

Applying Common Core Standards in Grades 4th-10th Using LEGO Robotics

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Abstract— Common Core Standards includes critical content for all students in American education. Forty-eight of the fifty states have adopted the standards as of 2012. Previously, every state had its own set of academic standards and students in each state were learning at different levels. In the new global economy, all students must be prepared to compete with students from around the world. Students are expected to develop a deeper mastery of content and demonstrate what they know through writing and other projects. Changes to curriculum and instruction are more student-centered with greater focus on skills, abilities, and a shift towards more performance assessments. This research was designed to apply mathematical processes of the Common Core Standard in a lesson plan for fourth through tenth grade students. The REU Mathematics team used NXT LEGO® Robotics to teach various scientific, mathematical, and design concepts, through designing, building, and programming the robots at each level. The students' received hands on experience with physics, mathematics, motion, environmental factors, and used problem solving in a collaborative group setting. The data was collected through observations.

Keywords- educational robots, robot programming, mobile robots, computer science education, inquiry based instruction

I. CRESIS

The Center for Remote Sensing of Ice Sheets (CReSIS) is a Science and Technology Center established by the National Science Foundation (NSF) in 2005, with the mission of developing new technologies and computer models to measure and predict the response of sea level change to the mass balance of ice sheets in Greenland and Antarctica. The NSF's Science and Technology Center (STC) program combines the efforts of scientists and engineers to respond to problems of global significance, supporting the intense, sustained, collaborative work that is required to achieve progress in these areas. CReSIS provides students and faculty with opportunities

to pursue exciting research in a variety of disciplines; to collaborate with world-class scientists and engineers in the US and abroad; and to make meaningful contributions to the ongoing, urgent work of addressing the impact of climate change. [1]

Due to the harsh environments in which CReSIS research has been done, the use of robotics has become very necessary. The use of robots can take the place of human researchers who would like to explore these places. Teaching K-12 students to build and program robots will vastly shape the future of where robotics technology will go and how data will be collected.

II. INTRODUCTION

The North Carolina Mathematics Standard Course of Study is organized in five strands or goals for K-12: Number and Operations, Measurements, Geometry, Data Analysis and Probability, and Algebra. These are the objectives for each goal in competencies at each grade level and throughout the high school courses. It is the framework upon which classroom instruction and assessment should be planned. It is the ultimate guide for textbook selections and the foundation of the North Carolina testing program. On June 2, 2010, North Carolina adopted the Common Core State Standards in K-12 Mathematics and K-12 English Language Arts released by the National Governors Association Center for Best Practices and the Council of Chief State School Officers. [2]

The Common Core State Standards Initiative is a state-led effort coordinated by the National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO). The standards were developed in collaboration with teachers, school administrators, and experts, to provide a clear and consistent framework to prepare our children for college and the workforce. The Common Core Standard is designed to build upon the most advanced current thinking about preparing all students for success in college and their careers. [2]

The mathematics education team applied the standard on grades four through ten. The team’s project was designed to teach the students how to build NXT LEGO® Robotics and program them to complete an obstacle course using the 5E (Engagement, Exploration, Explanation, Elaboration, and Evaluation) style lesson plan. The 5E teaching style is inquiry-based learning. In an inquiry-based classroom, the teacher’s role becomes less involved with direct teaching and more involved with modeling, guiding, facilitating, and continually assessing student work. The team worked with three different groups of students: elementary, middle and high school students. Within every section, the students were randomly grouped (3 to 6 members) with peers. The students used basic mathematical, problem solving, and teamwork skills to complete the task given to the group. The members of the mathematics education team took the role of teachers. The team followed the guidelines written out in the Common Core Standard as well as using the 5E lesson plan method.

III. COURSE PLAN

Before working with the students, the mathematics education research team studied the Common Core Standard for North Carolina, NXT LEGO® Robotics, and the 5E lesson plan. Our process started by visiting teachers at I.C. Norcom High School in Portsmouth, Virginia; the team was introduced to two teachers, Mr. Daron Moore and Mrs. Veronica Williams. Mr. Daron Moore was a Physics teacher for 9 years. He teaches physics and as well as preparing the school’s robotics team for competitions. His team recently placed 1st in the 2012 regional competition. Mr. Moore gave the math team a brief history of teaching different levels of students and how to effectively instruct them. Mrs. Veronica Williams was a mathematics teacher at I.C. Norcom. She has been a mathematics teacher for 20 years, she is currently teaching Algebra I and Algebra II. She talked about the effectiveness of the 5E lesson plan.

Later the math team researched NXT LEGO® Robotics using various sources such as the LEGO® Robotics websites, YouTube videos, and the NXT owner’s manual. LEGO® Robots kit came with the programming software; the software is an object oriented programming guide. Object oriented programming makes it less challenging to maintain and modify existing code as new objects can be created with small differences to existing ones. [3] The math team repetitively assembled and programmed the robots in order to master the process and concept of constructing the robot. An obstacle course was built to test and debug the robots to simulate the task assigned for student grade level grouping for P-12.

A. Methodology

- Introduction
- Discussion about Robotics and its history.
- Components of a robot, the design and testing
- Break the class into teams (according to the availability of robots)
- Build and program the robots

- Test on the course; Debug the robot to perform proficiently on the course
- Give an overview and ask the students what they have learn and ask a team to give a demonstration.

IV. USING THE 5E LESSON PLAN

With the assembly and program process of the robots mastered, the mathematics team moved to the teaching aspect of the project. The team assembled seven 5E lesson plans for each level of student: three for elementary school, two for middle school, and two for high school. The lesson plan was based on a typical school day in which the students will encounter. See Appendix. The 5Es represent five stages of a sequence for teaching and learning: Engage, Explore, Explain, Extend (or Elaborate), and Evaluate. [4]

A. Engagement

The purpose for the engagement stage is to peak students’ interest and gets them personally involved in the lesson, while pre-assessing prior understanding.

- The students became familiar with the project at hand and the learners shared their prior knowledge with robots and programming software. The team asked the students a series of questions such as “What do you know about robots?” “Have you ever assembled NXT LEGO® robots?” and “have you ever programmed a robot or anything pertaining to robots?”

B. Exploration

The purpose for the exploration stage is to get students involved in the topic, providing them with an opportunity to build their own understanding. Through self-designed or guided exploration students make hypotheses, test their own predictions, and draw their own conclusions.

- The REU mathematics team dissected the robots, telling what each part does. The team constructed a PowerPoint and the LEGO® tool chart to aid in this step. Afterwards, the students identified instruments and discussed how the robots function.

C. Explanation

The purpose for the explanation stage is to provide students with an opportunity to communicate what they have learned so far and figure out what it means. Explanation is the stage at which learners begin to communicate what they have learned.

- Learners investigated the various NXT robots and a video of higher-level robots used by NASA to explore areas. Afterwards, the students shared what they’ve learned and understand about Robotics.

D. Elaboration

The purpose for the elaboration stage is to allow students to use their new knowledge while continuing to explore its implications. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways.

- Learners applied their knowledge of robots and programming. The students were divided into two teams at each grade level; each team was to build, program, and test the robot while being timed. The mathematics team provided an instruction manual. There were no set time on the teams; therefore there was no pressure on the groups to configure their workings.

E. Evaluation

The purpose for the evaluation stage is for both students and teachers to determine how much learning and understanding has taken place. Evaluate, the final "E", is an ongoing diagnostic process that allows the teacher to determine if the learner has attained understanding of concepts and knowledge

- Learners demonstrated their understanding of robotics by implementing skills obtained by building, programming, and testing the robot on a course built by the instructors. The groups debugged the errors found in their program after navigation of the course.

V. OBSERVATION

A. Curriculum Observation

The North Carolina Science Essential Standards maintain the respect for local control of each Local Education Authority (LEA) to design the specific curricular and instructional strategies that best deliver the content to their students. Nonetheless, engaging students in inquiry-based instruction is a critical way of developing conceptual understanding of the science content that is vital for success in the twenty-first century. [3] Here is a list of competencies the team used

- Analyze motion in two dimensions using angle of trajectory, time, distance, displacement, velocity, and acceleration.
- Explain motion in terms of frame of reference, distance, and displacement.
- Develop understanding of fractions as numbers
- Solve problems involving measurement time and mass.
- Write and solve a number problem based on a real-world situation.

B. Standards for the 21st Century

- Inquire, think critically, and gain knowledge.
- Draw conclusions, make informed decisions, apply knowledge to new situations, and create new knowledge.
- Share knowledge and participate ethically and productively as members of our democratic society.
- Pursue personal and aesthetic growth. [6]

The team also exposed the students to each learning style; visual, auditory and kinesthetic. The team implemented different scenarios to balance the ability to learn the concept, considering the different learning styles. For the visual and auditory aspect of the scenario, videos were shown on how to

build, program, test, and debug the robots. For the kinesthetic aspect of the scenario, the team administered the NXT LEGO® Robotics Kits so the students could ponder the parts while they were being demonstrated.

C. Assembling Observation

The REU mathematics team was the facilitators over the groups. The team help mend problems in the build after the students finished building, along with facilitating in the testing and debugging phase. Some areas the groups had problems with were cooperation and understanding. In the Middle School section, there were problems with students getting involved; some students took control while others watched. To remedy the problem, the facilitators spontaneously started a modern day "assembly line". The facilitators assigned each group member a page to assemble. The alternative enhanced the cooperativeness and dependency on one another. Each group member had to pay attention to the "assembly line" in order to know what portions needed to be done when it is their turn to assemble.

D. Programming and Debugging Observation

When the assembling was complete, the mathematic team gave each group an overview of the obstacle course and a demonstration of how their robots should maneuver through the course. To make the demonstration easier, the team built and programmed a prototype robot to perform on the course. After the overview, the groups programmed the robots. The software used was part of the NXT LEGO® Robotics kit; it is an object oriented programming software similar to Alice™ and the C++ computer language. The groups used basic mathematics and physics to figure their way around the obstacle course. The groups configured the robots to perform specific tasks needed to operate efficiently. The groups programmed the robots to turn at 90° angles, the direction to turn, and when to turn. The programming technique was based on timing; each programming piece needed the correct timing to function properly. If the timing was off, the robot could've done thing such as run astray, crash into objects, and even fail to reach the finish line. There was no group to get the programming right on the first try. It took consistent attempts in order to perfect the program. Each team tested and debugged the robots numerous times.

VI. RESULTS

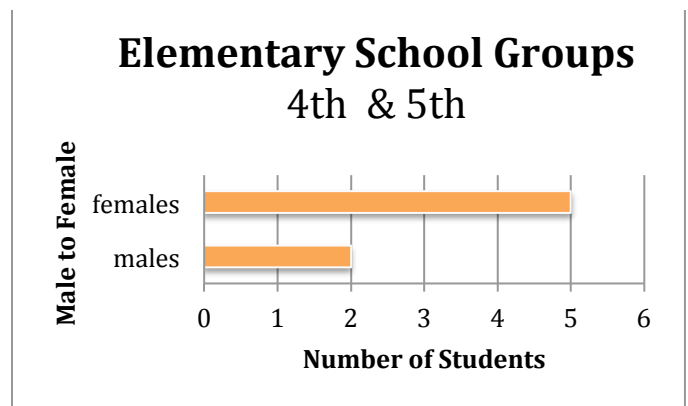


Figure 1. Shows the male to female comparison in the Elementary Group as well as the students attending

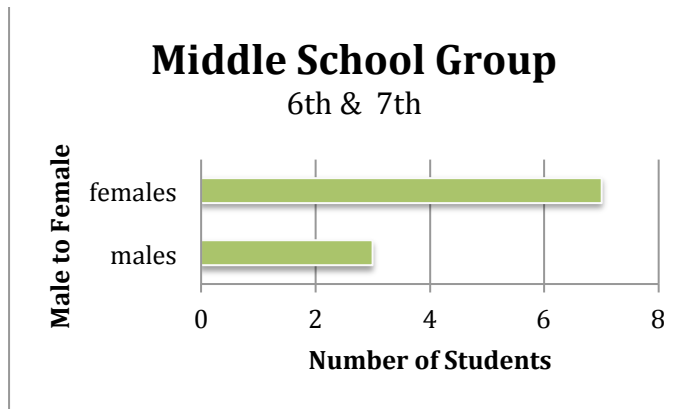


Figure 2. Shows the male to female comparison in the Middle School Group as well as the students attending

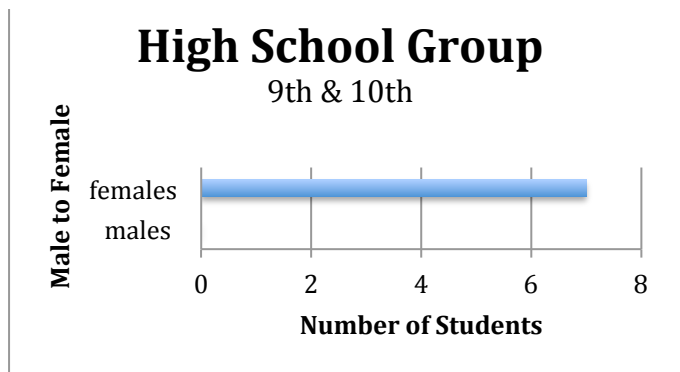


Figure 3. Shows the male to female comparison in the High School Group as well as the students attending

Assembling & Programming Robots

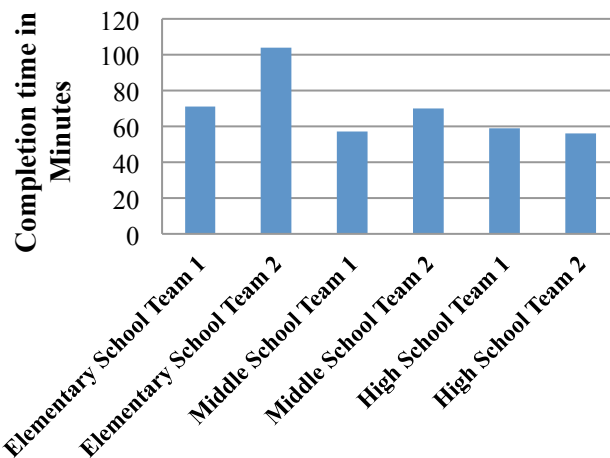


Figure 4. Shows the minutes taken assembling and Programming of the robots for each level of students

VII. CONCLUSION

The main focus of this research project was to apply the principles of the Common Core Standard adopted by the state of North Carolina while using the 5E lesson plan format and inquiry-based learning. The overall goal of this project was to examine the effectiveness of this Standard as it is implemented in the classroom setting. Observations were done at the elementary, middle, and high school levels to perceive how the students learned and responded to the Standard. The teaching strategies used assessed the students' independent learning abilities, enhanced thinking skills, and produced cooperation in the group setting. Further research on the applications of the Common Core Standards in mathematics needs to be done to on this project to get a clearer analysis of the effectiveness of The Common Core Standard.

VIII. RECOMMENDATIONS FOR FUTURE RESEARCH

This study was completed during several one-hour sessions for each grade level of K-12 student groups. The research further determined the success of the study but a longer time frame of one semester is strongly recommended. A period of at least eight three hour sessions on Saturday workshops or academies would allow in depth instructional time with robotics. The amount of data needed to measure enhanced student learning would be acquired as well.

A second recommendation would be to obtain one NXT LEGO® Robot per every two students. On the average, there were four students to a NXT LEGO® kit per team operating one robot. This process compromised equal time in robot assembly for each student. Installation of the NXT LEGO® Robotics software on laptop computers would be required for instruction purposes. The mathematics team experienced

problems finding a definite location to teach the class, assemble and program the robots.

The final recommendation for future research would include a work session for per-service educators as well as teachers at the elementary and middle levels.

IX. ACKNOWLEDGEMENTS

The 2012 REU Mathematics Team would like to thank CERSER Principal Investigator, Dr. Linda B. Hayden, for making the Research Experience for Undergraduate in Ocean, Marine, and Polar Science possible. The team would also like to give a special thanks to I. C. Norcom High School teachers; Mr. Daron Moore and Mrs. Veronica Williams for their support of the project. The team would also like to thank Dr. Darnell Johnson for being the mentor and a very special thanks to Mr. Je'aime Powell for constantly installing the NXT LEGO® Robotics software.

X. REFERENCES

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Appendix

Applying Common Core Standards in Grades 4 th -10 th Using LEGO Robotics Elementary Day 1		
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 	
Student Objectives	Engage	Learners will share prior knowledge about robots. Teachers will present a PowerPoint presentation to the students.
	Explore	Learners will identify and discuss how robots work. The team will dissect the robots, telling what each part does. Teachers will present the NXT LEGO Robotics Kit to the students.
Duration	50 minutes	
Materials	NXT LEGO Robotics Kits, and Computers, markers, boxes, tape	
Sequence of Events	1. Introduction 2. Discussion about Robotics and its history.	
Academic Standards	<p>The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org</p> <ul style="list-style-type: none"> • The learner will read, write, model, and compute with non-negative rational numbers • Solve problems involving perimeter of plane figures and areas of rectangles • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. • Develop number sense for rational numbers 0.01 through 99,999 	

Applying Common Core Standards in Grades 4th-10th Using LEGO Robotics Elementary Day 2		
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 	
Student Objectives	Explain	Learners will investigate the various NXT robots and a video of higher-level robots used by NASA to explore areas. The students will share what they understand about NXT robots.
	Elaborate	Learners will apply their knowledge of how robots are used, build and program robots.
Duration	50 minutes	
Materials	NXT LEGO Robotics Kits, and Computers, markers, boxes, tape	
Sequence of Events	<ol style="list-style-type: none"> 1. Components of a robot, the design and testing 2. Break the class into teams (according to the availability of robots) 3. Build and program the robots 4. Test on the course; Debug the robot to perform proficiently on the course 	
Academic Standards	<p>The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org</p> <ul style="list-style-type: none"> • The learner will read, write, model, and compute with non-negative rational numbers • Solve problems involving perimeter of plane figures and areas of rectangles • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. • Develop number sense for rational numbers 0.01 through 99,999. 	

Applying Common Core Standards in Grades 4th-10th Using LEGO Robotics Elementary Day 3			
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 		
Student Objectives	<table border="1"> <tr> <td>Evaluate</td> <td>Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.</td> </tr> </table>	Evaluate	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.
Evaluate	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.		
Duration	50 minutes		
Materials	NXT LEGO Robotics Kits, Computers, markers, boxes, and tape		
Sequence of Events	Give an overview and ask the students what they have learn and ask a team to give a demonstration.		
Academic Standards	<p>The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org</p> <ul style="list-style-type: none"> • The learner will read, write, model, and compute with non-negative rational numbers • Solve problems involving perimeter of plane figures and areas of rectangles • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. • Develop number sense for rational numbers 0.01 through 99,999. 		

Applying Common Core Standards in Grades 4th-10th Using LEGO Robotics Middle School Day 1		
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 	
Student Objectives	Engage	Learners will share prior knowledge about robot. Teachers will present a PowerPoint presentation to the students.
	Explore	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.
	Explain	Learners will investigate the various NXT robots and a video of higher-level robots used by NASA to explore areas. The students will share what they understand about NXT robots.
	Elaborate	Learners will apply their knowledge of how robots are used, build and program robots.
Duration	50 minutes	
Materials	NXT LEGO Robotics Kits, Computers, markers, boxes, and tape	
Sequence of Events	1. Introduction 2. Discussion about Robotics and its history. 3. Components of a robot, the design and testing 4. Break the class into teams (according to the availability of robots) and build robots.	
Academic Standards	The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org <ul style="list-style-type: none"> • Develop flexibility in solving problems by selecting strategies and using mental computation, estimation, calculators or computers, and paper and pencil • Represent problem situations with geometric models. • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. • Write and solve a number problem based on a real-world situation. 	

Applying Common Core Standards in Grades 4th-10th Using LEGO Robotics Middle School Day 2		
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 	
Student Objectives	Evaluate	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.
Duration	50 minutes	
Materials	NXT LEGO Robotics Kits, Computers, markers, boxes, and tape	
Sequence of Events	<ol style="list-style-type: none"> 1. Program the robots 2. Test on the course; Debug the robot to perform proficiently on the course 3. Give an overview and ask the students what they have learn and ask a team to give a demonstration. 	
Academic Standards	<p>The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org</p> <ul style="list-style-type: none"> • Develop flexibility in solving problems by selecting strategies and using mental computation, estimation, calculators or computers, and paper and pencil • Represent problem situations with geometric models. • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. 	

Applying Common Core Standards in Grades 4 th -10 th Using LEGO Robotics											
High School Day 1											
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 										
Student Objectives	<table border="1"> <tr> <td>Engage</td> <td>Learners will share prior knowledge about robot. Teachers will present a PowerPoint presentation to the students.</td> </tr> <tr> <td>Explore</td> <td>Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.</td> </tr> <tr> <td>Explain</td> <td>Learners will investigate the various NXT robots and a video of higher-level robots used by NASA to explore areas. The students will share what they understand about NXT robots.</td> </tr> <tr> <td>Elaborate</td> <td>Learners will apply their knowledge of how robots are used, build and program robots.</td> </tr> <tr> <td></td> <td></td> </tr> </table>	Engage	Learners will share prior knowledge about robot. Teachers will present a PowerPoint presentation to the students.	Explore	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.	Explain	Learners will investigate the various NXT robots and a video of higher-level robots used by NASA to explore areas. The students will share what they understand about NXT robots.	Elaborate	Learners will apply their knowledge of how robots are used, build and program robots.		
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Explore	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.										
Explain	Learners will investigate the various NXT robots and a video of higher-level robots used by NASA to explore areas. The students will share what they understand about NXT robots.										
Elaborate	Learners will apply their knowledge of how robots are used, build and program robots.										
Duration	50 minutes										
Materials	NXT LEGO Robotics Kits, Computers, markers, boxes, and tape										
Sequence of Events	<ol style="list-style-type: none"> 1. Introduction 2. Discussion about Robotics and its history. 3. Components of a robot, the design and testing 4. Break the class into teams (according to the availability of robots) and build robots. 										
Academic Standards	<p>The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org. [5]</p> <ul style="list-style-type: none"> • Analyze motion in two dimensions using angle of trajectory, time, distance, displacement, velocity, and acceleration. • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. • Write and solve a number problem based on a real-world situation. 										

Applying Common Core Standards in Grades 4th-10th Using LEGO Robotics High School Day 2		
Introductions	<ul style="list-style-type: none"> • Math Team Members • Students 	
Student Objectives	Evaluate	Learners will demonstrate their understanding of robotics by implementing skills obtained by building and testing the robot on a course built by the instructors.
Duration	50 minutes	
Materials	NXT LEGO Robotics Kits, Computers, markers, boxes, and tape	
Sequence of Events	<ol style="list-style-type: none"> 1. Program the robots 2. Test on the course; Debug the robot to perform proficiently on the course 3. Give an overview and ask the students what they have learn and ask a team to give a demonstration. 	
Academic Standards	<p>The Department of Public Instruction for North Carolina has developed state standards to provide guidelines for teaching on the K-12 school level. To view the standards online, go to www.ncpublicschools.org [5]</p> <ul style="list-style-type: none"> • Analyze motion in two dimensions using angle of trajectory, time, distance, displacement, velocity, and acceleration. • Explain motion in terms of frame of reference, distance, and displacement. • Develop understanding of fractions as numbers • Solve problems involving measurement time and mass. • Write and solve a number problem based on a real-world situation. 	