

RAS-SIGHT Final Report

Establishing Robotics Labs in Underprivileged Schools to Promote STEM based Education for Enhancing Skill Sets Prior to Entering Higher Education Settings

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I. GOAL OF THE PROJECT

The goal of the project was to establish robotics lab in underprivileged schools to promote STEM based Robotics education. The idea was to equip the students with coding and robotics skills so that they have a good exposure of robotics and they can opt the robotics as their career in future. The other idea was to empower the students so that they can earn using their technical skills set so that they can bear their expenses for the education. We have established robotics lab in two underprivileged schools where the students were able to build their own advanced robotics projects with ease after completing the robotics workshops while being able to confidently exhibit and present their hard-work in front of everyone. It has been concluded that once students are made aware of the context of robotics in K-12 levels in schools, their perception about prospective STEM careers became significantly positive, with them calling for incorporating robotics into their school's curriculum for improved academic performance.

II. INTRODUCTION, PROBLEM AND SOLUTION

We have been extensively observing that students after having entered into a university program and when working in the scope of research or undergraduate projects, find it extremely difficult to exhibit and harness these rudimentary qualities: critical and creative thinking, problem-solving strategies, team-work and cooperation, presentation skills and time management. Also, they don't have a basic technology literacy over multiple disciplines, that requires them to develop that knowledge base first before engaging in developing any engineering or technology projects in the initial years. Moreover, they lack a sense of explicit direction as to what they should opt for as a profession once graduated from university, which is very detrimental for their progress since they have already undertaken a study program of which they are technologically oblivious. Thus, such students are distinctively observed to be lagging behind the undergraduate and research milestones they are expected to achieve whilst in a university. Additionally, the students are observed to be more concerned about grades and landing "good" jobs for themselves, as opposed to treading on the arduous path of developing the required skill sets from scratch for prospering in their respective fields of science, engineering, technology

and math (STEM). Since there is not a lot of time for university students to spend on gaining basic knowledge on rudimentary STEM courses like basic programming and then applying them into their projects subsequently, thus, a need to have such technology-literacy be imparted to the students prior to university education has been identified. 21st century skill set needed by STEM university students today is lacking due to a visible gap in K-12 education that doesn't address the importance of imparting technology literacy, project-based education and transdisciplinary educational activities in those elementary years of education. Thus, it is assumed to be the cause of deficiency of those 21st century skill sets which slows down the students' progression in professional education settings like the university years.

Additionally, recent advances in robotics have revolutionized our personal and business lives. Today, commercial and industrial robots are in widespread use, performing jobs more cheaply and in some cases with greater accuracy and reliability than humans. Intense involvement of these artificial helpers in everyday life requires human specialists with up-to-date knowledge to maintain and monitor existing robots, as well as to develop new, smarter, safer, and more advanced machines [2]. To meet this need, researchers are speculating and employing methodologies that equip early educational learners in K-12 grades to adequately respond to the high demand for specialists in the field of robotics by developing and offering appropriate courses in schools' curricula to foster STEM skills in students. Teaching STEM through robotics allows students to learn the content of a subject area, such as mathematics, by applying the content in a real-world context [3]. Learning-by-doing is an educational approach with its roots in the theory of Jean Piaget, who claimed that knowledge is not transmitted to children, but is constructed in the children's minds [4] known as the theory of constructivism. Constructivism is the exact opposite of the traditional classroom pedagogy, where students loose engagement capacity due to minimal or no practical manifestation of their learning. Papert's Constructionism theory proposes that not only do we learn by doing, but we learn best when we are engaged in building some type of external artifact, be it a robot, a theory, or a story [5]. He breaks with Piaget by ascribing a larger role to the surrounding culture in providing the student with materials with which

he or she constructs, thereby putting schools at the forefront of this matter. Papert strongly believed that by programming the computer a child establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building [6]. Programming at K-12 level allows student to think inherently about problem solving. They must make processes explicit in order to teach the computer how to perform a given task. The computer is powerful in its universal application; it allows for experiences that can be personalized to each student. By combining programming and designing, both aided by the use of computers, as well as building robots, a student has been witnessed to have been provisioned with a rich and meaningful learning experience while having their problem-solving skills honed. [7]. Moreover, there are many important reasons identified by researchers for exposing K-12 students to robotics. As our world becomes increasingly technological, students need experiences at an early age that enable them to become comfortable with and knowledgeable about technology before stepping into professional spheres, like university settings. Robotics can often do this within a context students care about. This is especially critical for female students, as positive early exposure contributes to persistence in STEM courses and possibly, careers [8], [9]. Additionally, as observed with university students, including robotics throughout the K-12 curriculum helps better prepare students to enter the workforce as technologically literate with more experience under their belt [10]. Work in the area of K-12 robotics education began with Papert's Logo project [11] and continued with LEGO/Logo projects [12], [13] and the development of a programmable brick [14]. Completely in line with the research objectives of this study, one area of interest for introducing robotics in schools has been to speculate what skills children develop through robotics education in that they would not gain otherwise. Wagner found increases in the areas of science achievement and problem-solving skills with elementary school students using robotics as compared to those in a traditionally taught science class [15]. Another area of interest is the design process undertaken by students during robotics activities. These processes can provide insight into what and how students learn [16], [17]. Ubiquitously, LEGO platform has been used in majority of robotics educational programs for K-12 and university students alike [3], [18], [19], [25]. Fagin [21] and Schumacher [22] were among the first to introduce LEGO Mindstorms in basic programming courses. Fagin used Ada language to teach basic control sentences (sequential, iteration or selection) and Schumacher used Java to teach fundamental computer programming concepts and introduced the concepts of autonomous vehicles, embedded computer systems and simulation. Barnes [23] pointed out the usefulness of physical models to teach event-driven programming and the physical limitations of LEGO brick to achieve a good object oriented programming style.

But, while all of these previous studies reveal that using LEGO for introducing robotics into K-12 grades provides enriched, collaborative learning experiences for students,

with substantial positive impact on student's learning and enhanced STEM career prospects for them, the choice of LEGO for conducting our study has been found to be in contradiction with the intended objectives of the research. Due to its propriety nature, LEGO platform for robotics education tends to constrict the learning scope of robotics education for K-12 students. Thus, making the transition to build mega, real-life robotic projects without or outside of LEGO platform less harmonious and incomprehensibly daunting for students. Since the benefits of open source software and technology outweigh those of propriety ones [30], we have developed a proposed robotics education methodology comprising of an open-source software called EDVON, and a modular physical building platform called ProBot.

We are trying to introduce robotics teaching methodology in an underprivileged school where students do not have enough money to pay for such a state-of-the-art robotics education; but due to lack of resources we are not able to provide them robots and we are not able to teach more than ten students. Therefore we are looking for funding to provide robots to the students for effective learning; and also teach at least 40 students, which help us to generalize our findings. This study will be focusing on what are the challenges involve in introducing robotics education in an underprivileged school; and what could be the possible ways to overcome the challenges in order to provide effective learning experience to the students. We are aiming to establish robotics labs in an underprivileged school to provide them an environment where students of slums can also get trained and play their role to accelerate the technological advancement in the world. From this project total of 40 students from an underprivileged school will be benefited. Since we are establishing robotics lab in a school and training the teachers as well, this will help the school to make this a part of their curriculum and benefiting thousands of upcoming students in future. In the following section we have described the proposed methodology.

III. METHODOLOGY FOR ROBOTICS IN SCHOOLS

We have introduced an open-source robotics education methodology employing 3 tiers of a transitional approach for teaching robotics education to K-12 students: Beginner Level, Medium Level, Advanced Level. The tier-based approach was aimed towards achieving easy recruitment of participants for the next subsequent level [31]. Our proposed robotics education methodology comprises of EDVON, the graphical development software based on Scratch [20], and a ProBot, a modular robotics building platform. Each tier in the proposed methodology - Beginner, Medium, Advanced - spans over 16 hours worth of training, inclusive of both theoretical and hands-on training on programing ProBots through EDVON. Throughout the workshops and competitions, students in each tier are required to work with one ProBot per team, to encourage team-work. This, at times, was independent of students' choices, thereby challenging young learners to learn to adapt and supplement each other's

strengths in order to successfully build and solve their robotic problems collaboratively. Also, there is no age frame for any tier of the robotics education, thus, diversified age groups of K-12 students make up the three tiers, based on their level of experience with robotics and programming. In order to mentor and guide the students during a workshop, a team of trainers comprising of undergraduate and graduate students having majors in computer science, computer engineering, mechanical engineering and electronics engineering always be there to moderate student interactions and provide one-on-one assistance to individual students lagging behind. Each trainer attended to at most 4 student groups at a time in order to keep a balanced trainer-to-student ratio during the workshops.

The purpose behind designing the proposed pedagogy for imparting robotics education this way is to hone the reasoning capabilities, problem solving and communication skills in students from their elementary years of education to make them be better equipped in order to cater to their higher education requisites prior.

Fig.1 shows the transition of software adopted for beginner, medium and advance level, while Fig. 2 and Fig. 3 showing the educational robots that are used in the robotics education for tier1 and tier2. In tier3 or advance level students are encouraged to build their own robots to make them think out of the box.

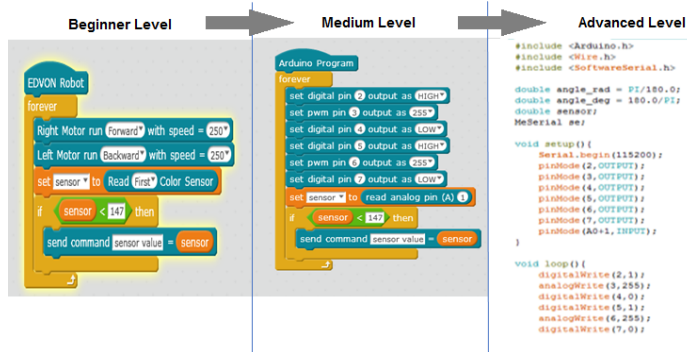


Fig. 1: Transition of Software (from left to right): Open source Edvon Software used for tier 1 and tier 2 students while Arduino IDE was used in tier 3 for a step-by-step transition towards programming with C

IV. OBSERVATION AND RESULTS

The projects developed by K-12 students for the hackathon competition are: light-based burglar alarm, traffic lights system, Red-Green-Blue (RGB) LEDs, water level detector, intruder alert system, dark sensors, metal detector with a human detection mode, 3-D printer, spy RC car for reconnaissance, smart parking system (see Fig. 4 and Fig. 5).

It has been observed that introducing robotics education to over 400 K-12 students in the underprivileged school-through the proposed 3-tiered methodology - helped in ultimately enabling students to design and build their own robots after only 48 hours worth of training. Also, the students in



Fig. 2: ProBot for tier 1 Beginner Level students

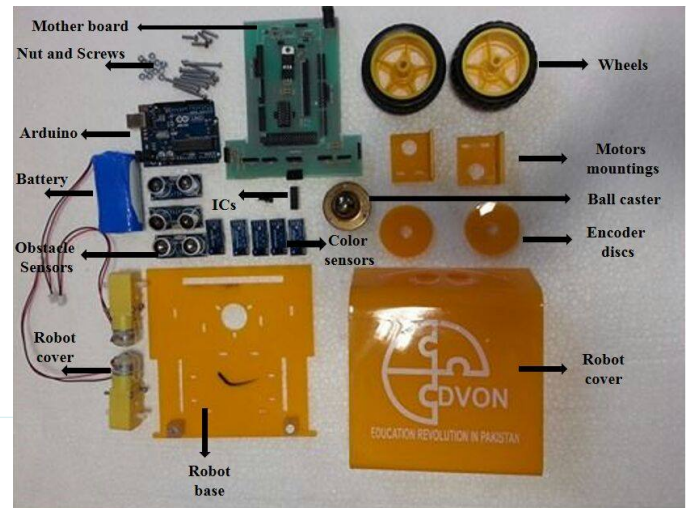


Fig. 3: The electronic, electrical and mechanical components for tier 2 Medium Level students for prototyping their ProBots

grades 8 and onward were observed to be more concerned about the evaluation and were mostly hesitant in asking for help. Whereas, the students in grades 3, 4 and 5 showed increased engagement in class interactions and discussions. Thus, it was observed that the earlier the robotics education be imparted in schools, the more confidence and productivity it showed in students' learning.

Additionally, extra-curricular activities were found to be significant in fostering team-work and 21st century skills development in students. Also, students who deemed programming as a viable career option for themselves in the future were in fact those who had participated in the proposed robotics education methodology, thereby symbolizing the importance of introducing robotics in school for enhancing skill sets prior to enrolling in university settings [10], [29].

For a quantitative evaluation of introducing robotics to underprivileged school, a survey had been conducted for the assessment of the effectiveness of the proposed methodology on a sample set of 104 underprivileged students. The results of the survey are as follows:

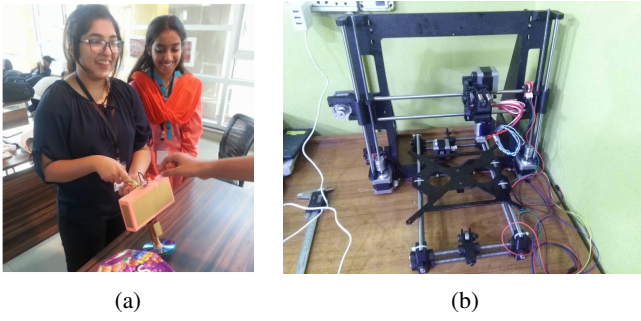


Fig. 4: (a) An all-girls team developed a metal detector with a human detection mode; (b) A 3-D printer developed by a group of 9th and 10th graders. They won the 1st prize.



Fig. 5: (a) A smart parking system built by a group of 4th and 5th graders for the hackathon competition; (b) The winning 3-D printer developed by a group of 9th and 10th graders.

A. Robotics in School making STEM and Computer Science Easy

The purpose behind introducing robotics in underprivileged schools it see the positive impact of robotics on computer science courses taught in schools. It was found that about 88.5% of students affirmed that robotics in school made STEM and computer science easier for them (see Fig. 6).

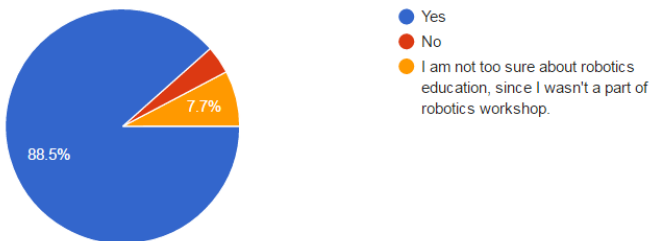


Fig. 6: Robotics education in school making STEM and computer science easy.

B. Robotics Education as an Interest Stimulus

In order to examine if the robotics education implemented engaged the students' interest in science and technology

courses, the survey showed that 97.1% of the students found robotics to be an interest stimulus for STEM courses, as depicted in Fig 7.

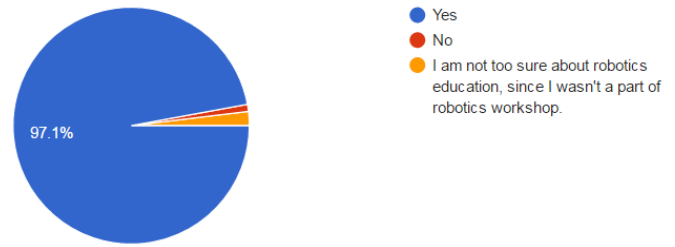


Fig. 7: Robotics education - an interest stimulus.

C. The Most Effective Education Methodology

With the adequate mix of both theoretical and hands-on experience with robotics, the proposed methodology leveraged the inherent engagement capability of robotics to sustained learning experiences for K-12 students. Thus, about 48% of the responses called for a mixture of both theoretical and hands-on activities in schools, as shown in Fig. 8).

Fig. 8: Education methodology most effective for teaching STEM and computer science in school.

D. Robotics in Schools honing Critical Thinking and Proportional Reasoning Skills

As shown in Fig. 9, about 76.5% found robotics education in schools to have helped them in honing their critical thinking and proportional reasoning skills, thereby bolstering the notion of its introduction prior to university years in K-12 grades.

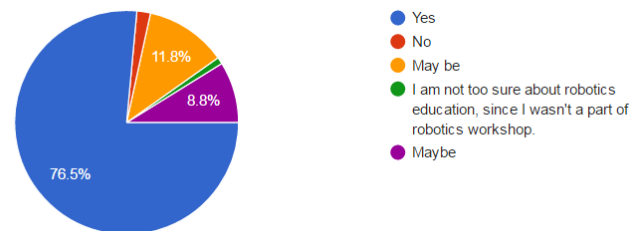


Fig. 9: Robotics education in schools honing critical thinking and proportional reasoning skills in students.

E. Need for the Necessary Skills Training in Schools

89.4% of the K-12 students who had taken the proposed robotics education believed that they should be trained for all the skills necessary for pursuing a STEM-based career while in school (see Fig. 10).

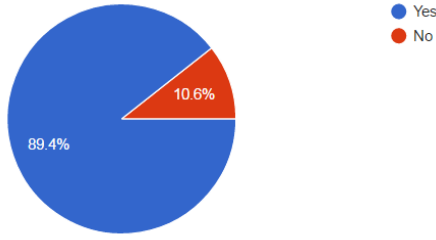


Fig. 10: Necessary skills training in schools for pursuing STEM careers.

F. Students' Support for Robotics Education

One very significant aspect got surfaced - 58.7% cited their increased interest in STEM and computer Science courses and looked forward to an enhanced academic performance whilst pursuing their robotics activities in school. Also, as shown in Fig. 11, 36.5% of the students wanted robotics education to be included in their curricula so that they don't have to juggle their interests with the academic requisites.

Fig. 11: Students' support for robotics education.

V. IMPACT OF THE PROJECT

The project has been designed to implement the robotics curriculum in underprivileged schools to understand how this will help them to grow technically and engage in educational activities in fun and more interactive way.

We have established two robotics labs in underprivileged schools, where we have trained 10 teachers and more than 600 students in this project.

After successful completion of the project, the students were able to code and understand the basics functions of the robotics and most importantly students were able to formalize how they can use robotics as a tool to solve their local problems.

From the RAS SIGHT funding, now the trained teachers teaching the same thing to the upcoming 1200 students. In this way more than 6000 students will be trained on robotics using the hardware and training we have provided to schools.

This training opened the new door of opportunities for the students who cannot imagine that they will be working on robotics in their life. The female teachers whom we have trained started small academies in their areas and start earning to serve their families.

The project played an important role for the community development and increase the opportunities for students and teachers both to upgrade their technical and soft skills.

VI. BREAKDOWN OF COST

The objective of this proposal is to establish the robotics labs in an underprivileged school to promote the STEM based robotics education and enabling the lower middle class students to get hands on experience on such state-of-the-art technology. Table. I shows the cost breakdown in US Dollar.

TABLE I: Cost Breakdown

ITEM	Quantity	Price per unit	Sum
Educational Robots	20	70	1400
Course's Handout	40	5	200
Promotion Material			300
Shields and certificates			100
Total Cost			2000

VII. BIOGRAPHIES OF PROJECT MEMBERS

Muhammad Nabeel: Nabeel is currently associated with Research Center for Artificial Intelligence and working as a Head of Robotics Lab at NED, University, Pakistan. He did his master in robotics from South Korea and worked as a researcher at TUM, Germany. He is also a co-founder and CEO of HAPTIKA and EDVON. To view his complete profile and publications kindly visit the following URLs, <http://www.hmnabeel.weebly.com/> <https://www.linkedin.com/in/hafizmuhammadnabeel/>

Hiba Ovais Latifee: Hiba is currently working with Research Center for Artificial Intelligence, NED University, Pakistan. He has done her BE in Computer and Information Systems Engineering from NED University, Pakistan. From the years 2013 to 2014, she served as the IEEE WIE NED University of Engineering and Technology Afinity Group's chairperson. Kindly visit the following URL to know more about her, <http://hibalatifee.weebly.com/>

Muhammad Khurram: Dr. Muhammad Khurram currently serving as an Associate Professor and Director of RCAI (Research Center for Artificial Intelligence). Dr. Muhammad Khurram received his PhD from Massey University New Zealand. He did his Bachelor and Master of engineering (By research) in Computer Systems from NED University, Karachi in 2002 and 2006 respectively. Kindly visit the following URL to know more about Dr. Khurram, <http://www.neduet.edu.pk/cise/mkhurram.html> <http://www.rcai.pk/ResearchCenterAI/ueber-uns/dfki-gmbh-robotics-innovation-center.html>

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