ASHESI UNIVERSITY COLLEGE

Robotics in the Ghanaian Classroom

Undergraduate Thesis

B.Sc. Computer Science

Kwadwo Busumtwi

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Robotics in the Ghanaian classroom

Undergraduate Thesis

Undergraduate thesis submitted to the Department of Computer Science, Ashesi University College in partial fulfilment of the requirements for the award of Bachelor of Science degree in Computer Science

Kwadwo Busumtwi

2016

DECLARATION

I hereby declare that this undergraduate thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: …………………………………………………………………..

Candidate's Name: ………………………………………………………………………

Date:………………………………………………………………………………………

I hereby declare that preparation and presentation of this undergraduate thesis were supervised in accordance with the guidelines on supervision of thesis laid down by Ashesi University College.

Supervisor's Signature: …………………………………………………………………

Supervisor's Name:………………………………………………………………………

Date:………………………………………………………………………………………

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Lastly, I would like to thank my family for supporting me throughout this thesis.

Abstract

Ghana needs more innovative thinkers and problem solvers to ensure sustainable growth for years to come. In the past, there have been revisions made to the Ghana educational curriculum to assist in development. Despite these changes, there still exists the predominant issue of rote learning occurring in the classroom. This leads to students being less independent as thinkers and problem solvers.

In recent years there have been studies and papers convinced that Robotics education in the classroom could enhance a student's critical thinking skills.

This study investigates the idea of using robotics in the Ghanaian classroom to garner more critical thinkers and problem solvers. This was done by having a teacher teach a group of students using Lego Mindstorms EV3 kits.

The results of the students who took part in the test were analyzed against students who did not take part in the study.

The result of the study were used to offer a suggestion for institutions looking to integrate robotics lessons into their classrooms.

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Chapter 1: Introduction

Problem-based learning is a method that challenges students to “learn to learn”. In Ghana there are a great number of students performing rote learning. This has led to some students having a poor foundation when it comes to critical thinking and problem solving techniques.

Ghana is a West African country located on the Gulf of Guinea. Regarded as one of the most stable African democracies, its main exports are gold and cocoa. The low level of industrialization in the country means development of roads, public/private goods and technologies are often outsourced to other countries. Like many African nations Ghana struggles to pay for basic imports and for social services (Adanu, 2008). A solution would be for the government to place emphasis on self-manufacturing to reduce cost. However, as recently as 2014, the African Economic Outlook reported a marginal growth of 1% for the manufacturing industry (Okudzeto, 2015). As early as 2007 Kwabena Asomanin Anaman et al noted that Ghana should push for the construction industry to be one of the main drivers for economic growth as against sticking to international funding. He expected that by 2015 Ghana would have progressed to become an industrial state (Osei-Amponsah, 2007). Unfortunately, Ghana at present is not an industrial state. Similarly Patrick Enu et al shared this sentiment and went a step further to provide examples of South Korea, Malaysia and Singapore as nations who went through low-income stage to progress to middle-income status through effective industrial policies (Enu, 2013). In order to ensure that the next generation of Ghanaian workers are technologically competent men/women, it is essential for learning techniques to be expanded on and to do away with rote learning.

Further academic papers have shown that there are deeper issues that seem to hinder the progress of education in Ghana. Patrick Awuah, co-founder of Ashesi University pointed out that problems with corruption, weak institutions and the leadership are contribute to the progress of development (Gouillart, 2009). To Mr. Awuah, education should serve a purpose of enlightening people to become responsible citizens and leaders of their respective nation. From the structure of the facilities and the curriculum used, all these factors needs to be taken into consideration. Mr. Awuah feels the educational system should be steered in a different direction if it is to prove beneficial to Ghana. Evidence from K. Akyeampong et al shows that students in African classrooms are learning by rote (Akyeamong, 2006).This issue leads to many students in school learning without necessarily understanding the concepts. As a result there is a situation in Ghana where students have little knowledge of the breadth of career options in Science, Technology, Engineering and Mathematics (Magnesi, 2007).

The Ghanaian Education system serves as the basis for the next generation of leaders that shall govern and define the outlook of the country. Whether Ghana remains a developing nation or progresses to a developed nation is dependent on the quality of men/women it produces for the forthcoming generation. The current Ghanaian national curriculum is narrow in areas such as in Mathematics and ICT (Buabeng-Andoh, 2014: Mangesi, 2007). The local school system, which operates throughout the country was modelled on a traditional British school system, and some textbooks are directly derived from British texts used in England years ago (Mawuli Gaddah, 2015). The focus is on rote learning, or learning by memorisation and repetition (Kwame Akyeampong, 2006). Although this can be effective for younger children, the lack of focus on individual thinking and problem solving is somewhat limiting. There are a number of institutions who, as a result, are making efforts to supplement the education of secondary students.

The Ashesi Innovation Experience (AIX)[1], hosted by Ashesi University College**,** is a 2 week long program held in August each year. A selection of high school students are chosen for this program. These students learn leadership skills in the first week and have the option of learning either robotics or entrepreneurship the following week. The goal of the program is to give students the opportunity to apply themselves in a constructivist way and in the process, broaden their thinking. This is done by teaching the students how to think critically and develop problem solving skills. It is well understood that a hands on approach to learning gets students excited about engineering and computer science (Maja J Mataric, 2007). The AIX program is a great example of how we can use robotics as a medium to get more students interested in Science Technology and Mathematics (STEM). STEM programs are of dire importance in today's society and have been shown to inspire innovation, new ideas and new industries (David Langdon, 2014). The current President of the United States of America (USA), Barack Obama has made it his priority to increase the number of students and teachers in these fields. His goal is to make American students reach their fullest potential in science and mathematics (U.S. Department of Education, 2015). This explains

[1] http://www.ashesi.edu.gh/academics/outreach-programmes/aix.html

why in 2009 the USA spent $4.7 billion. They are not alone in this, in 2009 the UK spent £2.5 billion on educational ICT whilst in New Zealand $410 million is spent every year on schools (Buabeng-Andoh,2014). The Ghana government has invested millions of dollars in to ICT facilities but they are unsuccessful in combining ICT in supporting learning . Buabeng-Andoh et al found that students attitudes towards technology is more as a tool for communication with peers. This is an example of how narrow the idea of technology is for students. There is however a branch of technology that helps widen career perspectives this branch would be that of robotics.

Studies have shown that robotics courses have benefited students. Students are given an opportunity to use their creative skills to design, program and operate their own robot (Brand, 2008: Alfieri, 2015: Parsons, 2004). These students tend to exhibit an increased understanding of concepts and increased confidence in work. Certain concepts of mathematics can be learnt through robotics. A case study by Eli Michael Silk attests to this fact. He investigates at length how robotics offers mathematical thinking to the end user through the real world manipulation. Instead of only studying theory the students put into practice mathematical concepts. For instance, the concept of covariance and quantitative relations involves recognizing that a change in one quantity affects a change in a related one (Silk, 2001) . One example of this theory is students realizing that increased motor rotations lead to an increase in distance covered by the robot. Some students find it easier to understand math concepts when they see them being applied in a real scenario. Through the numerous projects students work on, they gain a better understanding of the use of the circumference and other mathematical concepts by operating their robots. The Ghanaian Ministry of Education, by establishing an integrated system of scientific, technological and social innovation, aims to provide quality education for Ghanaians to help them promote rapid socio-economic growth (The introduction of ICT, 2009). Incorporating robotics into the Information and Communications technology (ICT) curriculum can prove beneficial for the nation through its influence in Computer Science and Mathematics (Ruzzenente et al, 2012). More importantly, it aims to broaden awareness of Science Technology Engineering and Mathematics (STEM) fields amongst Ghanaian students.

STEM is highly important in attaining an industrial society because of its ability to drive innovation and technological advancements. In the USA great advancements have come from those in the areas of STEM (Langdon, 2014). As highlighted before, Ghana is in a position where there is low annual growth in manufacturing, a limited education curriculum and narrow thinking of students (Adanu, 2008) (Charles Buabeng-Andoh, 2014) (Osei-Amponsah K. A., 2007). However it is this researcher's opinion that students will be motivated to pursue careers in STEM fields for professional work.

This would encourage more technological innovators to be brought into the nations' workforce; innovators who will be equipped with critical thinking and problem solving skills (Brand,2008). The largest example of this sort of activity are the robot competitions sponsored by FIRST (For Inspiration and Recognition of Science and Technology), an organization in the United States of America. FIRST estimates that over 212,000 students from age 6-18 participated in their four levels of robotics programs in 2009 (Silk, 2001). A stated goal of FIRST is to get young people to celebrate students who build and innovate with engineering and technology. Ashesi's AIX programme bears a strong resemblance to FIRST in this manner.

This thesis explores the idea of integrating robotics into the current Ghana Education System (GES) Information and Communication Technology (ICT) curriculum. A robotics module will be tested on a group of Ghanaian students in the Greater Accra Region. The aim of this paper is to investigate whether a robotics initiative heightens critical thinking and problem solving skills in high school students and gets more students interested in STEM (Science, Technology, Engineering and Mathematics). During the testing phase of the study, a curriculum will be tested on a group of high school students on which of these attributes will be measured and analysed. The main question this paper wants to answer is can robotics lead Ghanaian students to think critically and solve problems? Can this study get more students interested in STEM fields? Finally can students understand concepts of mathematics more easily as a result of this education?

Chapter 2: Related Work

There are a number of recent case studies which involve the idea of bringing robotics to tertiary institutions. Despite this, there has not been enough evidence of institutions at the junior high school level establishing such a model. It is therefore vital to take a deep look at these solutions that exist elsewhere. This chapter is mainly concerned with identifying relevant discussions on testing and applying robotics concepts on students. From these, we can ascertain in what ways robotics develops students education.

A robotics study was conducted in Ghana by a team at Ashesi University (Tettey et al,2007). The study's main objective was to heighten the students' capacity for problem solving through robotics. Classes met three times a week for nine weeks. In these classes, students were introduced to technologies like Linux, handy Board, the C programming language and basic electronics. Students benefited with an increase of confidence in their technical skills, greater awareness of research and garnered technical creativity. Frank Klassner et al established a similar project in Villanova University. Students taking this course were involved in projects like the Simple-Reflex Robot Design, Sensor Accuracy, and Robot Odometry, an individual "Capture the Balls" Contest, a team-based "Capture the Balls" contest and Robotic 8 puzzle solver. The researchers go on to suggest HandyBoard and Lego Mindstorms as being a good foundation for robotics laboratory in AI. Similar to the study in Ashesi University, students exhibited increased understanding of programming concepts and increased confidence. In both cases students strengthened their programming skills. This means they will be equipped with programming fundamentals at an early age which will serve them well in the professional world.

There are a number of researchers who offer opinions on robotics education. Researchers such as M.J. Mataric are pushing for robotics education to be expanded to the high school level. Compared to other studies, the researcher is keen to emphasize the advantage of bringing robotics to the younger generation. Mataric indicates that robotics helps convey concepts from math and science. Louis Alfieri et al (Alferi etl al,2015) are of the same school of thought. In their findings, students are more likely to see the relevance of mathematics because of the direct application of these concepts to programming tasks. This caused the researchers to coin the phrase "Robot Math" as a means to define these applications. Robot Math involves teaching proportional reasoning to students as a skill. The purpose of doing so was to equip students with skills to aid in daily decision making. Alfieri et al points out a number of factors that could de-stabilise mathematics learning such as incorporating too many mathematical methods. They therefore suggest more focus on mathematical concepts and avoidance of guess-and-check work by students. They propose that a robotic programming game that supports robot mathematics will touch on these factors. The game they designed is based on Abstraction Bridge Problems, a series of math word problems. Before and after using the game, students were asked to do an algebra test to rate their experience with the tasks. From the test results at the end of the game, it was realized that students had exhibited notable changes in their knowledge level of algebra to the point that it rose above their grade level. Students were given a pre-test to judge their grade level, algebra-taking plans and their familiarity with robots. There was a significant increase in student robotics interests and student appreciation for mathematics.

To teach robotics, the tool is almost as important as the method of teaching. The use of LEGO Mindstorms as a teaching tool for robotics is common throughout the literature reviewed. Simon Parsons et al (Parsons et al, 2004) outlined projects done using Lego Mindstorms. They detailed challenges done with the robots such as making use of robot sensors for tasks such as line following and colour detection. Researchers made use of this tool for a number of reasons. The first reason was the graphical user interface (GUI) environment of Mindstorms makes it easier for the students to learn programming as against using a text editor. Moreover, students find the robots intriguing and in working with the LEGO kits, their interest rarely waned. An alternative to this tool is use of robotic simulation (Liu,2013). The researcher reports on using Robotic Virtual Worlds curriculum as a medium to teach robot programming. It is noted in this paper that robotics involves various machines ranging from cell phones to bank machines. This further highlights the depth of robotics education. This study used an ANCOVA (analysis of covariance) to analyse two groups, one working with the Physical Bots and one working on the Virtual environment. Evidence provided by (Allison Liu, 2013) Liu et al showed learning with physical bots had the same test results but noted that learning with virtual environments is often slower in getting students to grasp concepts. Between the two technologies, Mindstorms and Robotic Virtual Worlds result in increased skills in programming. However, the mechanical side of robotics is less clear in using Virtual Worlds.

One of the main objectives of this thesis is to ensure students increase their capacity to think critically and gain problem solving skills. Elizabeth Mauch (Mauch, 2010) observed this with the robotics course she constructed. In her study she placed emphasis on getting students to understand the problem solving process. Students undertook a number of challenges which involved having to adopt cooperative learning and group problem solving. In doing so they developed communication and team-building skills. The key component of the course was the use of Lego Mindstorms. During the first week of the program, teachers familiarised themselves with the system. The course was also designed to help teachers explore why students become frustrated when presented with exercises that include solving math. By the end of the second week, forty students in grades six, seven and eight were enrolled in a one week camp. By the third week, teachers looked to discuss how they could integrate the system into their curriculum. In this week, teachers were taught how to implement robotic lessons using Lego Mindstoms in the classroom. By the end of the camp, students had created their own Lego robots. They also competed to see which group's robot could push a golf ball across a floor the quickest. Elizabeth's Mauch paper points out it is vital to not only educate students in robotics education but teachers looking to teach it. The gap in this research is that it does not detail how they discussed robotics being integrated into the curriculum.

Dr. Eric Wang and Dr. Rogers (2004) wrote the book "*Engineering with Lego Bricks and Robo Lab*". In this book Dr. Wang and Dr. Rodgers aimed at making engineering education less tedious for young students interested in the field. He fills the book with numerous engineering challenges t. The book uses Lego bricks to teach students principles of computer science, engineering and physics. Another aim of the book is to challenge students to apply creative thinking strategies to solve open ended problems. He does this by using the lesson plan to let students apply engineering principles and problem solving methodologies. One example of a methodology is the design process. To the authors the design process revolves around problem identification, exploring alternative solutions, design, optimize and communicate. The relevance in this research is it provides an alternative way of heightening reasoning skills amongst students.

William Church et al acknowledge that robotics gives students a chance to design and test programs with a hands on approach (Church, 2010). Church details how students partook in activities such as 'Testing Speed vs. Acceleration of Drag Cars' 'Simple Harmonic Motion', 'Ten Second Timer' and 'Microphone Sound Reduction'. In each case students worked in a team using various sensors to measure and analyse their robotics in various scenarios. They were expected to use concepts from their high school physics curricula to explain these concepts. For example in the ‘Testing Speed’ challenge students used the rotation sensor to measure distance, speed and acceleration of their car. In their analysis they had to compare factors that may affect speed and acceleration of the robot car. The findings of this project were that students were engaged more intensely with the work than other velocity vs. acceleration physics activities. Church et al found that robotics in the classroom is beneficial for conceptual knowledge development through its activities. Students exhibited heighted communication skills and became more confident as time went on. It is interesting to note that the researchers find some of their evidence may be anecdotal and further studies are needed.

Having spoken about the benefits of a robotics initiative in the secondary level, it is also good to examine how to best optimize the program. Mataric et al (Mataric, 2007) goes in depth to emphasize a need to make resources available and affordable for institutions. She details how robotics in educational institutions would reduce boredom in the classroom and increase hands-on learning. On the subject of STEM, the researcher is in agreement that STEM topics are not popular with children and students and indicates there is an undersupply of people in these jobs. Their solution was to design a robotics course that teaches science to middle school-level students. The robotics platform used in this program was the iRobot Roomba and Create platforms. The researchers were critical of the lack of affordable robotic platforms. They observed that robotic platforms in the current market must be truly inexpensive for schools to afford them. Affordable educational robots is a sentiment shared by Korsah et al. They find that there is a need to find a more proficient tool than Lego that is affordable for sufficiently low-cost for institutions without large hardware budgets. There exists a common issue of affordability in infusing robotics into the educational paradigm. Ernest Gyebi et al made note of institutions which have taken action to deal with this issue. In South Africa, the University of Cape Town teamed with Aachen

University to design a robotic platform for use in RoboCup Junior Competitions and education (Gyebi, 2013). The research also makes note of the African Robotics Network (AFRON), an organisation which has devised solutions to counter the issue of costly robots. The AFRON came up with the "Ultra Affordable Educational Robot" project which encompasses three robot design challenges: Tethered, Traditional (roaming), and All-In-One (self-contained). The objective of this programme is to design affordable robots which can be programed simply (Gyebi, 2013). The relevance of the AFRON's findings is that they make a detailed analysis of affordable educational robotics for institutions, a common void found in the research.

In conclusion, the studies in this chapter are important for their technologies and techniques used in bringing robotics to the classroom.

2.1 Contributions of this Thesis

Whereas work from other researchers have investigated the idea of robotics in the classroom, this study will investigate how it could be of value to education in the junior high school level. This paper is relevant for schools that have an ambition to expand their ICT curriculum.

Chapter 3: Methodology

This study primarily seeks to analyse whether robotics increases critical thinking skills and problem-solving capacity. To do this a study was conducted in a junior high school. This chapter describes the overall design and implementation of the study. It describes the materials used, the lessons constructed and how participants were chosen.

3.1 Research Design

In order to answer the primary research question a robotics module was designed. To conduct this test 9 students were selected with a minimum background of ICT at the JHS level from Mt. Olivet School. Students involved in the study had no prior experience in robotics. A control group of 9 students were also selected to gauge growth in problem solving with the test group. The overall sample contained 18 students (44% male, 55% female), with an age range of 13-14 years (median age was 13 years). Students were chosen at random by their teachers. The course is structured to revolve around problem-based learning in JHS mathematics. As a result, the topics taught were based on the JHS 2 curriculum for the second term.

The equipment used for this study were Lego EV3. The Lego EV3 was chosen for this experiment because of the affiliation Mt. Olivet has with the Robotics Inspired Education (**RiSE).** The mission of RiSe is to inspire students to pursue avenues in science, technology, engineering and mathematics. As part of the institutions partnered with RiSE, Mt. Olivet have been provided with 2 Lego EV3 kits. The EV3 kits contain software and hardware for students to create and program their own robots. Each kit consists a number of sensors and motors to enhance robot customization.

The lesson plans and material used in this chapter are included in Appendix 4.

3.2 Methods/Procedures

The experimental group met twice a week for an hour in a total of four weeks from the 8th of March to the 7th of April. The program was coordinated by an ICT teacher at Mt. Olivet.

Table 3.2

Curriculum Outline		
module	**Title**	**Duration(teaching periods)**
C.1	Introduction	1
C.2	Construction of Robots	1
C.2.1	Programming Robots	2
C.3	Going the Distance challenge	2
C. 3.1	Move in a square	1
C.4	Navigation Challenge	2
	Total	**9 hours**

The first week was used for pretesting and introducing students to lessons. Prior to the first activity both the test group and the control group were given a number of problems to solve. Afterward students in the test group were introduced to the class by building a basic robot from the EV3 manual. This was done in order to make the students have hands on experience with the equipment. In the next lesson, the students were involved in a team communication exercise by building a LEGO EV3 robots through instruction. To generate team cohesion 2 students built a robot while one person, the group leader, instructs them on building the robot. They did this whilst sitting back to back. The purpose of this exercise was to help develop oral communication skills.

In the second week (15th March) the students were instructed by the ICT teacher on the fundamentals of the EV3 software using action blocks. Action blocks control program actions by using motors, images, sound and light on the EV3 brick. To make the activity more challenging students were instructed to prepare for a race with the other groups. The purpose of this was to give students extra motivation. The students had to determine the number of rotations they would need to cover the track and time their robots best time. The following day the students had a race to determine who had designed the best program. Students were graded based on their speed and motion.

Fig. 3.1: A group's robotic car

In the third week the instructor made the students start the Going the Distance challenge. This challenge consists of the students designing, building and calibrating a robot car to travel a specified distance.

The three groups program their cars at various speeds and record the distance travelled at motor powers of 35%, 75% and 100%. On a graph sheet, they plot the recorded distances using a line graph. The purpose of this exercise was to provide a discussion on how increased power in addition to time affected distance covered by the car. In doing so students were gradually introduced to proportion.

Each group composed an analysis of the data uncovered. Due to the Easter holidays the students could not participate in the study during the fourth week.

As a consequence, the Move in a Square activity was moved the week of the 30th of March. However due to students having examinations the study was pushed further to 4th April. During this week the students learned how to use the large motor, move Steering & move tank block to make angled turns

The Navigation Challenge involves the students programming their robots to move through a sketched map whilst staying on the dark line. The majority of this challenge involves combining the logic of the Going the Distance Challenge with that of the move in a square challenge. At this point students have successfully managed to get their car movements

This study seeks to analyse whether students can think critically and solve problems as a result of this education. To answer this question a series of critical thinking learning problems was instilled within the course to engage and expand the learning of the class. The ICT teacher after every lesson asked the students a number of questions. What did you enjoy the most about the activity? What part of the activity was the easiest? What did you observe?

The point of these questions is to act as a reflection for the students. In addition it forces them to probe why their solution is the most efficient for their task.

At the end of the experiment students will be tested again in order to record any changes in their cognitive-reasoning skills.

3.3 Data Collection tools

For this study, the main tools used in collecting data were tests composed of mathematical story problems. The tests were scored based on the Assessment Rubric for Critical Thinking (ARC) from St. Petersburg College. This method was adopted to measure changes in critical thinking skills from the beginning till the end of the experiment.

Fig 3.3: ARC scoring card

Performance Element	Exemplary (4)	Proficient (3)	Developing (2)	Emerging (1)	Not Present (0)	Score
III. Problem Solving *Select & defend your chosen solution.*	Thoroughly identifies and addresses key aspects of the problem and insightfully uses facts and relevant evidence from analysis to support and defend potentially valid solutions.	Identifies and addresses key aspects of the problem and uses facts and relevant evidence from analysis to develop potentially valid conclusions or solutions.	Identifies and addresses some aspects of the problem; develops possible conclusions or solutions using some inappropriate opinions and irrelevant information from analysis.	Identifies and addresses only one aspect of the problem but develops untestable hypothesis; or develops invalid conclusions or solutions based on opinion or irrelevant information.	Does not select and defend a solution.	4 3 2 1 0 ○ ○ ○ ○ ○ **N/A** ○ **Comments:**

3.4 Data Analysis

The scores of the control and experiment groups were compared to gauge the difference in their cognitive reasoning. To do this we used four elements of the ARC rubric: Communication, analysis, problem solving and evaluation.

Chapter 4: Results

This section analyses the results of the pre and post test data. This data is used to answer the primary research question. It also notes observations and recommendations for the study. The Full text of the tests used are included in Appendix 3

4.1:Pre-Test and Post-Test Analysis

The results below show the pre-test and post-test scores for the problems the control and experiment group solved.

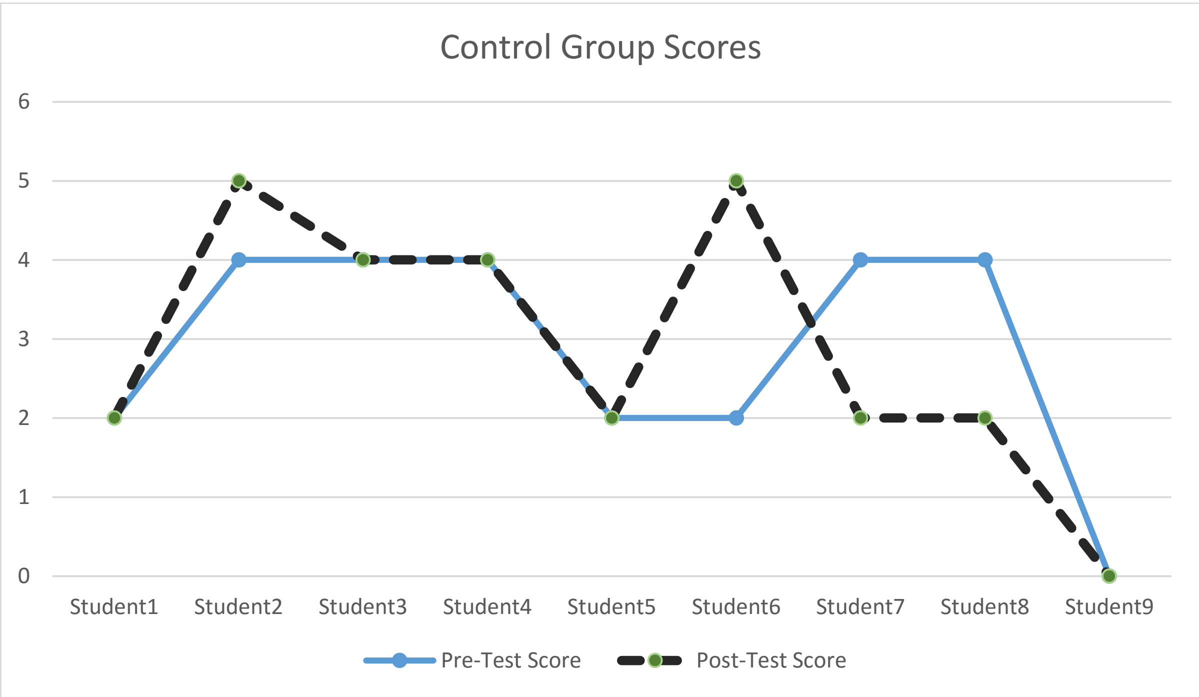

Figure 4.1

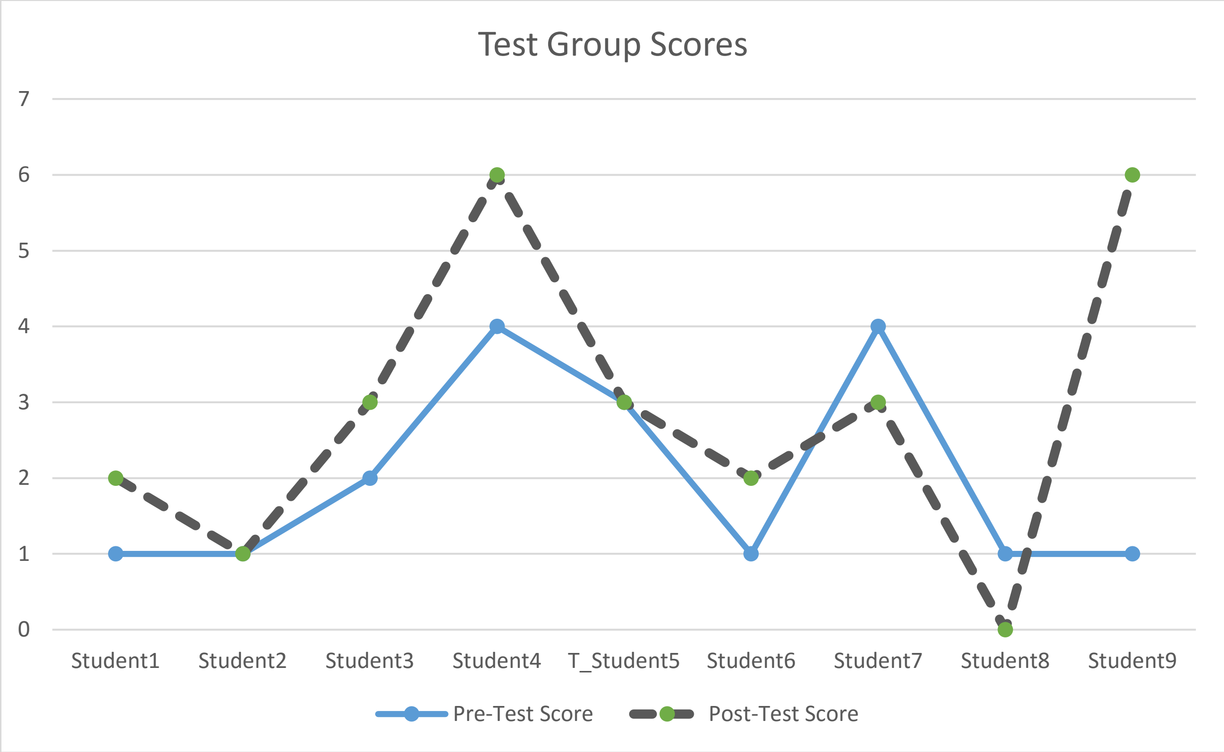

Figure 4.2

As shown from the diagrams above, the scores of the test group improved significantly in comparison to the control group. It is interesting to note that some of the students in the Test Group did far worse than the pre-test.

To illustrate the difference in the two groups the mean difference was calculated and is shown below.

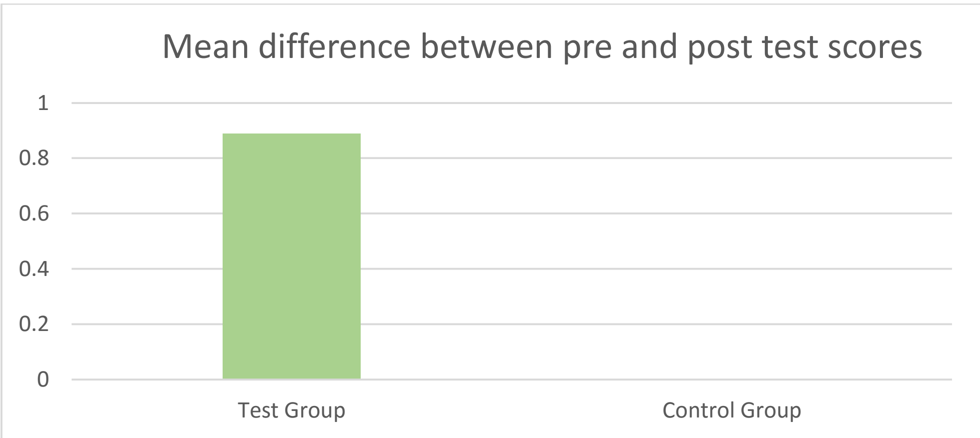

Figure 4.3

To answer our main research question we used the ARC metric to measure how the students' cognitive reasoning changed over time. The graph below shows how the students measured up on the ARC metric.

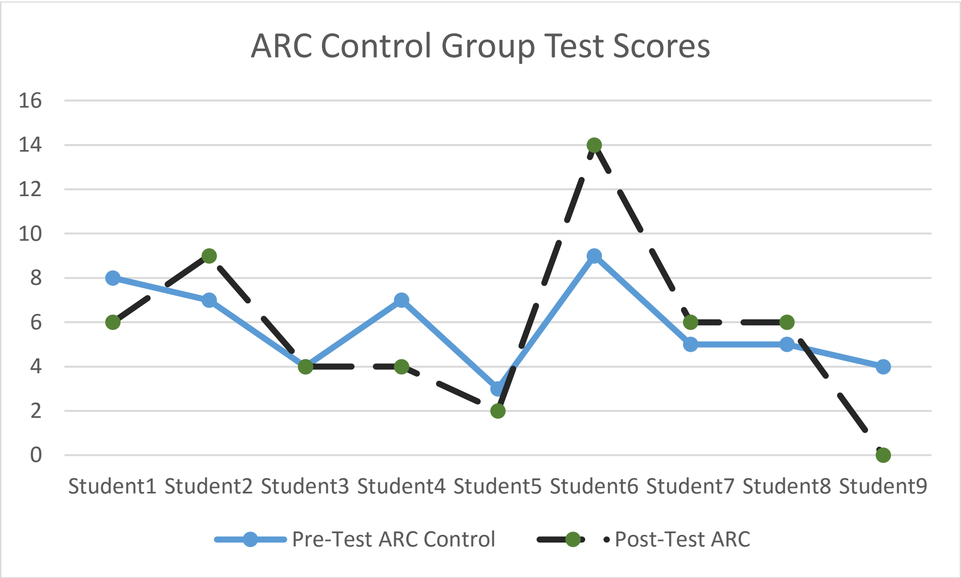

Figure 4.4

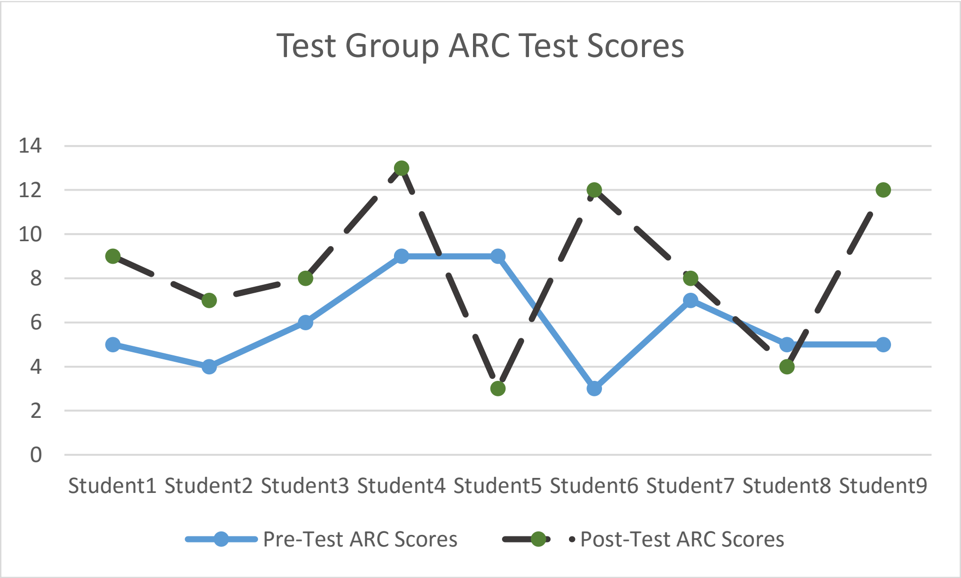

Figure 4.5

From the diagrams above we can observe that in terms of their problem solving skills the test group did better than the control group.

Again, calculating the mean difference we can illustrate this more clearly below

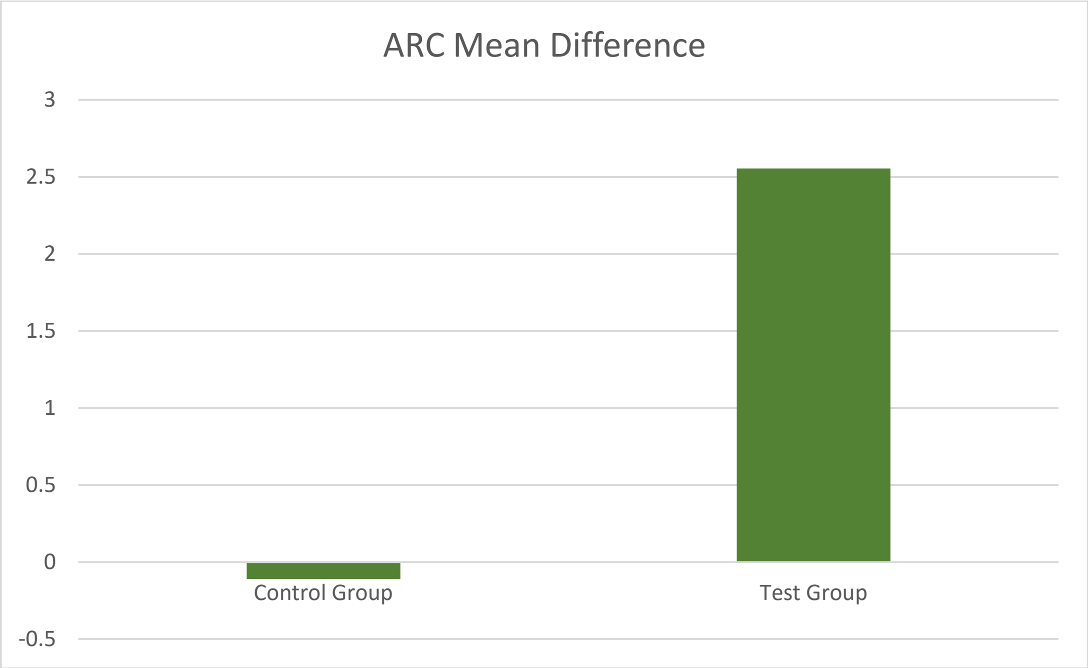

Figure 4.6

From the diagram above we can see that the Test group's problem solving skills improved.

Another aim of this thesis is to determine whether this study gets students more interested in STEM fields? Students were asked at the end of the study whether they were more interested in studying ICT due to the study. Feedback from the test group is show below

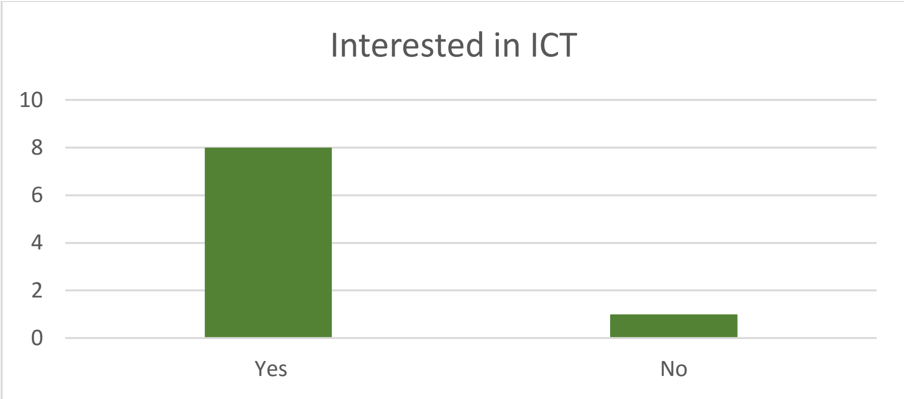

Figure 4.7

From the feedback received 88% of students became more interested in ICT due to this education.

This study is also focused on determining if students found greater confidence to solve mathematics problems. The data below illustrates this.

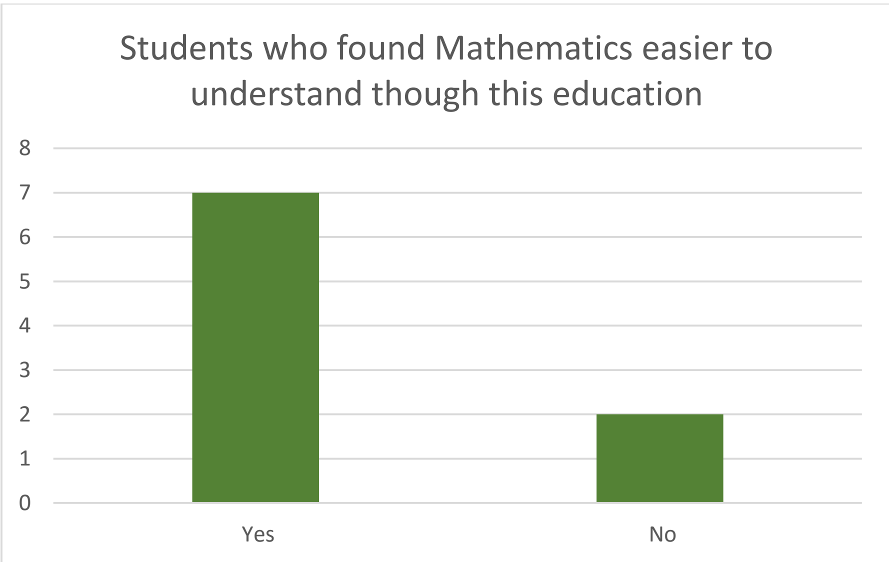

Figure 4.8

4.2 Observations

Students who took part in this study were from the very beginning very optimistic about what they would be learning. Some students wanted to make a robot they could have conversations with. Another group of students were not sure what they wanted to be in future so were hoping to explore through this program.

From the first day it was clear teamwork would be a huge issue. There were several disagreements between groups about how they wanted to proceed with things. It is not surprising then that for some students the most important lesson learnt was acceptance of other people's ideas.

4.3 Challenges

This study was conducted by an ICT teacher who was generous enough to learn how to program and construct the LEGO EV3 without any previous knowledge. Unfortunately, on occasion he had to take leave due to personal issues. This meant the classes sometimes had to be cut short or moved to other days.

Some of the students had after school classes and as a result could not make an appearance for every single class.

4.4 Recommended features for robotics education in JHS

- **Eliminate the price-gap:**

  There still exists the price gap when it comes to getting schools to acquire Lego Equipment. The equipment is still too expensive to expect such a project to be brought to the public schooling system. As a result an investigation should be done to find less costly equipment. At present, organizations like the African Robotics Network have designed robotics equipment which come with their own unique equipment.

- **Keep the link with the GES curriculum:**

  This education has extra value if it simplifies transmitting course knowledge to students. From our investigation, students in the test group able to thoroughly understand a small portion of their educational curriculum through the program.

- **Push for more innovation:**

  Unfortunately, the students could not have the opportunity to design more cars. In future project implementations there should be more hands on work when it comes to customization.

- **More teacher training:**

  The material provided at present is too little for an institution to train their teachers. Revisions should be made for more teachers.

Chapter 5: Summary

This study investigates the effects of a robotics education on critical thinking skills in students at the JHS level. As stated previously, the scope of this project is bigger and should be investigated further.

Our study revealed that robotics does indeed lead to increased problem solving skills using the ARC metric.

In addition, students were more enthused with the idea of studying ICT as a result of this education and had greater confidence in their problem solving abilities.

A greater student sample should be tested on and more material provided to students and institutions wishing to adopt this model in their schools.

5.1 Limitations

This scope of this study requires a bigger sample size. To ultimately determine if robotics education leads to greater critical thinking and problem solving skills it should be replicated elsewhere. Otherwise the results only speak for Mt. Olivet Methodist Academy and not necessarily the GES system.

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Appendix

Appendix 1

JHS Curriculum: Ratios and Proportions

UNIT	SPECIFIC OBJECTIVES	CONTENT	TEACHING AND LEARNING ACTIVITIES	EVALUATION
	The pupil will be able to:			Let pupils :
UNIT 2.11 **RATIO AND PROPORTION**	2.11.1 express two similar quantities as a ratio	Comparing two quantities in the form a : b	Guide pupils to compare two similar quantities by finding how many times one is of the other and write this as a ratio in the form a : b E.g. Express 12km and 18km as a ratio i.e. 12 : 18 = $\frac{12}{18} = \frac{2}{3}$ = 2 : 3	find the ratio of one given quantity to another
	2.11.2 express two equal ratios as a proportion	Expressing two equal ratios as a proportion	Guide pupils to express two equal ratios as a proportion. E.g. 12km, 18km and 6 hours, 9 hours can be expressed as a proportion as follows; 12km : 18km = 6 hours : 9 hours 2 : 3 = 2 : 3 i.e. $\frac{12km}{18km} = \frac{6hours}{9hours}$	express given ratios as a proportion
	2.11.3 solve problems involving direct and indirect proportions	Direct and Indirect proportions	Guide pupils to solve problems involving direct proportion using: (a) Unitary method E.g. If the cost of 6 items is GH¢1800, find the cost of 10 items; i.e. Cost of 1 = GH ¢ $\frac{1800}{6}$ = GH¢300 ∴ cost of 10 = GH¢300 x 10 = GH¢3000 (b) Ratio method	solve real life problems involving direct and indirect proportions

JHS Curriculum: Ratios and Proportions

UNIT	SPECIFIC OBJECTIVES	CONTENT	TEACHING AND LEARNING ACTIVITIES	EVALUATION
UNIT 2.11 CONT'D) **RATIO AND PROPORTION**	The pupil will be able to:		Express the two quantities / ratios as proportion. The ratios are 6 : 10 = 1800 : n $\frac{6}{10} = \frac{1800}{n}$ n = $\frac{10 \times 1800}{6}$ n = 10 x 300 n = GH¢3000	Let pupils :
	2.11.4 share a quantity according to a given proportion	Application of proportion	Guide pupils to apply proportions in sharing quantities among themselves. E.g. Ahmed and Ernest shared the profit gained from their business venture according to the proportion of the capital each contributed. If Ahmed contributed GH¢100 and Ernest contributed GH¢800 and Ernest's share of the profit was GH¢100, how much of the profit did Ahmed receive?	apply proportions to solve word problems
	2.11.5 use proportion to find lengths, distances and heights involving scale drawing	Scale drawing using proportions	Guide pupils to find lengths, distances and heights involving scale drawings. E.g. The height of a tower of a church building in scale drawing is 2cm. If the scale is 1cm to 20m. How tall is the actual tower? i.e. 1m = 100cm ∴ 20m = 2000cm 1 : 2000 = 2 : h $\frac{1}{2000} = \frac{2}{h}$ h = 2 x 2000	find the actual distances from scale drawings E.g. maps

UNIT	SPECIFIC OBJECTIVES	CONTENT	TEACHING AND LEARNING ACTIVITIES	EVALUATION
UNIT 2.11 (CONT'D) RATIO AND PROPORTIONS	The pupil will be able to:		= 4000cm ∴ actual height = 40m.	Let pupils :
UNIT 2.12 **RATES**	2.12.1 express two quantities as a rate	Rate as a ratio of one given quantity to another given quantity	Guide pupils to recognise rate as the ratio of one given quantity to another given quantity. E.g. A car consumes 63 litres of petrol per week. i.e. 9 litres per day. Explain other examples of rates E.g. bank rates, discount rates etc.	express two quantities used in everyday life as a rate
	2.12.2 solve problems involving rates	Simple interest, Discount and Commission	Guide pupils to solve problems involving: (a) Simple Interest E.g. Calculate the simple interest on savings of GH¢1000 for one year at 20% interest rate. i.e. GH¢1000 x $\frac{20}{100}$ = GH¢20 (b) Discount E.g. A discount of 10% is allowed on goods worth GH¢6000. What is the new price? i.e. $\frac{10}{100}$ x 6000 = GH¢600 ∴ discount = GH¢600 New price = GH¢5400 (c) Comission E.g. Calculate 15% commission on a sale of GH¢1000 i.e. $\frac{15}{100}$ x 1000 = GH¢150	find the simple interest on savings find commission on sales calculate the discount and new price of goods

Appendix 2

Pre-Test Questions

Directions: Show all work, describe how you got the answer using mathematics and words, and circle your final answer.

Problem1:

The Problem: Two friends are having a competition to see if they can cycle at the same speed. In order to synchronize their bicycles, they first tried to make them both travel the same straight distance. Kofi cycled at 1100 degrees of wheel rotations and travelled forward 100.7 metres. Kwame completed 1100 degrees of wheel rotations, but only travelled forward 65.2 metres. How many rotations should Kwame complete in order to move at the same distance as Kofi? Explain your answer using math and words. Why did you choose this method to solve this problem? Could you have used an alternative?

Kofi			
	Target Distance	Wheel Rotations	Actual Distance
1	150m	1100	65.2metres
2	150m	?	100.7metres

Problem 2:

Nii Apa needs six new parts for his car. One part costs Ghc500 each. He has Ghc2,000 to spend. Does he have enough money for the parts? If not how much more does he need?

Problem 3:

Jude wanted to visit his friend Nanette at Mt. Olivet. When he got to the school he heard that she was at the school canteen. Feeling confused, he asks you to direct him to the canteen from the school gate. Explain in detail how you would direct Jude.

Problem 4:

For Valentines Day Langford is going to buy a rose for Baaba. To get to the florist he has to move 200 metres. He covers 100 metres at a speed of 20 metres/s . How long has he travelled for and how long till he gets to the florist?

Appendix 3

Post-Test Questions

Directions: Show all work, describe how you got the answer using mathematics and words, and circle your final answer.

Problem 1:

The Problem: Two friends are having a competition to see if they can cycle at the same speed. In order to synchronize their bicycles, they tried to make them both travel the same straight distance. Kofi cycled at **1100 degrees** of wheel rotations and travelled forward **100.7 metres**. Kwame completed **1100 degrees** of wheel rotations, but only travelled forward **65.2 metres**. How many rotations should Kwame complete in order to move at the **same distance as Kofi**? Explain how you came up with your answer in detail.

Kwame			
	Target Distance	Wheel Rotations	Actual Distance
1	150m	1100	65.2metres
2	150m	?	100.7metres

Problem 2:

Antoinette needs 10 new parts for her car. One part costs Ghc100 each. She has Ghc800 to spend. Does she have enough money for the parts? If not, how much more doe she need?

Problem 3:

Jude wanted to visit his friend Nanette at Mt. Olivet. When he got to the school he heard that she was at the computer lab. Feeling confused, he asks you to direct him to the lab from the school gate. Explain in detail the steps Jude has to take to get to the lab.

Problem 4:

To celebrate Easter, Robert has to do some shopping at the market. To get to the market he has to travel a distance of 600 metres. On his motor bike he covers 10 metres in 60 seconds. How long till he gets to the market? Graph his journey on a line graph.

Extra questions

1. Are you more interested in ICT now as a result of the robotics lessons? Circle either yes or no.

   Yes / No

2. Do you find mathematics problems easier to solve now? Circle either yes or no.

   Yes/No

3. Do you think you will find mathematics easier to understand if you had more of these lessons? Circle either yes or no.

   Yes / No

4. What was the most important lesson you learned? Explain

____

____

____

____

Appendix 4

<u>Curriculum</u>

Description

This study will cover the basics of robotics using the EV3 tool kit. Topics covered include will revolve around distance, time , speed, angles and ratios and proportions. This course will include programming in the Graphical Language. Lessons will be for an hour.

Course Objectives

By the end of this module Students will be expected to gather critical thinking ability in ICT. In addition students will be able to integrate ICT tools into specific Mathematics.

Students will be able to

- Thoroughly explain ideation steps towards solving problems
- Develop programs using Graphical langauge

Course Material

Lego NXT Kit, Computers with loaded software for each robotics platform or activity, tables for planned demonstration & an assistant facilitator

Evaluation

Students will answer problems that requires some of the skills they will learn in the class. There will be a control group who will not partake in the class but in the pre and post-test phases. The students enrolled in the robotics course will also take the pre and post-test problems. The results of the two will be compared to determine whether the core principles of the course were successfully taught.

Learning Strategies

1. **Interactive lessons**: If presenting to the whole class, the presentation needs to be short and interactive. When asking whole class questions give plenty of wait time. Don't cut off slower students' learning by calling on the first hand that comes up. Don't express judgement of responses. When an answer is off target, try to figure out and address the student's reasoning. Have students with accurate responses explain their reasoning or strategies as well. Part of the purpose of an interactive lesson is to assess understanding of the content presented. Therefore, you must ask questions and assess students' understanding (asking "does everyone understand?" is NOT usually helpful). A strategy for gaining feedback from a range of students must be employed.

2. **Use small group activities**: Following the whole class presentations, small group and or independent practice needs to take place. In small groups, students should talk about strategies and help each other with the learning task. It is important for the teacher to walk around and assess individual understanding during small group work and independent practice.

3. **Large group discussion:** Getting responses from the large group also helps students see there is usually more than one way to solve a problems and different strategies can be evaluated.

4. **Lesson Closure**: Asking simple reflection questions at the end of a lesson helps students attach meaning to the knowledge and store it in long term memory. Ask students to respond orally or in writing to questions like:
   - What did we learn today?
   - How does what we learned today connect to or add to something we have already learned?
   - How can what we learned today help us in the future?

Curriculum Outline		
module	**Title**	**Duration(teaching periods)**
C.1	Introduction	1
C.2.1	Construction of Robots	1
C.2.2	Programming Robots	2
C.2.3	Going the Distance challenge	2
C. 2.4	Move in a square	2
C.4	Navigation Challenge	2
	Total	**10 hours**

***A teaching period consists of an hour.**

C.1 Introduction

Objective: This teaching period aims at breaking the ice between the teacher and students. This helps each other's names and personal information and at identifying individual learning needs and goals, expectations and possible learning difficulties.

Key Points:

- Conduct Pre-Test

The instructor introduce(s) themselves. Then the trainees are asked to form groups of 3 and each one to introduce himself/herself to the rest of the group in 2-3 minutes. Additionally students are asked to provide personal information, to express individual learning needs and goals, expectations and possible learning difficulties. Lastly one representative each group briefly introduces the members of his/her group to the class.

Alternatively after this introductions the students interview each other for 5 minutes and then introduce themselves to the whole class.

Soon after this the instructor will provide the students with the pre-test sheet which contains a problem for the students to solve in 30 minutes.

For the next activity students, still in their groups, are given freedom to construct whatever they wish using the materials supplied in fifteen minutes.

The questions listed are guidelines only. The best questions will arise from what actually takes place during your training. Feel free to use whatever discussion questions best guide your participants to a thorough reflection of the activity. You do not need to ask every question in order to reflect on the training experience.

- **What did you enjoy the most about the activity?**
- **What did you do?**
- **Did you find that it was difficult to get started? Why?**
- **What part of the experience was the easiest?**
- **What did you observe during this activity?**

C.2 Robotics as a Learning Tool

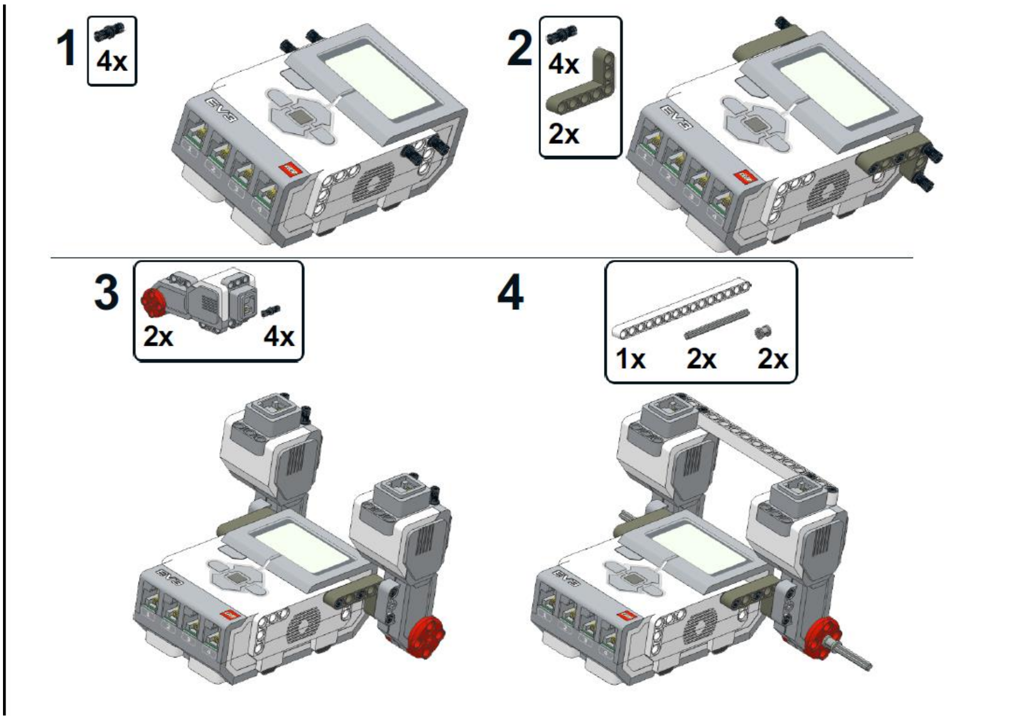
The focus of this section is to introduce the materials included in the Lego Mindstorms EV3 kit and the EV3 software. It is organized into 5 parts. In the first part the students familiarize with the materials which they are going to use in the construction of their model. In the second part they get involved in construction a robot car. The remaining parts of this section are introductions the basic programming feature of the software

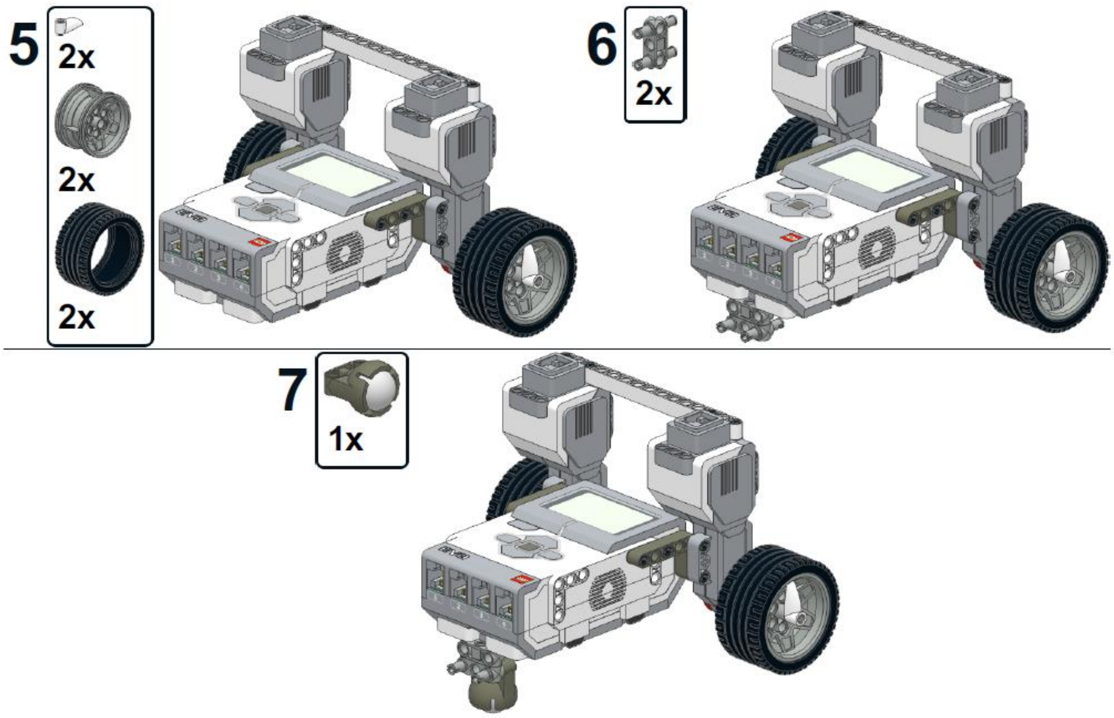
2.1 Introduction to Lego EV3 brick and sensors (2 teaching periods):

Students , in the same groups as the first day, are given one Lego Mindstorms Ev3 kit. In groups the instructor asks groups to try to identify the sensors, the motors and the construction parts, such as block, axels etc. of their kit. Afterward, the instructor makes a brief introduction to NXT brick functions.

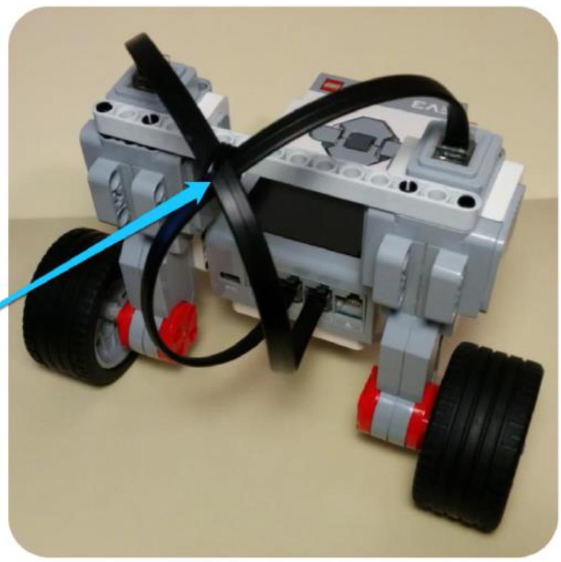
The groups are then instructed to begin building the robot-car. Pictured below are instructions to build the car.

Reference (**http://www.damienkee.com/lego-mindstorms-resources/**)





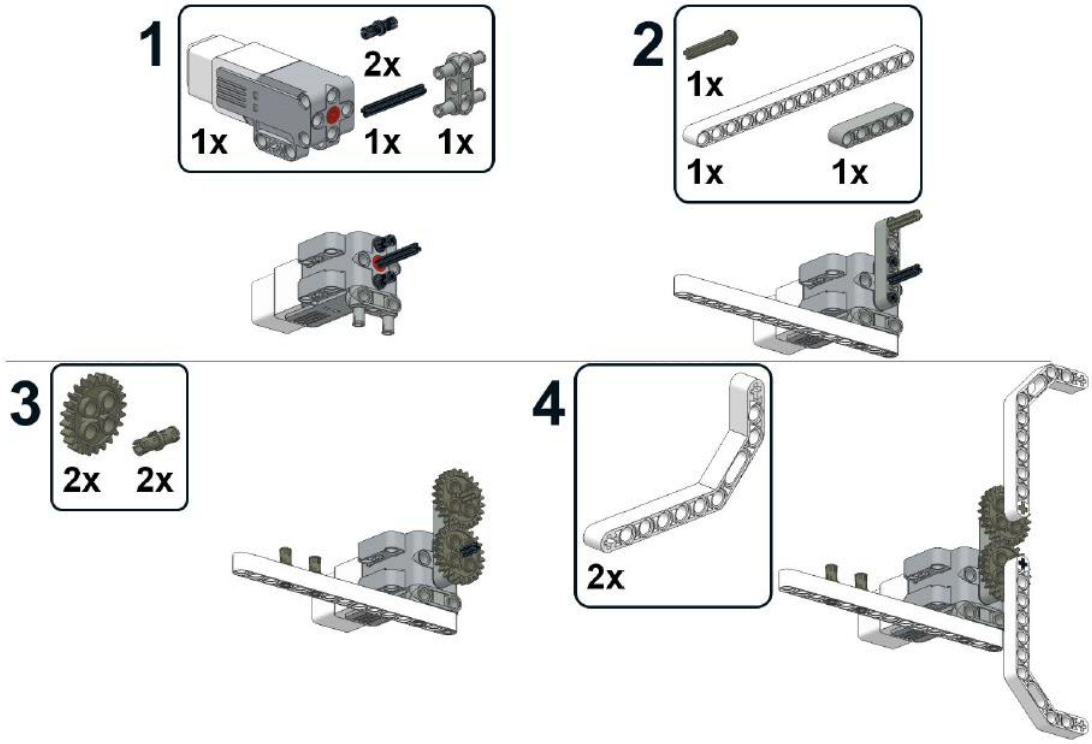
Plug in the Motor Cables

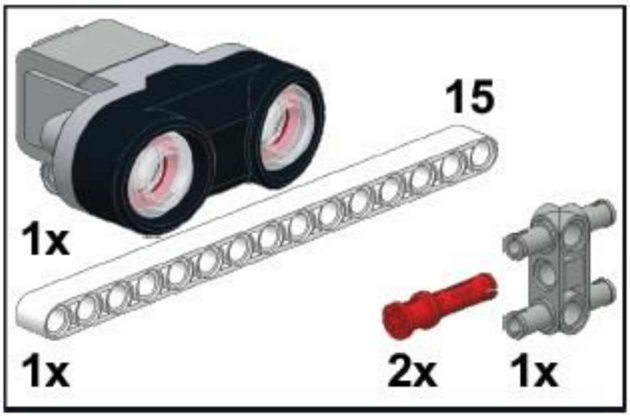


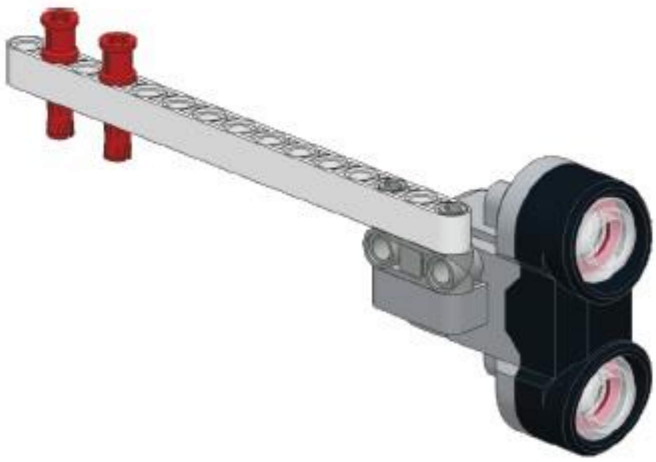
One into 'B'
One into 'C'

Make sure they crossover

Grabber Attachment







1

To help build communication during the build process students will construct the car using a Team Communication exercise.

Procedure:

- The group selects one person to be the leader for this exercise
- The other two participants should sit back to back to the leader
- The leader should instruct the group how design the object using the build instructions
- The two group members building the robot are not to speak or gesture in any way if there is a misunderstanding.
- Once the object is completed the group members face one another and discuss the differences of appearance

Good questions for discussion

- **How did each team decide who would be the leader?**
- **Did you geel confident and comfortable during the exercise?**
- **What were the main reasons for error?**
- **Did you get better as you went along?**
- **What might you do differently next time?**
- **How might you use what you've learned from this exercise in the future?**

•

2.2 Programming Robots

This part is focused on the LEGO EV3 programming environment and the development of guiding robots with varying configurations. For example activation of motors using programming blocks within the EV3 Software.

The students, working in groups undertake specific introductory activities to the programming environment of LEGO Mindstorms EV3. The initial project is to get their car to move forward in a straight line.

Using the Lego EV3 (*reference: http://www.nr.edu/csc200/labs-ev3/ev3-user-guide-EN.pdf*):

Turning on the EV3 brick

Starting screen

To turn on the EV3 brick press the center button.

After you press the button the center button will turn red

And the starting screen will be displayed.

When the light changes to green the brick is ready.

Shut Down screen

To turn the brick off, repeatedly hold the button

on the top left corner until the shutdown screen appears.

Using the directional buttons you highlight and

select the check mark to turn off the brick .

To cancel the shutdown operation highlight and select the X mark.

You select the options by using the centre button.

Connecting the Ev3 Technology to the computer

Using the USB cable, plug the mini-USB end into the EV3 brick’s

PC Port. Plug the USB end into your computer

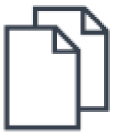
USB Cable connection

EV3 Brick Interface

The EV3 Brick Interface has four basic screens that give you access to different functions on the Ev3 brick.

Run Recent 

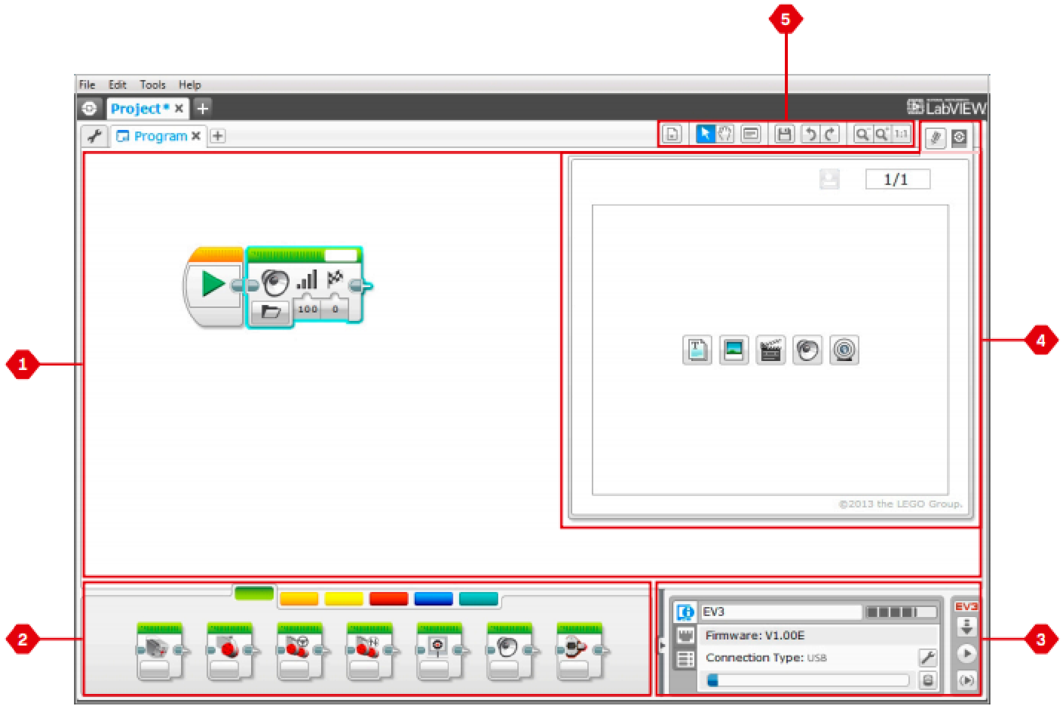
This screen contains the recently run programs. The program at the top of the list which is slected by default is the latest program run

Fle Navigation 

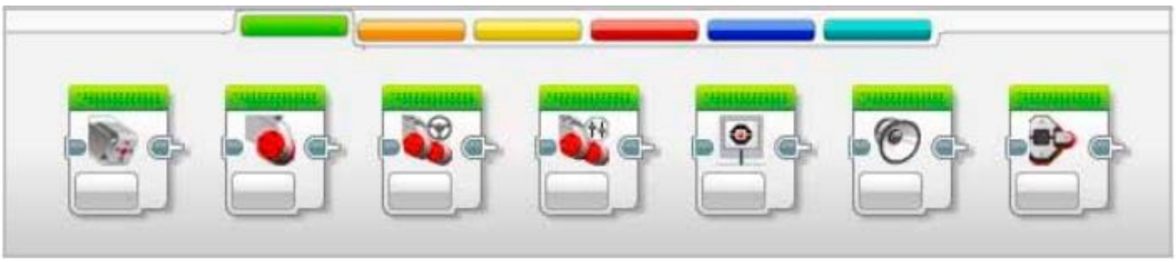
This screen is where you will access and manage all the files on your EV3 bruck , including files stored on an SD card

Files are organized in project folders. Files can be moved or deleted.

1. Programming Canvas
2. Programming palettes-Programming building blocks
3. Hardware Page-
4. Content Editor
5. Programing tools



Programming Blocks and Palettes

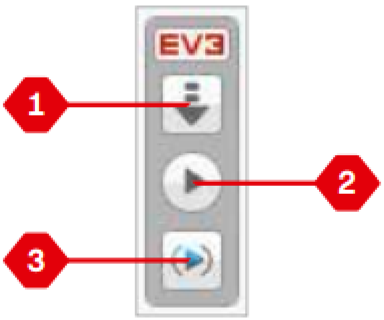


Action Blocks

(In order from left to right) + Medium Motor + Large Motor + Move Steering + Move Tank + Display + Sound + Brick Status Light

Hardware Page controller buttons

1. Download- Downloads the program to the EV3 brick
2. Download and Run- Downloads the Program to the EV3 brick and runs it Immediately
3. Download and Run selected- Downloads only The highlighted blocks to the Ev3 brick and runs Them immediately.



For the purpose of this exercise students will need to let their cars move forward.

Below is a snippet of a sample forward program.

1. The first block is a 'start' block.
2. The second block is a 'move steering' block with mode set to 'rotations'. The steering value is set to zero, so the robot will move in a straight line, the power is set to +50 so the robot will move forward at 50% power, the number of rotations is set to two and the option to apply the brake after the motion is 'on'. Thus this block will make the robot move two wheel rotations forwards in a straight line.

Using this program as an example the instructor will instruct students to program their robots to move forward.

2.3 Drag Race Challenge

Students are now able to get their robots to move forward.

Now is the time for the Drag Race Challenge.

Have a distance preferably of 25 feet set. Robots from each team are to race against each other. At the finish each group's machine should have a unique signature celebration.

Students have one class session to test and program their robots.

Material:

- **A stopwatch for timing**

Scoring:

- Design:4 points
- How straight the robot moved: 2 points
- Robot Celebration:1 point

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C.3 Going the Distance challenge

This section focuses on combining mathematics principles in the JHS with Robotics. Proportion and Time.

Material:

- Meter Rule

Activity:

Each group programs their car to travel for different amounts of time. In each time interval they will have to record the distance it travels at a motor power level of 30.

The time range from 5-10 seconds.

After recording their distances students plot their graph with the points for each time interval.

They will repeat the above steps for motor levels of 75 and 100.

The instructor will ask the students to make observations of the experiment. On the next page is a copy of the activity sheet for each group.

Going the Distance challenge

Using the LEGO NXT EV3 design, build and calibrate a car than travel a specified distance.

Program:

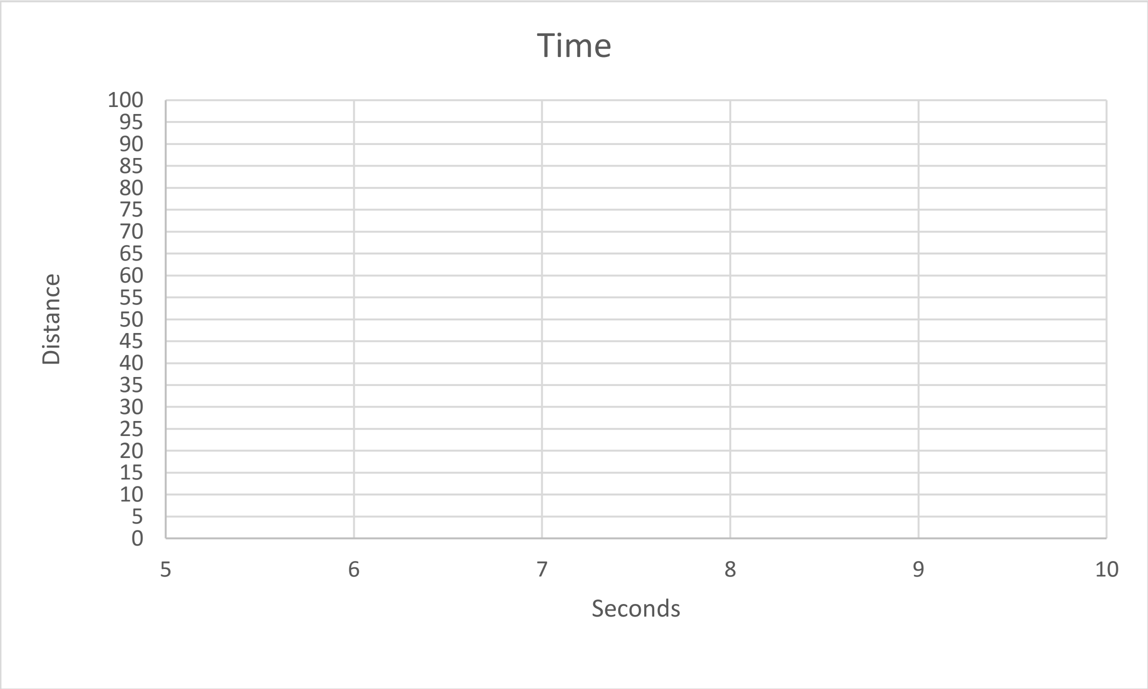
Program your car to travel to travel for different amounts of time and record the distance it travels for a motor power level of 30. The time will range from 5 – 10 seconds.

Create a graph that shows how far your car traveled when programmed for a given amount of time.

The data collected should be shown as data point.

Repeat the above steps for motor power levels of 75 and 100.

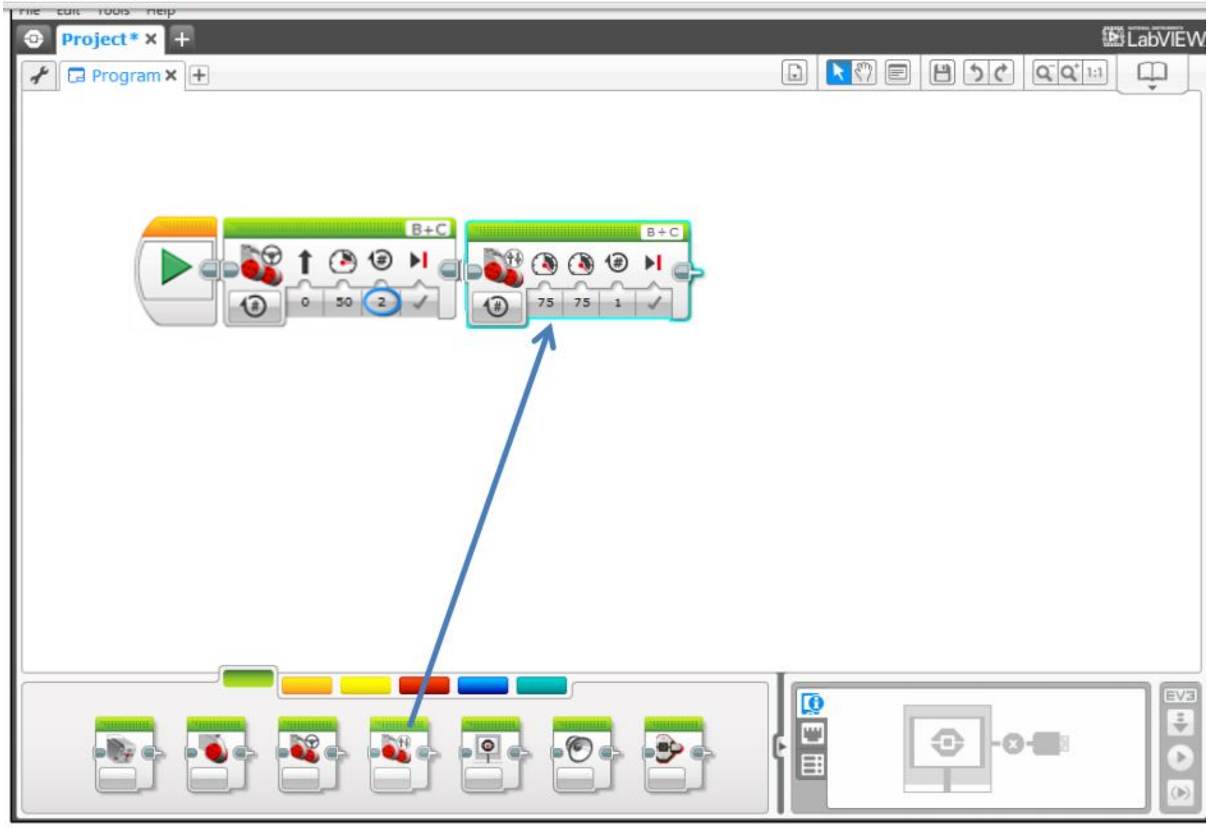
What do you observe from the graph? Detail and explain.



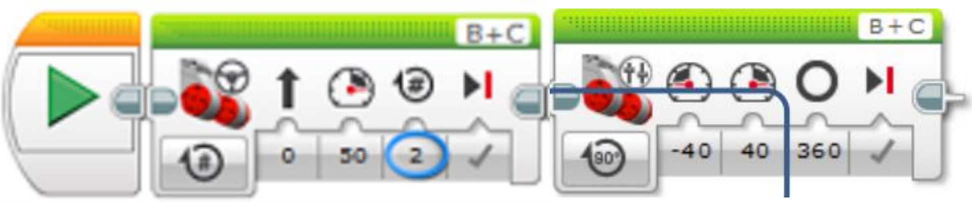
C.3.1 Move in a square

Students are now able to program their robots to move forward. The next activity involves getting the cars to move in a square.

Using the forward snippet from the previous section we will attach another block to get the car to make a turn.

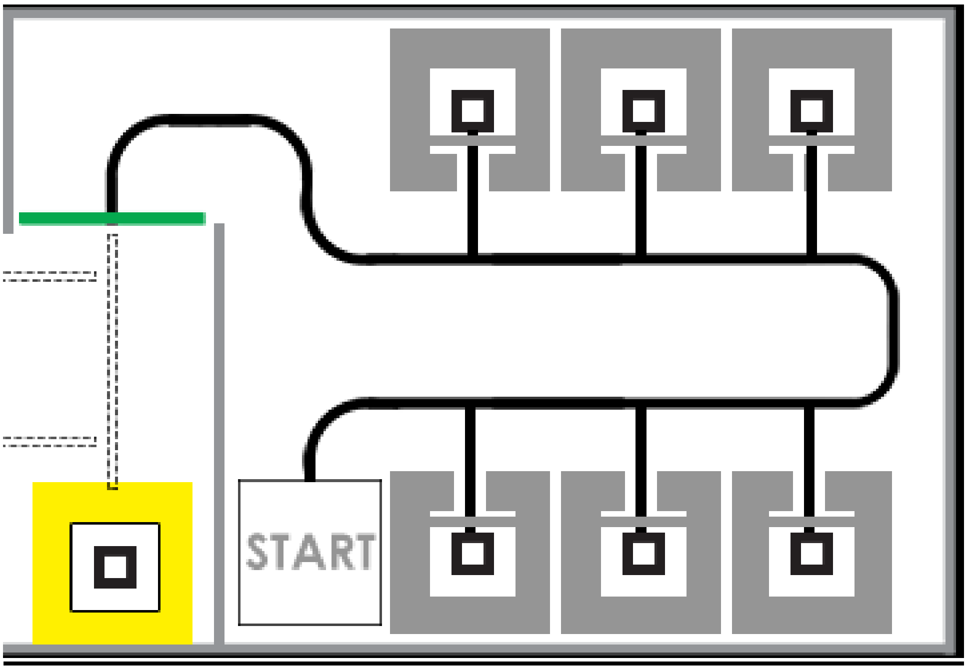


1. **Drag a move tank block to the program area**
2. **Change the parameters on the 2nd motor block**
3. **Change the Block type to 'On for Degrees' and the motor power to -40 for left and 40 for the right**
4. **Now set the wheel degree rotation to 180 degrees. The degree rotation controls how many degrees the wheels on the robot turn. You can download and test the program to note if the robot makes a 90 degree turn right or left. Adjust the degrees until the robot makes a 90 degree turn to the left**



For the remainder of the session ensure the students are able to make their robots can move in a complete square.

C.4 Navigation Challenge



Using the skills the students have learned from the previous two exercises.

Let the students move their robots from the start position to the green line.

The dimensions for this are 8ft + 5ft. Otherwise you can make a sketch