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A Review on Educational Robotics as Assistive Tools For Learning Mathematics and Science

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ABSTRACT
Robots have become more common in our society as it penetrates the education system as well as in industrial area. More researches have been done on robotics and its application in education area. Are the usage of robots in teaching and learning actually work and effective in Malaysian context? What is the importance of educational robotics in education and what skills will be sharpened in using robotics in education? As programming is vital in educational robotics another issues arise – which programming is suitable for Malaysian schools and how to implement it among the students? As per whole discussion, a new robotic curriculum will be suggested. This paper present a review on educational robotics, its advantages to educational fields, the hardware design and the common programming software used which can be implemented among Malaysian students. The results from the overview will help to spark the interest to not only researchers in the field of human–robot interaction but also administration in educational institutes who wish to understand the wider implications of adopting robots in education.

Keywords:- Educational Robotics

I. INTRODUCTION

Robots refers to the machines that provide some form of autonomy to assist its user in performing certain task. Robots in industry are often deployed in areas of human activities that are dangerous, dirty and dull. However, recently robots have found niche application in entertainment, education and other applications that may benefit from user – machine interaction. Various researchers have shown that robotics are a suitable platform to train students in STEM (Science, Technology, Engineering and Mathematics) related skills (Bakke C.K., 2013). However such implementation still requires fine tuning and exploration. The potential of such technologies can be seen with the investments from various companies in developing robotic related toys such as Lego Mind Storm, NTX robotics. The emphasis is encouraging the development of the mind by constructing robots and programming the robots to perform certain task.

Recently, as the debating in parliament about poor Malaysian performance in PISA and TIMMS is seriously discuss, Malaysia embraces the aim to improve its mathematics and science education particularly on PISA and TIMMS rating, robotics could be a feasible could function as a assistive tool to facilitate and enhance learning process. The activities related to the development of robotic can be further investigated to enhance the student development process. However, the complexity of the task needs to be correlated to the student age and mental development. The task and curricular developed must also examine and fully optimize the advantage of learning methods often associated with robotics such as constructivism, tactile learning, reinforced learning, creative and critical thinking which involves higher order thinking skills.

This review on the existing works on applying robotics in education will focus on the advantages and proven effects achieved from integrating robotics in education and the robotics platform that are currently being developed and used by educators.

II. CHALLENGES, EFFECTS AND ADVANTAGES OF INTEGRATING ROBOTS IN EDUCATION.

The advantages of implementing robotics are it serves as a tool to develop cognitive and social skills for students. According to Alimisis (2013), robots became an integral component of society and had great potential in being utilized as an educational technology. Robotics has attracted the interest of teachers and researches as a valuable tool to develop cognitive and social skills for students from pre-school to high school and to support learning in science, mathematics, technology, informatics and other school subjects or interdisciplinary learning activities. However, one of the challenges is teachers not ready to implement the new technology in school. On the contrary, in Gerretson et al., 2008, the collected data revealed that the teachers struggled to integrate the technology in a manner that supported interdisciplinary instruction, particularly because lack of time and appropriate curricular materials. This research shows robotic technology to be used as a model to support education for sustainable development, specific curriculum, adaptable to local contexts, needs to be readily available. The analysis indicated that the technologies served as an effective management tool for teachers and a strong motivational tool for students despite the reported lack of resources. This problem can solved eventually as more developers such as Lego Mindstorm are producing learning materials and the instruction sets for the educators to integrate into the activities.

However, in making educational robotics more accessible to teachers and trainers, a phase of exposure starting curriculum can be created and implemented. And more user-friendly nature of the new generation robots should be introduced. In 2003, USA a pilot project has been conducted on integrating a hands-on robotics component into two summer programs for inner-city high school students: the Science and Technology Entry Program (STEP) and Playing2Win (P2W). A paper by R. Goldman et.al (2003) presented the pilot project using an educational robotics curriculum that was developed to enhance teaching of standard physics and math topics to middle and early high school students in inner-city schools in New York City. The lessons were centered around the LEGO Mindstorms robotics kit and the RoboLab graphical programming environment. The project had multiple goals to support its main purpose. The primary goals were to develop and test curriculum, curriculum materials and supplemental resources using the LEGO robot, geared toward an inner-city public school population. A secondary goal was to examine the use of practical applications for the technology within a non-traditional educational environment in order to anticipate technical difficulties in our implementation plan. The project was composed of four stages: (I) Curriculum Development, (II) First Implementation, (III) Innovation and Modification, and (IV) Second Implementation. This has the further benefit of expanding the base of teachers trained in educational robotics and giving them the tools, experience and confidence to integrate robotics into their curricula in the future. According to Vinesh Chandra (2010), the user-friendly nature of the new generation of robots presented new opportunities for teachers to revisit their pedagogical approaches of teaching mathematics. Through innovative learning activities, robotics could show the connections between mathematics and the real world. More importantly it captured children's' attention and interest and as consequence they enjoy the experience. Activities with these qualities are more likely to deliver desirable learning outcomes.

Despite of user-friendly, educational robotics should also be more interactive and enjoyable to use and implement. From Wei, C-W. et al. (2011), JCLS (Joyful Classroom Learning System) was designed with flexible, mobile and joyful features. The developed JCLS consists of the robot learning companion (RLC), sensing input device, mobile computation unit, mobile display device, wireless local network and operating software. The JCLS in C-W Wei et.al. (2011), result showed the increased in learners' motivation and offer a more joyful perception to learners during the learning process for the experimental group. Table 1 shows five components and potential devices used for designing JCLS. It included the experiential learning theory, constructivist learning theory and joyful learning. The JCLS system has been applied in real world for supporting children to learn mathematical multiplication. The formal experiment, including an experimental group and a control group, was conducted with 47 elementary school students in grade two in Taiwan. The experimental group, composed of 24 students including 9 boys and 15 girls, was arranged to learn with the JCLS. The control group, composed of 23 students including 10 boys and 13 girls, was arranged to learn with traditional learning method by using the blackboard. It helps the student's experimental group to concentrate on the instruction and learning activity. Table 1 shows the five components and potential devices to be used for designing a JCLS

Table 1 : Five main components and potential devices to be used for designing a JCLS (C-W Wei *et al.* 2011)

Element	Example	Function
Robot learning companion	LEGO MINDSTORMS NXT Wowwee, Robosapien And Aldebaran Robotics Nao	Interaction
Sensing input device	Barcode, RFID, QR Code Electronic pen, and Laser projector keyboard	Input
Mobile computation unit	Laptop, OLPC, Netbook, PDA Samrtphone, iPhone & iPad	Processing and storage
Mobile display device	Embedded display in the RLC Protable projector, Touch screen Electronic paper & Eye screen	Output
Wireless local network	Bluetooth, Wi-Fi, ZigBee & GroupNet	Data exchange

On the other hands, educational robotics has been proved to serve students better between gender. Sullivan & Bers (2012), seeks to highlight the differences between gender in application of the robotics. Boys had a higher mean score than girls on more than half of the tasks, very few of these differences were statistically significant. Boys scored significantly higher than girls only in two areas: properly attaching robotic materials, and programming. The TangibleK Program consisted of a six lesson robotics and programming curriculum that was implemented in three different kindergarten classrooms (N = 53 students).The study looks at the TangibleK Robotics Program in order to determine whether kindergarten boys and girls were equally successful in a series of building and programming tasks. But, overall both boys and girls were able to complete the program. This shows that robotics integration can be implemented without restrictions in both genders even at a pre- school level.

To enhance the higher thinking skills among Malaysian students, educational robotics brings good effects in constructivism learning. In term of constructivism learning, Bers et.al (2002), the article presented a constructionist approach to introducing robotic technology in the early childhood classroom. The authors demonstrated how this approach is well suited, since the four basic tenets of constructionism have a long-standing tradition in early childhood education:

(a) learning by designing meaningful projects to share in the community,

(b) using concrete objects to build and explore the world,

(c) the identification of powerful ideas that are both personally and epistemologically significant, (d) the importance of self-reflection as part of the learning process.

The article introduced a methodology for teaching pre-service teachers to integrate technology in the classroom. It also described four different experiences in which pre-service teachers designed and integrated robotic projects done with LEGO Mindstorms and ROBOLAB to engage their young students in exploring and learning new concepts and ways of thinking.

One of major issue among students is lacking the problem-solving skills. And by implementing robotics in mathematics, students are more exposed to creative ways in solving problems. In Adolphson (2002), a mathematical embodiment through robotics activities studies was examined. This study looked at the emergence of mathematical understanding in middle school students as they engaged in open-ended robotics activities. The study chronicled the mathematics they used, the mathematics they perceived themselves to be using, and the opportunities for the embodiment of mathematics understandings as they engaged in meaningful open-ended problem solving activities using robots. In addition, the study sought to understand how the students cooperatively organized their efforts and negotiated meaning as they solved complex tasks. In this study, the students' choices influenced the complexity of the mathematics that emerged from the activities.

Robotics seems to exemplify an appropriate use of technology to create meaningful, open-ended, problem solving activities. Further research is required in order to adapt these types of robotics activities into the in-school context as part of a transformative mathematics curriculum.

In Silk & Schunn (2007), a report of a project "Using robotics to teach mathematics: Analysis of a curriculum designed and implemented" investigated the use of engineering as a context in which to learn mathematics through an evaluation of a LEGO-based robotics curriculum. An analysis of the curriculum was performed in order to identify the types of mathematics topics that students would have opportunity to learn, and investigated the extent to which those topics were aligned with the national standards. The findings suggest that robotics is a promising engineering context in which to engage students in thinking about mathematics, but that rather supports are required to effectively enable students' mastery of the more general mathematical ideas. In the first investigation in the curriculum, several topics are find the most relevant in applying robotics according to the proportion of time; general problem solving, equation, accuracy and precision, number comparison, circles, multiply whole numbers and measurements (length and perimeter).

Educational robotics not just beneficial in mathematics, but also beneficial in various area such as science, engineering and technology as well. Vollstedt (2005) examined the ways to improve student knowledge and interest in science, mathematics, robotics, computer programming, and engineering as well as improve the methods in which instructors teach science in local schools. In order to improve science education, a curriculum based on LEGO Educational Division's "Race against Time" was created which utilizes LEGO Mindstorms for Schools kits and Robolab software. The curriculum included sections that were both hands-on and Internet based. Twelve local middle school teachers were trained in building robots with LEGO bricks and programming them with Robolab. The middle school teachers introduced the program to their students. Results of pre and post physics, Robolab, and engineering attitude tests as well as teacher interviews showed that the curriculum helped improve students' knowledge of science, mathematics, robotics, computer programming, and engineering.

As the educational robotics is applied among students, it brings good effect and positive changes among the students. Griffith (2005) examined potential relationships between high school students' attitudes and interests in science, mathematics, engineering, and technology, and their participation in the FIRST Robotics Competition six-week challenge to design, and built robot. A sample of 727 South Carolina public high school students participated, and data were collected using pre- and post-survey questionnaires. Data analyzed was collected from the group of students participating in FIRST Robotics (treatment), which was the experimental group, and the group of students who are not participating in FIRST Robotics (control). Findings indicated that there were significant attitudinal differences between students in the experimental group (FIRST), and students the control group pre- and post-survey responses, with students in the FIRST group had statistically significant higher attitude means than control students. In Barker & Ansorge (2007), it was reported that a pilot study that examined the use of a science and technology curriculum based on robotics to increase the achievement scores of youth of ages 9 to 11 in an after school program. The study examined and compared the pretest and posttest scores of youth in the robotics intervention with youth in a control group. The results revealed that youth in the robotics intervention had a significant increase in mean scores on the posttest and that the control group had no significant change in scores from the pretest to the posttest. That means the results showed that the robotics program had the positive impact upon the experimental group. In addition, the results of the study indicated that the evaluation instrument used to measure achievement was valid and reliable for this study.

The past recent years 2011 and onwards, researchers have been actively investigate about the implementation of educational robotics in early childhood education. The vast majority of them were analyzing sequencing skills among early childhood in term of basic mathematics, science, technology and enginnering. In Salgen et al. (2011), a study was done to investigate what pupils aged 10-12 can learned from working with robots, assuming that understanding robotics is a sign of technological literacy. A cognitive and conceptual analysis was conducted to develop a frame of reference for determining pupils' understanding of robotics. Lego Mindstroms NXT robots was used, and four perspectives were distinguished with increasing sophistication: "psychological", "technological", "function" and "controlled system". In the study, the interaction was done with pupils on one-to-one basis and the role of the teacher was fulfilled by the researcher. In the study, the pupils learned about robots, what robots were, what they are used for, how they function, and what the robot was able to do, and in this sense they certainly became more culturally technological literate. It was concluded that the robotics program challenge pupils to manipulate, reason, predict, hypothesize, analyze and test and the learning process with the pupils needed scaffolding by a teacher who asked questions, focused attention, gave direction, deal with frustration, gave information, and helped to tackle difficult problems. In Kazakoff et al. (2012), the impact of programming robots on sequencing ability during a 1-week intensive robotics workshop at an early childhood STEM (science, technology, engineering & math education) elementary school in the Harlem area of New York City was examined. Using robotics in suitably designed activities promoted a constructivist learning environment and enabled students to engage in higher order thinking through hands-on problem solving. In the constructivist model, the students were urged to be actively involved in their own process of learning. The group of children who participated in the 1-week robotics and programming workshop experienced significant increases in post-test compared to pre-test sequencing scores. Figure 1 illustrates one of the examples of the story sequencing card sets used for post test. Children were assessed using a picture-sequencing task. During robotics week children used LEGO Education WeDo Robotics Construction Sets, with the CHERP hybrid tangible-graphical software, and a variety of art materials to build and program their robots. Figure 2 illustrates LEGO_ WeDo robot, an example of a LEGO_ WeDo robot constructed by a child during the study

Figure 1: Figure illustrates one of the example of intentional-type sequencing story card sets used (Kazak off *et al.* 2012).

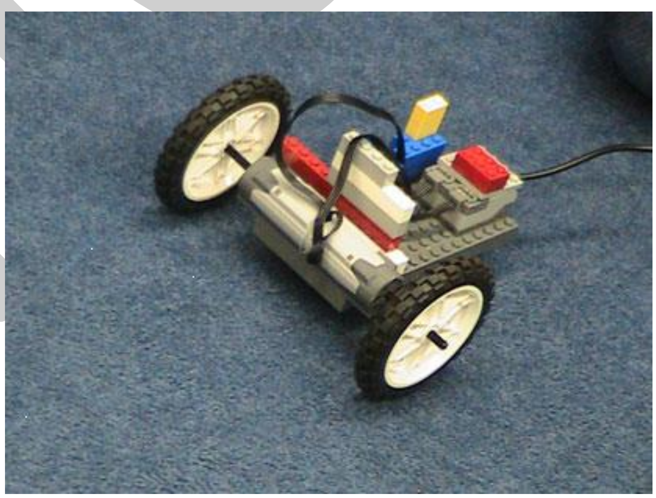

Figure. 2: LEGO_ WeDo robot. An example of a LEGO_ WeDo robot constructed by a child during this study (Kazakoff et al, 2012)

In Kazakoff and Bers (2013), the impact of programming of robots on sequencing ability in early childhood and the relationship between sequencing skills, class size, and teachers' comfort level and experience with technology was examined. Fifty four children were included in data analysis and a significant interaction was found between group assignment and test results but no significant interactions were found for school assignment. The Creative Hybrid Environment for Robotic Programming (CHERP) system was used in the study. CHERP is an interactive programme that utilizes wooden block with logo to be converted into computer programmers to enable a robot to move. This technology involves the use of a camera to recognize the logo using image processing methods and involves the utilization of physical blocks for programming instead of manipulating the virtual programming blocks which is the common trend in most programming tools for children in the market. A picture sequencing task was chosen for the study to evaluate the children sequencing capability. After an ANOVA analysis, the classroom studies showed a significant increase in sequencing scores for the experimental groups versus the control groups. The study may indicated the need for teacher training and professional development programs that focus on engaging teachers in using technology in their classrooms. Figure 3 shows the two interfaces of CHERP. The photo on the left screen is a screen shot of the graphical programming language, and the photo on the right shows a sample of the tangible wooden blocks

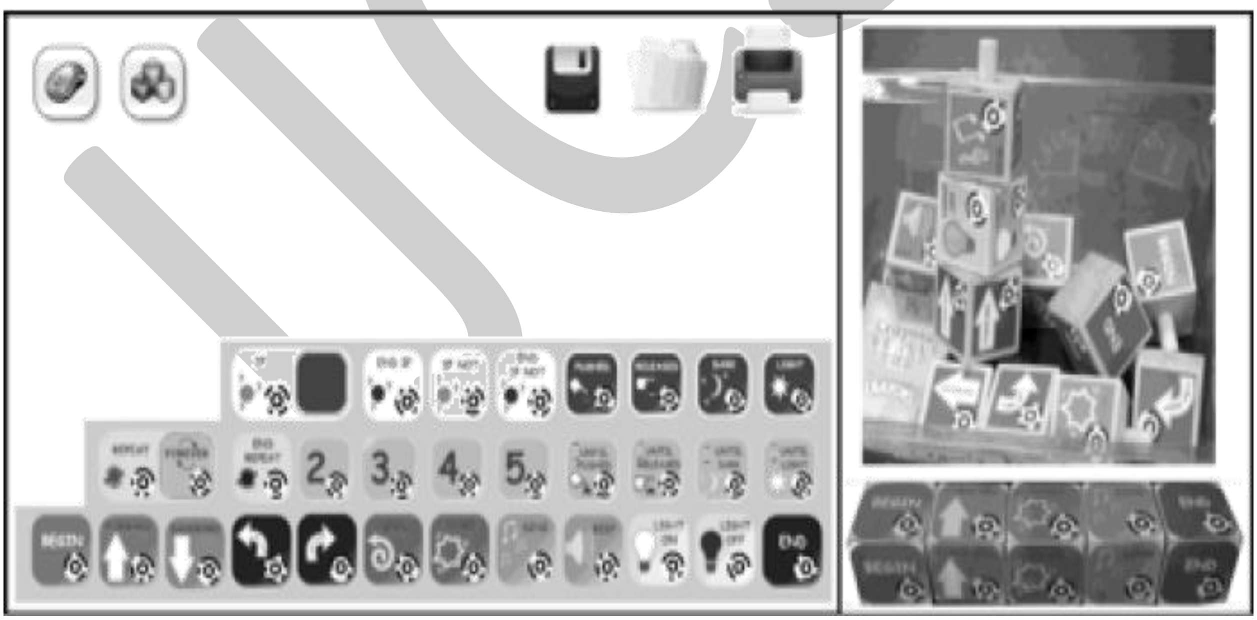

Figure. 3:Two Interfaces of CHERP (Kazakoff and Bers , 2013)

In Bers et al. (2014), engaged in construction-based robotics activities with children as young as four in early childhood. The TangibleK Robotics Program paired developmentally appropriate computer programming and robotics tools with a constructionist curriculum designed to engage kindergarten children in learning computational thinking, robotics, programming, and problem-solving. The paper documents three kindergarten classrooms' exposure to computer programming concepts and explores learning outcomes. Results point to strengths of the curriculum and areas where further redesign of the curriculum and technologies. Overall, the study demonstrates that kindergartners were both interested in and abled to learn many aspects of robotics, programming, and computational thinking with the TangibleK curriculum design.

Sullivan (2013) examined qualitatively the implementation of an intensive weeklong robotics curriculum in three Pre-Kindergarten classrooms consisted of 37 participants at an early childhood STEM (Science, Technology, Engineering, and Math) focused school in the Harlem area of New York City. Children at the school spent one week participating in computer programming activities using a developmentally appropriate tangible programming language called CHERP, which is specifically designed to program a robot's behaviors. The children used CHERP to program "Robot Recyclers" that they constructed using parts from LEGO® Education WeDo™ Robotics Construction Sets. The Robot Recyclers were designed to help carry, push, and/or sort recyclable materials found in the classroom. Researchers were participant-observers in the robotics lessons over the course of curriculum implementation. Each lesson was taught by the researchers, with classroom teachers present in order to facilitate classroom management and assist with small group work.

A combination of interviews, video, photographs, and classroom observations were used to document the students' experiences. Classroom teachers were also interviewed and asked to complete anonymous pre and post surveys. Results from this study provide preliminary evidence that pre- Kindergarten children can design, build, and program a robot after just one week of concentrated robotics work. Additionally, results indicate that teachers were able to successfully integrate robotics work into their classrooms that included foundational math and literacy concepts while also engaging children in the arts.

As conclusion, educational robotics is still a new approach in Malaysian education that yet to be explored. It has the vast potential to be explored and implemented among Malaysian students which should be integrated with suitable curriculum in the local context. However, a lot of researches have to be done in the early stage of the integration to keep the curriculum up to the national standard.

III. RELATED SKILLS TO IMPROVE IN APPLYING ROBOTIC IN EDUCATION AND IT'S EVALUATION

As previous section explores the effects of applying robots complimenting the existing curricular, this section will explore the in detail how programming and building robots can improve on the specific skills that are often related to science and mathematics such as sequencing skills, reasoning skills , meta cognitive skill and etc.

The first skills related to educational robotics is metacognitive skills. Highfield (2010) describes a series of tasks in which robotic toys are used to develop young children's mathematical and metacognitive skills. Metacognitive skills refers to learners' automatic awareness of their own knowledge and their ability to understand, control, and manipulate their own cognitive processes. Table 2 and table 3 show the task in the year 1 context and in the pre-school context respectively. Table 4 describes the processes and concepts explored while using simple robotic toys. Thirty-three children participated in the project, of which 11 were children, aged three and four years, and drawn from a metropolitan pre-school. Twenty-two Year 1 children from a nearby state school were also involved. None of the children or teachers had experience with robotic toys before they began the project. In both settings the children and their teachers chose to use the Bee-bots and Pro-bots, although a range of robotic toys were supplied. The children were engaged in "play" experiences with the toys and then completed weekly tasks, developed collaboratively by the teachers and the researcher, for approximately 2 hours per week over 12 weeks. Robotic toys present unique opportunities for teachers of young children to integrate mathematics learning with engaging problem-solving tasks. Bee-bots and Pro-bots, developed as part a larger project examining young children's use of robotic toys as tools in developing mathematical and metacognitive skills.

The toys served as catalysts, providing unique opportunities for tasks focusing on dynamic movement. The development of tasks that have multiple solutions engenders flexible thinking and encourages reflective processes. As children program the robot and then observe its movement they can see their program in action and decide if their plan has worked as expected. This visual process encourages children to reflect on their program thus making mathematical concepts "more accessible to reflection". There were three different types of tasks:

(i) structured tasks (teacher-directed tasks designed to develop particular concept or skills)

(ii) exploratory tasks (structured to allow application of knowledge, exploring concepts and skills more freely)

(iii) extended tasks (open-ended and child-directed tasks with which children engaged for an extended period of time, and with limited teacher scaffolding)

Exploratory and extended tasks provide opportunities for problem solving, whereas structured tasks focused on discrete skills required in the more advanced tasks. It also promoted persistence and sustained engagement as the children attempted to complete the problem solving goals.

Table 2 : Task in the Year 1 context (Highfield ,2010)

Task	Descriptor
Comparative steps	A structured task: Starting from a base line, the children predicted and compared the step lengths of the two robots informed the children's understanding of the robot step as unit of measure.
Partitioning and doubling distance	A structured task : Using a start, finish and half way point with masking tape) children estimated and programmed the robot to move to the half-way point and then doubled the number of steps to complete the task.
Robot people	A structured task : Using the language of robotic programming to program the robot. To enable spatial concepts including viewing from different orientations and perspectives.
Robot speedway	An exploratory task : Setting about a number of small cones and programming the toy to weave between the cones.
Moveable island	An extended task : creating a teacher-made island on a grid, by adding a series of obstacles (Example : bridge & quick sand), for creating the adventure for the toys.
Design your own island	An extended task : children, working in small groups, design and made island for their toy. Children programmed the robot to move through their island.

Table 3 : Task in pre-school context (Highfield ,2010)

Task	Descriptor
Positional language	A structured task : Moving the robot to a finishing point Example : "move from here to under that chair" (altering the length and complexity of the instructions increases task difficulty.
Robot play & investigation	An exploratory task: Free play, working in pair or individually, programming the robot to move between partners to develop measurement concepts; changing the distance increased task difficulty.
Building a robot home	An exploratory task : Using plastic blocks to construct an appropriately sized home for robot. To develop 2D and 3D spatial sense and measurement skills.
Constructing & representing tracks	Exploratory task : Using pre-cut lengths of wooden track to make a series of tracks and programming the toy to move around the track using a variety of tools such as directional image cards.

Table 4 : Processes and concepts explored while using simple robotic toys (Highfield ,2010)

Spatial concepts	* Capacity : creating & measuring space (example : tunnel to fit the robot inside) * Angle of rotation : exploring the rotation of the robot * Directionality : examining concept (forward, backward, rotate, left and right) * Position on a plane : using increasingly complex language (example : over there) *Transformational geometry : exploring concepts such as rotation and linear motion.
Measurement	* Informal and formal units : Such as hands, blocks and measuring tapes in creating programs. * Identification and literation of a unit of measure : Example , when moving the toy – using hand and eye gestures as place holders in measuring distance. * Direct comparison : using the toy's length to compare directly the distances needed to complete a pathway.
Structure	* Grid : Developing and using grids showing the toy's step length to assist in planning and developing programs * Gesture & movement : Using gestures and body movement to indicate and imagine the structure of regular steps.
Number	* Perceptual and figurative counting : to ascertain the number of steps required to complete a given pathway. * Comparison of number : compare the movements pathways
Problem solving	* Estimation : Require to complete a pathway * Re acting * Trial and error * Recall of prior knowledge * Investigating multiple solutions * Evaluating solutions
Representation	* Semiotic understanding of symbols; Example – the forward arrow meaning one step forward * Constructing and recording programs using symbols: symbols include tallies, arrows and invented notations to show movement and location

Another skills related to educational robotics involves mathematics. Kazakoff & Bers (2012) showed how robotics in kindergarten classroom impacts sequencing skills in classroom. The studies showed a significant increased in sequencing scores for the experimental groups versus the control groups. When children program robots, they engaged in sequencing the commands that comprise a robot's program.

Sequencing was an important early childhood skill found in both curricular frameworks and, subsequently, in many learning assessments. Sequencing along with sorting, measurement, and pattern recognition were a child's mathematical building blocks; starting with these foundational skills, children began to think of the world mathematically (Sarama & Clements, 2003). The list of mathematics skills were reasoning skills, problem solving skills, sequencing skills, apatial skills, math calculations, math word problems, math rules and procedure and math language. Silk (2010) examined on how learning environments influence the ways that middle school students used math to engage with and learn about robotics. In addition to the popularity of robot competitions, robotics was chosen as the context for the study for a number of reasons that make it a discipline especially suited for investigating the role of mathematics in the development of physical and technological understanding for improving design solutions. Data from two observational studies suggest that existing formal (scripted inquiry) and informal (competitions) learning environments in this domain were limited in their support for connecting math with robotics.

In light of the evaluation of these existing learning environments, two additional studies were conducted documenting the design, implementation, and redesign of a new learning environment intended to more effectively align learning and engagement with the connection between math and robots. Pre-post assessments and analyses of student work support the hypothesis that a model eliciting learning environment can facilitate learning while maintaining interest in both disciplines, and facilitate the development of a greater sense of the value of math in robotics. Two additional studies expanded on the previous work. The first study identified two contrasting approaches for connecting math with robots in the context of the model-eliciting learning environment from the previous studies. One approach used mathematics as a calculation resource for transforming input values into desired output values. The second approach used mathematics as a mechanistic resource for describing intuitive ideas about the physical quantities and their relationships.

The second study manipulated instructional conditions across two groups of students that encourage the students to take on one of these approaches or the other. Both groups engaged in high levels of productive mathematical engagement: designing, justifying, and evaluating valid strategies for controlling robot movements with connections to mathematics. But only the mechanistic group made significant learning gains and they were more likely to use their invented robot math strategies on a transfer competition task. All six studies taken together provide a rich description of the range of possibilities for connecting math with robots. Further, the results suggest that in addition to carefully crafting environments and associated tasks to align math and robots, which instructional designers ought to pay particular attention to helping students frame their approaches to using math productively as a tool. situations. The study involved maths skills ; calculational and mechanistic groups problem solving which applied in robot movements and proportion reasoning. The example of problem solving is shown in figure 4 below.

Figure 4 shows an example of how many motor rotations it took to cover a distance of 40 cm and 60 cm respectively.

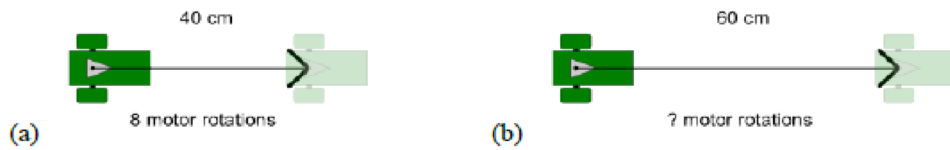

Figure 4 : The basic robot movement problem (Silk, 2010)

Baker (2011), investigated on mathematics used in a semiformal learning environment via robotics. This study contributes to both educational practice and theory through examining the mathematics used by urban youth in an after-school robotics program and the environment in which that activity occurred. The work had several audiences, including mathematics education practitioners, mathematics education researchers, out-of-school-time educational practitioners, and learning theorists. The research built on the knowledge of how youth used mathematics outside of the classroom as well as how various sociocultural learning theories can be used to understand the affordances and constraints of an afterschool STEM development program located, like most of these programs, between what are considered formal and informal learning environments. The project was a continuation of a larger three-year participant-observation study across three sites.

This qualitative study included participant observation with youth through a cycle of the program. Observational data was triangulated with experience interviews and clinical task-based interviews, the latter being designed to investigate the participants ‘used of mathematics in more depth. The mathematics used of the youth matched much of the previous research on how people used mathematics outside of school time, with some notable differences. Specifically, in the robotics program the youth drew on a varied set of mathematics learned and used in school, out of school, and during robotics. Figure 5 below shows the description of robotic-related math tasks used in the program.

#	Name	Task	Materials	Math Content
1	Making kits	a. Gave youth box of 100 washers and asked them to make groups of 25. b. Asked youth to cut five 8" portions of string.	Box of washers, string	Measurement: *counting, unitizing, exemplar*
2	Random arithmetic	a. Leroy said he was one yard stick and 28 inches tall. How many inches tall is he? How tall in feet? b. How many feet is 140 inches?	Scrap paper	Arithmetic: *adding and dividing* Measurement: *facts and conversion*
3	Base height	a. The motor was 2 1/2" and the nut debris was 1 ¾", how tall did the base need to be to clear this? b. The bolt debris was 5 3/8", how tall would the base need to be now?	Scrap paper, robot, and nut and bolt debris	Arithmetic: *adding fractions*
4	Making Shapes	a. Pretending a piece of paper is a sheet of plywood, measure a base that is 6.25" by 7.5". b. Working with an irregular piece of paper, make a 3" by 4" base.	8.5" by 11" sheet of paper, paper with corners cut off (irregular)	Measurement: *linear, use of ruler, angles* Geometry: *parallel and perp. lines*
5	Center of a Wheel	Youth given a 6" diameter circle made of paper, asked to find the center.	6" paper circle	Geometry: *Circles*

Figure 5 : The description of robotic-related math tasks (Baker , 2011)

According to Nunes et al. (2009), development of math's capabilities and confidence in primary school project came through several key findings which were:

(i) Mathematical reasoning, even more so than children's knowledge of arithmetic, was important for children's later achievement in mathematics.

(ii) Spatial skills were important for later attainment in mathematics, but not as important as mathematical reasoning or arithmetic

(iii) Children's attention and memory also played a small but consistent part in their mathematical achievement

(iv) Children's from high socio-economic status backgrounds were generally better at mathematical reasoning than their peers

(v) Streaming, or ability-grouping, in primary school improved the mathematical reasoning of children in the top ability group, but the effect was small. It hindered the progress of children in other groups.

(vi) Children's self confidence in math's was predicted most strongly by their own competence, but also by gender (girls are less confident than boys) and by ability grouping. Children's attainment, although largely determined by cognitive and social factors, was also influenced by their self-confidence.

IV. PROGRAMMING SOFTWARE AND TOOLS

The availability of various programming software and robotic hardware has enabled the wide use and application of robotics in education. This section will explore the existing platforms available in the market.

Selecting the suitable platform for students is an imperative process to ensure effectiveness and to reap the full benefits of such implementations. As the discussion is done about the easiest programming software up to the complicated, Malaysian education should start with the easiest programming software as the educational robotics starts to be introduced in the early childhood stage. And the educational robotics curriculum should be flexible in term of integrating it in science, technology, and engineering and mathematics subjects in schools. LEGO education WeDo Robotics Construction Set and KIWI (Kids Invent with Imagination) robots with CHERP programming are the latest approach used for early childhood education.

In Ruzzenente et al. (2012), a study was done to survey the currently available kits for tertiary education in robotics. The selection criteria are (i) modularity (ii) re-usability (iii) versatility and (iv) affordability. The focus is on toolkits that allow ease of re-use to teach in different curricula (such as electronics, programming, or human-robot interaction). It also considered the interoperability with libraries and open-source frameworks. The integration was in the form of a robotic manipulator built with LEGO Mindstorm NXT and its integration with Matlab and the ROS robotic framework. However, Matlab and ROS are complex languages that will not be suitable for primary and secondary school students. Apart from having code based languages, MATLAB requires pre-requisite knowledge on C language. However, the 4 criteria in platform selection can be applied in choosing programming platform for primary and secondary school students.E.R. Kazakoff et.al. (2012) examined a software that is more suitable for children which is the CHERP (Creative Hybrid Environment for Robot Programming) software. The CHERP software programming is used for 1 week intensive robotic workshop for young children. CHERP is a hybrid tangible and graphical computer language designed to provide young children with an engaging introduction to computer programming.

The Creative Hybrid Environment for Robotic Programming (CHERP) system allows young children to program with interlocking wooden blocks or corresponding on-screen blocks and to transition back and forth between the two interfaces. The tangible block-based and graphical on-screen icons represent the same actions for the robot to perform in either case (Horn, Crouser, & Bers, 2011). CHERP is a hybrid tangible and graphical computer language designed to provide young children with an engaged developmentally appropriate introduction to computer programming.

PERMATA pintar Negara program in Rizauddin et al. (2010) conducted using the LEGO NXT Mindstorms for robotic and programming. The PERMATA pintar Negara is a unique program conducted by Universiti Kebangsaan Malaysia (UKM) where highly potential students all around Malaysia is selected based on IQ test called UKM1 and UKM2.It has been proved that during the 3 weeks camp, the students can upgrade their sense of creativity by developing various types of robot with the versatility of LEGO NXT Mindstorms. It helped to facilitate an active learning environment, interpersonal communication skills and programming skills among students. By using the LEGO NXT Mindstorms that has been largely used as an affordable, motivational and effective teaching material for robotic and programming, the camp can provide hands-on experience which gave the selected students the opportunity for creativity and sense of achievement. It has been proved that during the camp, the students can upgrade their sense of creativity by developing various types of robot with the versatility of LEGO NXT Mindstorms. Robotic construction kits such as LEGO Mindstroms, offer a new kind of manipulative for young children to explore and play with new concepts and ways of thinking.

In Bers et al. (2002), the software consisted of ROBOLAB, a graphical programming environment with tiered levels of programming. It allows users to drag and drop graphical blocks of code that represent commands such as left and right turns, reverse direction, motor speed, motor power, and so on. Users can drag the icons together into a stack, in a similar way than assembling physical LEGO bricks, and arrange them in logical order to produce new behaviors for a robotic construction (Figure 6).

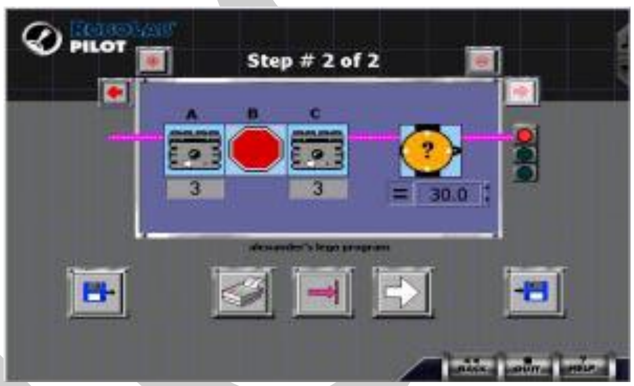

Figure 6. The *ROBOLAB* programming environment (Bers *et al.* 2002)

In Kazakoff et al. (2012), the LEGO education WeDo Robotics Construction Set used, is a robotics kit that allows children to build LEGO robots that feature working motors and sensors. Robotics offers children and teachers a new and exciting way to tangibly interact with traditional early childhood curricular themes. The work demonstrates that it is possible to teach young children to program a robot with developmentally appropriate tools, and, in the process, children may not only learn about technology and engineering, but also increase their sequencing abilities, a skill applicable to multiple domains – mathematics, reading and even basic life tasks.

In Ruzzenente et al. (2012), the hardware design were divided into complete starter kits and Integrated Robotic Lego Manipulator.

Hardware: Complete Starter Kits

Complete Starter Kits can be divided into two classes: versatile (Lego-like kits designed around basic building blocks) and non-versatile (such as industrial robots, household robots, robotic aircraft and humanoid robots. Versatile is valued because:

(i) it allows the possibility of morphological changes to the robot; and/or
(ii) whether it allows the possibility of expanding the hardware.

(i) Non-versatile kits: Manipulators

This type of kit allows the user to experiment with manipulators with different degrees of freedom (DOF).

Servobotics RA-02 Robotic Arm- The RA-02 Robotic Arm is an assembled manipulator that costs EUR 235. The kit includes servomotors, body parts, a PCB board and proprietary software to communicate with it.

Robot Arm Trainer- This manipulator is constructed for teaching basic robotics. It has five DOF and it is possible to interface with a PC using proprietary software. It costs approximately EUR 80.

Lynx- The Lynxmotion Arms of the AL5xx series is a robotic arm made of anodized aluminum and plastic; it has five DOF and a clamping tool. Control is done through proprietary software. Stand-Alone programming is available to adequately control a microcontroller (PIC, Arduino). The cost of this arm is approximately EUR 250.

(ii) Non-versatile kits: Household Robots

Pioneer Robot 3DX-The Pioneer 3DX is a differential drive vehicle, with two-wheeled motors, each implemented by a continuous current electric motor. It is equipped with an array of eight series sonar, arranged around the perimeter.

Khepera III Robot- developed by K-Team includes a mounted DsPIC processor which can be programmed in C or C++, 4KB of RAM and 66 KB of flash memory.

Hemisson- The Hemisson robot was specifically designed for robotics education.

iRobot Create- iRobot Create is a robot designed for educational robotics and is derived from the commercial product iRobot Roomba, a completely autonomous vacuum cleaner.

MiaBot- MiaBotPro is a robot developed by Merlin Robotics. Programming is done using the appropriate developer kit and the robot communicates via wireless and Bluetooth.

WowWee Rovio- The WowWee Rovio is a mobile robot equipped with a webcam that can be used to pilot the robot from a distance using a computer or cellular phone.

E-Puck- The E-Puck is a circular robot 75 mm in diameter, produced by the École Polytechnique de Lausanne (EPFL).

(iii) Non-versatile kits: Robotic Aircrafts

Skybotix's Coax Helicopter- The Coax helicopter kit consists of a micro-UAV project for the research market and educational robotics.

Parrot AR. Drone - The AR. Drone is a 4-propellered helicopter designed with the use of materials that are particularly light and resilient.

AscTec Quadrotor Pelican- This helicopter is developed for commercial markets for research purposes.

(iv) Non-versatile kits: Humanoid Robots

Aldebaran Robotics Nao- The robot, 50 cm tall, is completely programmable and extremely versatile.

(v) Versatile kits

Boe-Bot - BoeBot is a robot produced by Parallax. Albeit a bit dated in terms of hardware, it is still used for the versatility of its on-board electronics that can be easily upgraded. The price is approximately EUR 150 and is not supported by ROS.

Stingray Robot - The Stingray Robot from Parralax provides a mid-size platform for a vast range of robotic projects and experiments. This robot can be controlled via a proprietary programming language. The price is approximately EUR 335 and is not supported by ROS.

LEGO Mindstorm - LEGO Mindstorms are a line of product from LEGO, which combines programmable bricks with electric motors, sensors, LEGO bricks,

VEX - The Vex Starter Kit costs EUR 300 and contains more than 500 pieces, a configurable frame, a programmable microcontroller, 3 variable-speed motors, a servomotor, gears, 2 sensors for the bumper, various types of wheels and a radio controller for wireless control of the robot.

FischerTechnik - FischerTechnik is a division of the Fischer Group, which proposes solutions for the teaching of scientific topics for diverse academic levels, from primary levels to university graduate studies.

An integrated robotic Lego manipulator

The LEGO series seems to be an extremely versatile platform that can cover a variety of age groups with reported application in primary (Kazakoff et al.,2012), to tertiary level. In Ruzzenente et al. (2012), an example of the versatility of the LEGO Mindstorm NXT kit, the robotic manipulator is used which is integrated with Matlab/ROS for a higher education robotics course. Figure 7 shows the manipulator is controlled from a Matlab script, which sends commands to the robot through ROS. Using rviz (a ROS data visualization tool) one can see the kinematic model move in sync with the actual robot. If the robot were not present, the ROS commands would go directly to rviz, thus allowing for the debugging of the entire robot model without the need to access the hardware itself.

Figure 7. The LEGO robotic manipulator shown in real life and visualized through *rviz*.

In Bers et al. (2002), the LEGO Mindstorms robotic construction kits was used with a group of pre-schools children. The hardware is composed of the LEGO Mindstorms RCX, a tiny computer embedded in a LEGO brick (Figure 8). This autonomous microcomputer can be programmed to take data from the environment through its sensors, process information, and power motors and light sources to turn on and off. An infrared transmitter is used for sending programs from the computer to the Mindstorms RCX. The Mindstorms RCX has been the result of the collaboration between LEGO and researchers at the MIT Media Lab. Figure 8 shows the RCX programmable brick with the wheels, motors, and sensors.

Figure 8. The RCX programmable brick with wheels, motors, and sensors (Bers *et al.*, 2002)

In O' Connell, 2013, an electronics kit that enables robotic education activities that make sure of readily available classroom materials was described. The developed product, PaperBots Robotics Kit, open up accessibility to robotics education for users who formerly could not afford many of the available options. The controller is an Arduino based development board that is programmable by either the Arduino environment or with the Labview. Test groups of kindergarten to six grade students successfully constructed robots using paper, craft materials, and the PaperBots Robotics Kit. They were able to intuitively construct with the materials, and the kit and program their robots using a provided LabVIEW interface. The participants also enjoyed their experiences with the product while gaining some experience in engineering principle.

V. SUMMARY AND CONCLUSION

As reviewed, most of the software used by educators in secondary and primary schools involved block and graphical programming such as ROBOLAB and CHERP. Various hardware platforms were used by various researchers with the most popular being the LEGO series which produces several platforms for different age groups with LEGO Wedo for the younger groups and mindstorm series for the older students. Lego series robotics kits are versatile kits which can be configured into different shapes and structure that further allow flexibility in the activity design. There were two early childhood educational robotics curriculum available for implementation which are TangibleK curriculum for KIWI robot and LEGO WeDo curriculum, as proposed by Devtech Research Group by Tufts University.

However, there exist a myriad of other robotic products which some are flexible and some fixed structures as explained in Ruzzenente et al. (2012). As these products become available to the public, which some come together with support curricular, there is plenty of area that can be explored and refined by educators to meet specific objective in their application especially in STEM related curricular. Robots present an excellent platform for educators in connecting the abstract concepts in STEM subjects as compared with other forms of assistive tools. The application of robotics which combines elements of intuitive learning with constructivism learning enables students to learn and visualize the concepts at a higher level. With the available robotics platforms available in the market, education researchers need to continually explore the suitability of such products according to the specific age groups. The application of robotics in enhancing STEM subject education is still at an infant stage and can be further enhance and strengthen according to the respective demographic environment.

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