

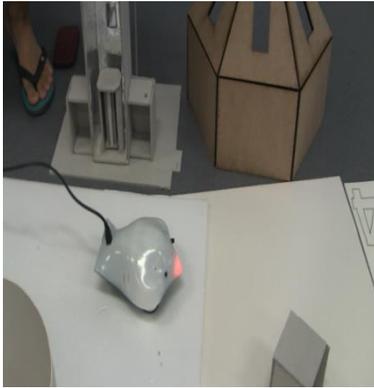Fig. 4. Navigate in rectangle

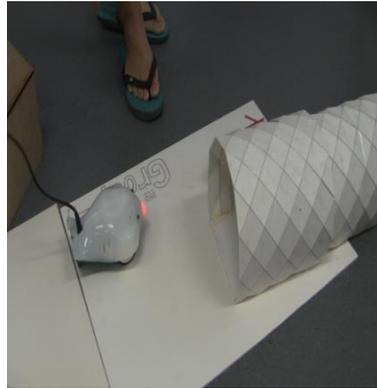

Fig. 5. Move to rough terrains

Fig. 6. Going home

The second brief story (Fig. 7.) was about the robot moving down a slope into a car park. The accelerometer was used to control the descending speed of the robot. In the car park, the light sensor detected darkness. This caused the robot to reverse and move in another direction. The robot stopped when the obstacle sensors encountered a wall.

Excerpt from the team was "Many more creative applications of the Finch were programmed by our schoolmates and us. We were to make use of the built-in sensors of the Finch robot to come up with creative uses and functions of the Finch."

For part two, students had displayed solutions to move the robot to each internal side of their rectangle box, navigate the robot at each external side of their rectangle box or movement of robot to each side of an imaginary rectangle box. Moreover, numerous sizes and materials of rectangle boxes were also noticed during the demonstration. Students had found out that the robot obstacle sensors work best with materials of brighter surface. All these were evidences of student's creativity and research work.

Different complexity levels of Python codes were seen for parts one and two implementation of mini-project four.

IV.   SURVEY RESULTS

A total of 74 respondents had done to this survey. The survey questions and results were tabulated in Table II.

TABLE II. Survey results

Questions	Strongly agree and agree
Q1. The mini-projects 1 to 3 had helped me to better understand loops, if-else statements and lists in Python programming language.	97.3%
Q2. The mini-project 4 had enhanced my creativity, research and problem solving skills.	93.25%
Q3. The mini-project 4 had improved my Python programming skills.	90.54%
Q4. The mini-projects had motivated me to learn Python programming language.	91.9%

The results of survey questions one to four had shown high percentages that the mini-projects using Finch not only improved students creativity, research and problem solving capability but also helped and motivated them to learn Python programming language.

Since there were a diverse student interest and wide range of student learning ability, a mixture of student comments were received in the survey. Generally, students had fun and enjoyed working in mini-projects using the Finch. Very few students commented that the projects were too easy. The Finch robot was reliable to a certain extent although there were a few occasions where at least one of the sensors malfunctioned or the robot needed to be replaced. Overall, the robot was able to achieve our objectives at this level of education and positive results were achieved.

V. CONCLUSION

The discovery of mini-projects using the Finch robot not only provided opportunities for students to exhibit and hone their creativity, problem solving, and research skills but also had helped the students understood basic concepts of Python programming language. The very low-cost robot, Finch, had allowed one robot for almost every two students. Therefore, more hands on experience opportunities were provided for the students and the students were to work in a team so that they could consult each other. One drawback was the extra preparation time by the instructors and consideration factors in educational design of mini-projects. Nonetheless, the computer programming and use of a real object like the robot to aid students learning in various areas had created very high learning values.

Finally, the experienced and information provided in this paper will be useful for others interested to adopt a similar approach, specifically in a course of more than 250 students, students of varied interests, and students with dissimilar learning skills.

In future, the expansion of the pedagogical activities using robots to at least the DW module may be carried out since overall positive results were obtained in the mini-projects.
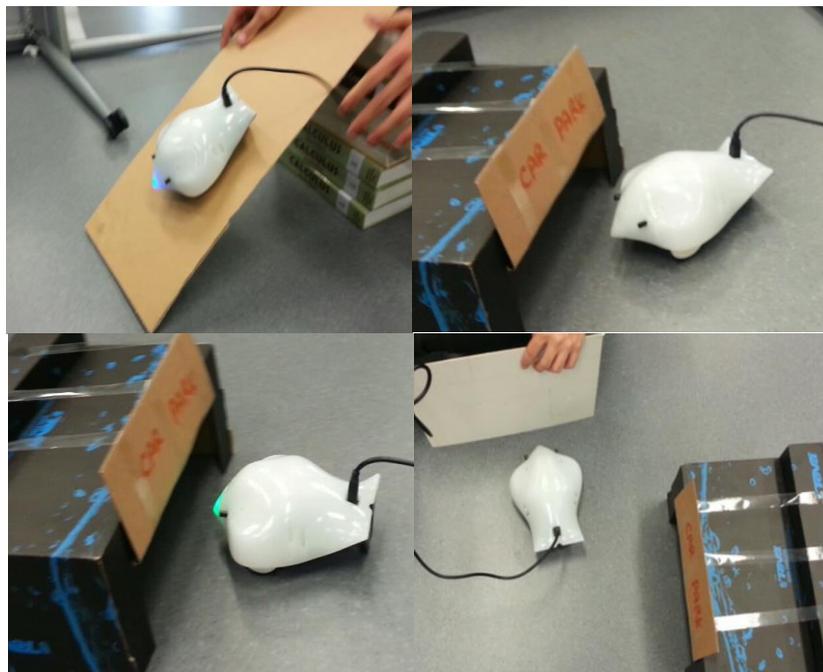
Fig. 7. Finch to car park and stop

REFERENCES

[1] Kay, J. S. and Moss, J. G., "Using robots to teach programming to K-12 teachers," 42nd Frontiers in Education Conference (FIE), 2012, pp. 1-6.

[2] Lin, H-T. and Kuo, T-H. "Teaching programming technique with edutainment robot construction," 2nd International Conference on Education Technology and Computer (ICETC), 2010, pp. V3-226 to V3-229.

[3] Dagdilelis, V., Sartatzemi, M., Kagani, K., "Teaching with robots in secondary schools: some new and not-so-new pedagogical problems," 5th IEEE International Conference on Advanced Learning Technologies (ICALT'05) 2005, pp. 757-761.

[4] Schumacher, J., Welch, D., and Raymond, D., "Teaching introductory programming, problem solving and information technology with robots at West Point," 31st IEEE Frontiers in Education Conference, 2001, F1B-2 to F1B-7.

[5] Yu, X., "Using LEGO Mindstorms in the undergraduate curriculum in IT," International Symposium on Information Technology in Medicine and Education (ITME), 2012, pp. 270-273.

[6] Panadero, C. F., Roman, J. V., and Kloos, C. D., "Impact of learning experiences using LEGO Mindstorms in engineering courses," IEEE EDUCON Education Engineering 2010, pp. 503-512.

[7] Barnes, D. J., "Teaching introductory Java using LEGO Mindstorms models," 33rd ACM Technical Symposium on Computer Science Education, SIGCSE 2002, pp. 147-151.

[8] Gavan, C. and Anderson, M. "Engaging undergraduate programming students: experiences using LEGO Mindstorms NXT. 13th SIG Information Technology Education (SIGITE) 2012, pp. 139-144.

[9] Goldweber, M. et al., "The use of robots in the undergraduate curriculum: Experience reports," 32nd ACM Technical Symposium on Computer Science Education, SIGCSE 2001, pp. 404-405.

[10] Lauwers, T., Nourbakhsh, I. and Hamner, E., "CSbots: design and deployment of a robot designed for CS1 classroom," 40th ACM Technical Symposium on Computer Science Education, SIGCSE 2009, pp. 428-432.

[11] Bowers, S. and Yerion, K., "Programming personal robots within an introductory computer science course for engineering majors," Journal of Computing Sciences in Colleges, October 2013, vol. 29, issue 1, pp. 133-139.

[12] Summet, J. et al, "Personalizing CS1 with robots," 40th ACM Technical Symposium on Computer Science Education, SIGCSE 2009, pp. 433-437.

[13] Markham, S. and King, K. N. "Using Personal Robots in CS1: Experiences, Outcomes, and Attitudinal Influences," 15th Innovative and Technology in Computer Education 2010, ITiCSE 2010, pp. 204-208.

[14] Han, J. et al., "A trial English class with a teaching assistant robot in elementary school," 5th ACM/IEEE International Conference on Human-Robot Interaction (HRI) 2010, pp. 335.

[15] Howell, A. L., McGrann, R. T. R. and Eckert, R. R., "Teaching concepts in fuzzy logic using low cost robots, PDAs, and custom software," 38th ASEE/IEEE Frontiers in Education Conference, 2008, T3H-7 to T3H-11.

[16] Klasser, F. "A case study of LEGO MindStorms' suitably for artificial intelligence and robots courses at the college level," 33rd ACM Technical Symposium on Computer Science Education, SIGCSE 2002, pp. 428-432.

[17] Klassner, F. and Anderson, S. D. "LEGO MindStorms: Not just for K-12 anymore," IEEE robotics & automation magazine, June 2003, pp. 12-18.

[18] M. Kulich et al., "SyRoTek – distance teaching of mobile robotics," IEEE transactions on education," vol. 56, no. 1, February. 2013, pp. 18-23.

[19] Kim, S. H. and Jeon, J. W. "Introduction for freshmen to embedded systems using LEGO mindstroms," IEEE transactions on education, vol. 52, no. 1, 2009, pp. 99-108.

[20] Lew, M. W., Horton, T. B. and Sherriff, M. S. "Using LEGO Mindstorms NXT and LEJOS in an advanced software engineering course," 23rd IEEE Conference on Software Engineering education and training (CSEE&T) 2010, pp. 121-128.

[21] http://www.finchrobot.com