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Robotics as a Means of Increasing Student Achievement in Middle School Science

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ROBOTICS AS A MEANS OF INCREASING STUDENT ACHIEVEMENT IN MIDDLE SCHOOL SCIENCE

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ABSTRACT

This study reports on the effectiveness of a Robotics engineering curriculum in increasing the middle school students' achievement in science and math. Specifically, it aimed to find out if the students taking the robotics class performed significantly higher in science and math than a control group. The research examined and compared the scores in a pre and posttest and the normalized learning gains of students taking robotics in addition to their regular science and math versus those who are taking science and math only. Although this study showed that there is no significant difference in the science achievement scores of students between the experimental and control group, gender was identified an as important factor that affects the learning outcomes in a Robotics class. Further analyses also showed that despite the fact that students used general math ideas as they engage in the problem solving process during robotics-driven activities, their knowledge of math is no different from those who are not taking robotics.

INTRODUCTION AND BACKGROUND

In the early 19th century, the orientation of the education program was focused on 3 basic skills: reading, 'riting, and 'rithmetic also known as 'the three Rs'. The central role of the three Rs in education is obvious especially in elementary education. How can anybody expect a student who struggles with these basic skills to be successful in other subjects like Geography and Science if the student cannot read at all (Papert, 1993).

Looking back, this argument was undeniable when the only available material for learning was books. But looking forward, in this age of computers and many forms of multimedia, students have easier access to different bodies of knowledge and reading is no longer the primary and unique way to learn. This is especially true now that science and technology have permeated every aspect of education.

At present, the struggle for educators is to better prepare students for the science and technology of the 21st century. In its current science education reform, the American Association for the Advancement of Science (1993) asks science teachers to integrate technology and inquiry-based teaching into their instruction and recommends that technology be used as a vehicle for learning science. The National Research Council (1996) encourages teachers to apply "a variety of technologies, such as hand tools, measuring instruments, and calculators as an integral component of scientific investigations" to support student inquiry.

These mandates arise from growing concern that the United States is not preparing a sufficient number of students, teachers, and practitioners in the areas of science, technology, engineering, and mathematics (CRS report for Congress on Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action), considering that the country's economy is highly dependent on advanced technology. Technology and related innovation are responsible for at least half of U.S. economic growth

(Bonvillian, 2002). Industries that rely on technology need new scientists and engineers every year to help propel their success and it is up to those in our schools to produce these graduates.

Unfortunately, U.S. students are less prepared than many other first-world countries in terms of science and math. According to the report of the Congress Research Service a large majority of secondary school students fail to reach proficiency in math and science. When compared to other nations, the math and science achievement of U.S. pupils and the rate of STEM degree attainment appear inconsistent with a nation considered the world leader in scientific innovation.

The results of the Trends in International Mathematics and Science Study (TIMSS) given in 1995 and in 1999 show that students in the United States are falling behind their international counterparts somewhere in the middle grades: “It (TIMSS and TIMSS-R) suggests that our children do not start out behind those of other nations in mathematics and science achievement, but somewhere in the middle grades they fall behind” (Valverde & Schmidt, 1997). TIMSS also showed that US twelfth graders scored below average and among the lowest in science, math, physics, and advanced mathematics (Gonzales, et al., 2000).

In 2007, however, TIMSS reports that compared to 1995 results, the average mathematics scores for both U.S. fourth- and eighth-grade students were higher.

Table 1. Results of the Trends in International Mathematics and Science Study (TIMSS) on the performance of US students on Math and Science.

	Mathematics		Science	
	4^{th} Grade	8^{th} Grade	4^{th} Grade	8^{th} Grade
1995	518	492	542	513
2007	529	508	539	520

At the fourth grade level, the U.S. average score in 2007 was 529, 11 points higher than the 1995 average of 518. At the eighth grade level, the U.S. average mathematics score in 2007

was 508, 16 points higher than the 1995 average of 492. But the average science scores for both U.S. fourth- and eighth-grade students in 2007 were not measurably different from those in 1995. The U.S. fourth-grade average science score in 2007 was 539 and in 1995 was 542. The U.S. eighth-grade average science score in 2007 was 520 and in 1995 was 513. These findings are supported by the Program for International Student Assessment (2007) in their science literacy assessment conducted in 2006 where they report that fifteen-year-old students in the United States scored lower in science literacy than their peers in 16 of the other 29 countries.

If innovation is going to continue to drive the United States' economy, its educational system must improve the students' scores in both Math and Science and also entice graduates into STEM careers (Bonvillian, 2002). One new approach to improving STEM education that is gaining popularity is the use of Robotics to teach content. Advances in technology have brought down the cost of robots and made it easier to bring them into classrooms with tight budgets.

It has long been recognized that experiential, hands-on education provides superior motivation for learning new material, by providing real-world meaning to the otherwise abstract knowledge. Robotics has been shown to be a superb tool for hands-on learning, not only of robotics itself, but of general topics in science, technology, engineering, and math (STEM) (Matari´c, 2004).

Robotics is a growing field that can significantly impact the nature of engineering and science education at all levels, from K-12 to graduate schools (Matari´c, 2004). Apart from being a subject itself, it can also be used as an instructional tool in a wide array of subjects ranging from early childhood (Bers, M., et al., 2002), elementary (Bell, S., 2008), middle school (Norton, S., et al., 2006) , technological and vocational secondary education (Moundridou & Kalinoglou, 2008), Computer Science (McNally, et al., 2006), Engineering (Ringwood & Monaghan, 2005),

Computer Programming (Lawhead, et al., 2002), to Artificial intelligence (Parsons & Sklar, 2004) and Psychology (Miglino, et al., 1999).

Research indicates that Robotics can be used in all levels of education for a variety of purposes such as developing students' ability to solve mathematical and logical problems (Lindh, et al., 2007), enhancing problem-solving and critical thinking skills (Ricca, et al., 2006), motivating students to pursue STEM related careers (Ruiz-del-Solar & Aviles, 2004), promoting positive youth development (Bers, M., 2000), addressing at-risk student populations (Miller, G., et al., 2000) , and promoting teamwork (Weinberg, J., et al., 2005). Moreover, Robotics is also being used in the integration of technology in special education classes (Kärnä-Lin, E. et al., 2006).

The idea of using robotics in education is based on earlier research work of the MIT mathematician and Piaget's pupil, Seymour Papert, the creator of the LOGO programming language in the 1970's. Breaking with traditional computer aided instruction models where computers essentially programmed children, Papert attempted to create an environment where children programmed computers and robots. In doing so, the children could gain a sense of control over technology. He believed that children could identify with the robots because they are concrete, physical manifestations of the computer and the computer's programs. Furthermore, Papert believed that learning is more effective when students are experiencing and discovering things for themselves and that the computer is a perfect medium for discovery learning. This led to the development of the constructionism which Papert considers as both a theory of learning and a strategy for education (Papert, 1980). It builds on the "constructivist" theories of Jean Piaget, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed by the mind of the learner. Other researchers have also identified the concrete nature of robots as one of their important advantages. By testing scientific

and mechanical principles with the robots, students can understand abstract concepts and gain a more functional level of understanding (Nourbakhsh, et al., 2005). Students can also learn that in the real world there is not necessarily only one correct answer to every question. Beer et al. (1999) felt that it was more important for their students to come up with creative solutions to problems than it was to recite answers they memorized in class.

Early adopters of Robotics in the classroom have reported many successes; however, there is a clear lack of quantitative research on how robotics can increase STEM achievement in students. Most research involving robotics in the classroom was conducted with high school and college students with results assessed by teacher or student perceptions rather than rigorous research based on student achievement data. Another concern about existing research on the use of Robotics is that the bulk of it has not been conducted in the most challenging, high needs settings.

In this study, the effect of implementing a Robotics Engineering curriculum in increasing student achievement in middle school science and math was conducted in a public school consisting of underserved students.

Given the testing-mandate in Louisiana, as is the case across the country, students are expected to attain proficiency in benchmark knowledge and demonstrate proficiency by taking tests designed to measure the content standards. This then leads to defining student achievement as academic achievement measured by standardized test scores, in this case, determined by the Louisiana content standards specified in the Grade Level Expectations.

The Louisiana Grade-Level Expectations published in 2004, (LA Department of Education, 2004) breaks down the science standards into grade-specific expectations. The Grade-Level Expectations or GLE’s provide guidance to public school teachers to create educational curricula. The GLE’s are categorized by grade and subject. In middle school, each grade-level

tackles a specific branch of science. For example, science at the sixth grade-level focuses on physical science concepts, seventh grade-level focuses on life science and eight grade-level focuses on earth science. Before the student can exit the eighth grade level, it is expected that he/she has mastered all the GLE's in all three grade-levels, as determined by testing.

To ensure the success of students during state-wide testing, the East Baton Rouge Parish School System implemented the Benchmark Assessment Program in which students in grades 2-8 who access the general curriculum are tested in the core subject areas: English/language arts, mathematics, science, and social studies. The benchmark assessment measures the growth of a student in one school year through a comprehensive pretest in August and a posttest in May. In addition, it also implements a LEAP-like test following every curriculum unit to gauge mastery of content throughout the year. With the test content being aligned to the Grade Level Expectation's (GLE's) from the Louisiana comprehensive curriculum and the East Baton Rouge Parish curriculum, the information gathered from the program guides the district in its classroom instruction and strategic accountability plan.

For this study, the impact of a Robotics curriculum on student achievement is determined by evaluating student performance to a test aligned with the benchmark assessment. The Math data, on the other hand, were completely derived from the middle school Math pretest and posttest benchmark assessment since its inclusion was not originally part of the research.

The research questions that are investigated in this study are: (1) Is there a significant difference in the science mean gain scores of the control and experimental groups? (2) Does gender influence the effectiveness of Robotics in increasing student achievement? (3) Which science GLE's have been impacted the most by Robotics? (4) Is there a significant difference in math score gains of the control and experimental groups?

MATERIALS AND METHODS

Overview

The research utilized a pretest/posttest quasi-experimental study with a control group design. The control group consisted of students who were not enrolled in the Robotics class and did not have access to the robotics kits or computers, while the experimental group was composed of students taking Robotics as an elective in addition to their regular science class. The students assigned to take Robotics as an elective class were randomly selected by the school counselor.

The science achievement was measured and analyzed using a questionnaire developed by the researcher. The testing instrument was a paper and pencil, 28-item questionnaire with one right answer and three distracters per question. Each assessment question was derived from the 6th Grade Physical science State Benchmark Assessment. The development of this questionnaire was necessary because the district Benchmark assessment measures the mastery of students in three different branches of science; that is, the science test for 6th grade covers Physical science, the 7th grade is tested for Life science while the 8th grade is tested for Earth science.

The science pretest was administered to all students in their respective science classes before the start of the 2nd semester. During this time, students are already acclimated to taking pretests and posttests since it is given before and after every unit of the middle school science curriculum as part of the benchmark assessment program.

To ensure that the test connects middle school science with Robotics, key educational outcomes of the Robotics Engineering curriculum used in this study were aligned with the Louisiana GLE's. The alignment is best described in Table 1. Originally, the Robotics class meets for 90 minutes every other day during the regular semester, but it was shortened to 60 minutes to allocate some time for tutorial in preparation for the state-wide testing. Because of the

shortened period, there was not enough time to finish the whole Robotics Engineering curriculum. It was then necessary to remove some of the questions that address the unfinished activities. Specifically, questions number 4, 8, 9, 10, 11, 14, 18, 19 & 20 were disregarded in the analysis of the data. The GLE's to which these questions pertain can be found in Appendix B.

Participants

This study was conducted at a public middle school within the East Baton Parish School District in Baton Rouge, Louisiana, where the researcher taught Robotics Engineering as a first time elective subject. The researcher received her training from Carnegie Mellon University Robotics Academy before the school year started.

The participants in the study were all middle school students during the 2009-2010 school year. Of the approximately 160 students in all grade levels, complete data were collected from 132 students (the reduction was due to absences and drop outs). The demographics of the school can be described as a high-needs population such that 99% of the students have African-American ethnic background and 91% were from a low socio-economic background (defined as qualifying for free or reduced lunch).

The overall sample (including both the experimental and control groups) consisted of 132 students, with an age range of 11-14 years. All participants are taking middle school science: 6th grade physical science, 7th grade life science and 8th grade earth science. The experimental

Equipment

Papert's work served as the basis for a partnership between the MIT Media Lab and LEGO Corporation (Martin, et al. 2000). In 1998, LEGO released the first generation Mindstorms line, the RCX: kits consisting of electric motors, sensors, LEGO bricks, and LEGO technic pieces grouped around a central controlling unit. Along with several extension kits, it developed into

Table 2. Alignment of the Robotics Engineering Curriculum with the Louisiana GLE's

Robotics Link (A description of how robotics in general and this curriculum in particular addresses the standard on the left.)	**Louisiana General Learning Expectations**
The guided investigations in Robotics Engineering are targeted at specific relevant questions about robotics technologies and concepts that lead to rich exploratory experiences. Some investigations focus on specific portions of the inquiry process, such as evidence-gathering or hypothesis evaluation. Others begin with a question and seek an answer using general inquiry processes. Explanation and evaluation are primary abilities applied in answering questions, not simply calculations or summarization.	Hypothesis & evidence: **LAGLE--Science--Grade 6— PS--ASI—16** Use evidence to make inferences and predict trends
	Experimental design: **LAGLE--Science--Grade 6--PS--ASI—5** Identify independent variables, dependent variables, and variables that should be controlled in designing an experiment
	Observations & predictions: **LAGLE--Science--Grade 6-- PS--ASI—7** Record observations using methods that complement investigations (e.g., journals, tables, charts)
	Data analysis & acquisition: **LAGLE--Science--Grade 6— PS--ASI—11** Construct, use, and interpret appropriate graphical representations to collect, record, and report data (e.g., tables, charts, circle graphs, bar and line graphs, diagrams, scatter plots, symbols)
Understanding the significance and meaning of measurements are central to the understanding of robotics: • Distance the robot travels (linear measurement, meter stick) • Amount a motor turns (angular measurement) • Directional change of the robot (angular measurement, protractor) • Speed of the robot (rate measurement, meter stick, built-in timer) • Physical quantities measured by sensors (touch, sound, light, distance)	**LAGLE--Science--Grade 9— PS--MSR—19** Measure the physical properties of different forms of matter in metric system units (e.g., length, mass, volume, temperature)
Robotics is able to demonstrate many applied physical concepts. Here are a few examples: • Mechanical advantage (gears) • Basic circuitry (sensor operation) • Digital and analog electronics (sensors) • Light (lamp, light sensor) • Sound (ultrasonic, sound sensors) • Speed (motors) • Friction (robot movement)	Amplitude and frequency: **LAGLE--Science--Grade 6--PS—TRE--32** Identify and illustrate key characteristics of waves (e.g., wavelength, frequency, amplitude)
	Light and reflectivity: **LAGLE--Science--Grade 6--PS—TRE—26** Describe and summarize observations of the transmission, reflection, and absorption of sound, light, and heat energy.

(Table 2 continued…)

Quantitative measurement is a staple of all investigations.	Color and perception: **LAGLE--Science--Grade 6--PS—TRE--36** Explain the relationship between an object's color and the wavelength of light reflected or transmitted to the viewer's eyes.
	Ultrasonic waves: **LAGLE--Science--Grade 6--PS— TRE—26** Describe and summarize observations of the transmission, reflection, and absorption of sound, light, and heat energy.
	Simple machines: **LAGLE--Science--Grade 6--PS— TRE--27** Explain the relationship between work input and work output by using simple machines.
	Speed, distance & power: **LAGLE--Science--Grade 6--PS--MOF--14** Construct and analyze graphs that represent one-dimensional motion (i.e., motion in a straight line) and predict the future positions and speed of a moving object. **LAGLE--Science--Grade 6--PS--MOF--16** Compare line graphs of acceleration, constant speed, and deceleration

Table 3. Frequency of participants categorized by grade level and gender.

Categories	Male	Female	Total
Control			
6th Grade	6	8	14
7th Grade	15	9	24
8th Grade	17	16	33
Experimental			
6th Grade	18	9	27
7th Grade	11	14	25
8th Grade	6	3	9
Total	73	59	132

the most successful product in the company’s history. Eight years later its successor, the LEGO Mindstorms NXT, finally saw the light of day, first in the United States in August 2006, and two months later in Europe. In the same year, it won the Innovation Toy Award in the “Technology” category (Moundridou, 2000). The retail kit consists of 577 pieces including LEGO bricks, motors, gears, different sensors (touch, light, sound, ultrasonic), and an intelligent “NXT Brick”

with an embedded microprocessor. Also, the set includes the Mindstorms NXT-G software. By programming the NXT brick using a PC, one can create an autonomous robot with LEGO bricks. The Mindstorms NXT software is an icon-based programming language, loosely based on LOGO. It allows users to drag and drop in certain order graphical blocks of code representing commands such as left and right turns, reverse direction, motor speed, motor power, etc. and thus define the behavior of the robotic construction.

There are 3 main categories of the hardware components of the NXT.

- The central controlling unit: the NXT brick
- Output devices: motors
- Input devices: sensors

The NXT "brick"

The central component of the NXT is the programmable controller, also known as The Intelligent Brick (Figure 1). It's the NXT's brain, featuring a 32-bit ARM7 microcontroller with 256K flash and 64K RAM memory—running at 48MHz—and a second 8-bit AVR microcontroller with 4K flash and 512B RAM memory, running at 4MHz. (NXT User Guide). It is enclosed by a plastic box a little thicker than an average paperback containing eight ports, three keys, and a computer screen. Simple programs can be written, and downloaded programs executed, and connection to a PC or Mac can be accomplished using the included USB cable or via Bluetooth. On top of the Brick, there is a 100x64 pixel LCD display and four buttons that control the Brick's operating systems: orange for on/off; dark gray for clear/back; and two light-gray buttons for navigating the menus displayed on the LCD. It also has a built in speaker that provides 8kHz sound quality. The brick can be powered by six AA batteries or a rechargeable battery pack that comes with the education base set.

Motors

The three Interactive Servo Motors provide the robot with the ability to move. Using the Move block automatically aligns their speeds so the robot moves smoothly. Each motor has a built-in Rotation Sensor. The rotational feedback allows the NXT to control movements very precisely. The built-in Rotation Sensor measures the Motor rotations in degrees with an accuracy of +/- one degree.

Sensors

The NXT robot is able to gather information from its surroundings using the sensors. The NXT kit includes a light sensor (capable of sensing shades of grey, not true color) and a sound sensor that can detect the amplitude of a sound (loudness, but not detail) as well as a touch sensor (a simple pressure switch) and an ultrasonic sensor which uses echolocation to determine the distance to objects.

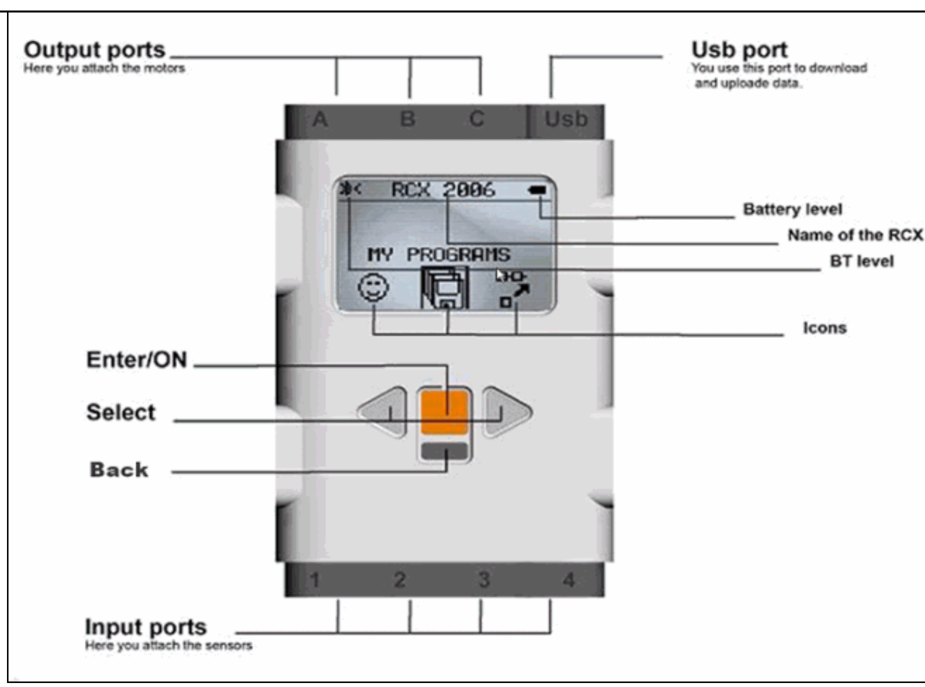


Figure 1. The NXT brick. It is the brain of the LEGO® MINDSTORMS® Education robot. It is a computer-controlled LEGO brick that provides programmable, intelligent, decision-making behavior.

Figure 2. NXT motors with embedded rotation sensor connected to its respective ports on the NXT brick using cables that resemble telephone cables.

Figure 3. The NXT sensors. The default settings used for the test programs on the NXT requires the touch sensor to be connected to port 1; the sound sensor to be connected to port 2; the light sensor to be connected to port 3 and the ultrasonic sensor to be connected to ports 4 on the NXT brick.

Curriculum Context

The Robotics Engineering curriculum used in this study was developed by Carnegie Mellon University's Robotics Academy. The curriculum was designed to teach STEM concepts utilizing LEGO Mindstorms NXT Robots, focusing on mathematical competency and technological literacy. The lessons were developed for students "to do" math and science rather

than study it by contextual learning with the premise that an engaged student learns better. The activities require students to apply fundamental mathematics and science concepts to solve robotic problems.

Students start by learning basic robot construction, programming and movement, and then move on to working with sensors and more complex robot behaviors. Twelve in-depth research projects cover key STEM concepts, step-by-step programming instructions, and many challenging questions to reinforce key educational outcomes (Appendix B). At the end of the course, students are expected to demonstrate competence in programming basic robot behaviors using motors and rotation, sound, light, touch and ultrasonic sensors. Step-by-step videos teach students how to use the programming language, build robots, basic robot behavior and use of sensors. The curriculum comes in the form of a CD. It is divided into four areas: introduction, basics, projects and reference. In the introduction section, students learn how to get the NXT up and running. The basics section provides resources that relate to the NXT brick and to LEGO. One feature includes the NXT menu consisting of nine helpful videos that teach valuable lessons that are important in understanding and operating the NXT.

The body of the curriculum is located in the projects section of the CD. In the projects, the main activities section is divided into two areas; the research prototypes and the investigations. The lessons are divided into 4 components: connect, construct, contemplate and continue. The connect link makes the connection between the activity and an actual robot performing the behavior to be learned in the lesson. In the construct phase, building and programming guide are presented with the rest of the lesson. In the contemplate section, students are challenged to think about what they just learned. In the continue section, students are challenged to extend their new learning to develop a deeper understanding.

Building

Lego Mindstorms NXT Robot uses both the technic and brick building system which is ideal for fast and sturdy building of 3D objects. It offers unique building instructions consisting of illustrations instead of words to indicate how each part should go together, and numbers to indicate the count and size of the parts needed. Figure 4 shows an example of a building instruction. In this study, the students built a Taskbot model with the sensor attachments included as needed depending on the activity. All activities of the Robotics Engineering curriculum were accomplished using this Taskbot model.

Figure 4. Example of a building instruction. The parts needed are shown first then the assembly of each part to the main structure is shown.

Figure 5. An illustration of a Taskbot model with its ultrasonic, touch, and sound sensor attachments.

Programming software

The LEGO Mindstorms robotics system can use multiple programming languages such as NXT-G, LabVIEW, RobotC, MATLAB and many others. In this study, LEGO Mindstorms Edu NXT Programming v2.0 (NXT-G) was used since it comes bundled with the NXT educational kit. The software is based on the LabVIEW software interface that offers a user-friendly, icon based interface. It consists of drag and drop blocks from the left side of the screen on to the diagram. Each block performs a unique function such as moving the motors, displaying a message, detecting a sound, or measuring a distance. By combining a series of blocks the robot can be programmed to do almost anything. Once the program is written on a PC or Mac, it can be downloaded to the NXT using a USB cable. The NXT then executes the code that it received.

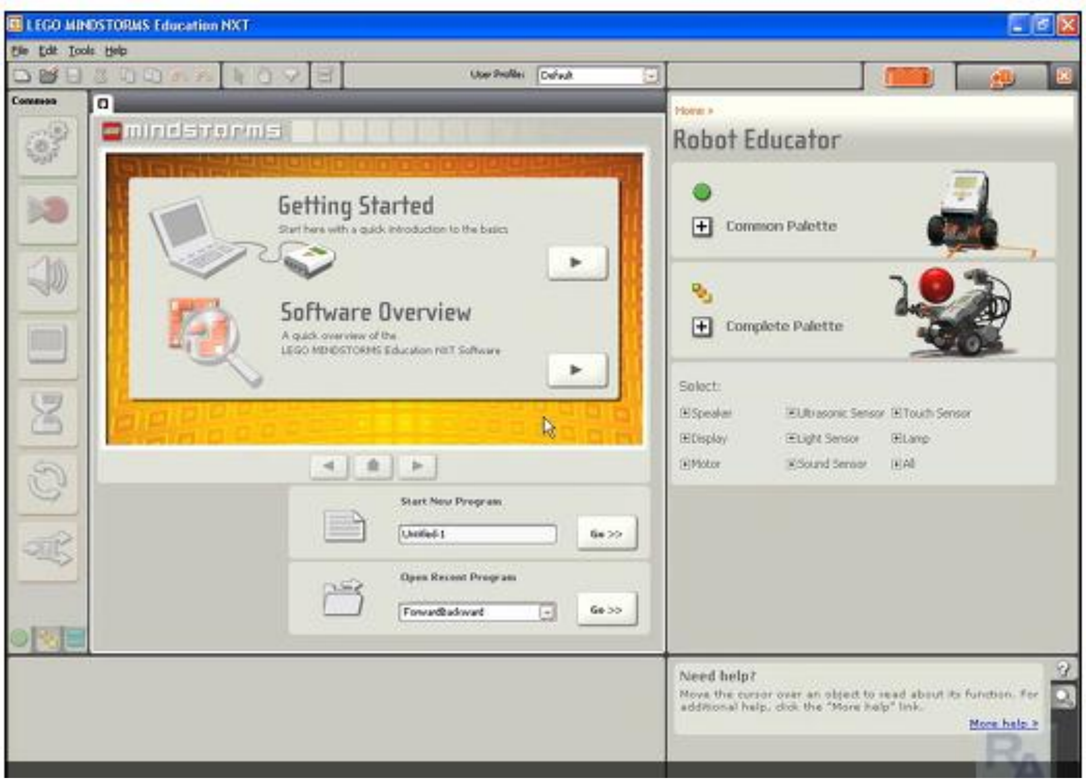


Figure 6. LEGO Mindstorms EDU NXT-G programming software start-up screen.

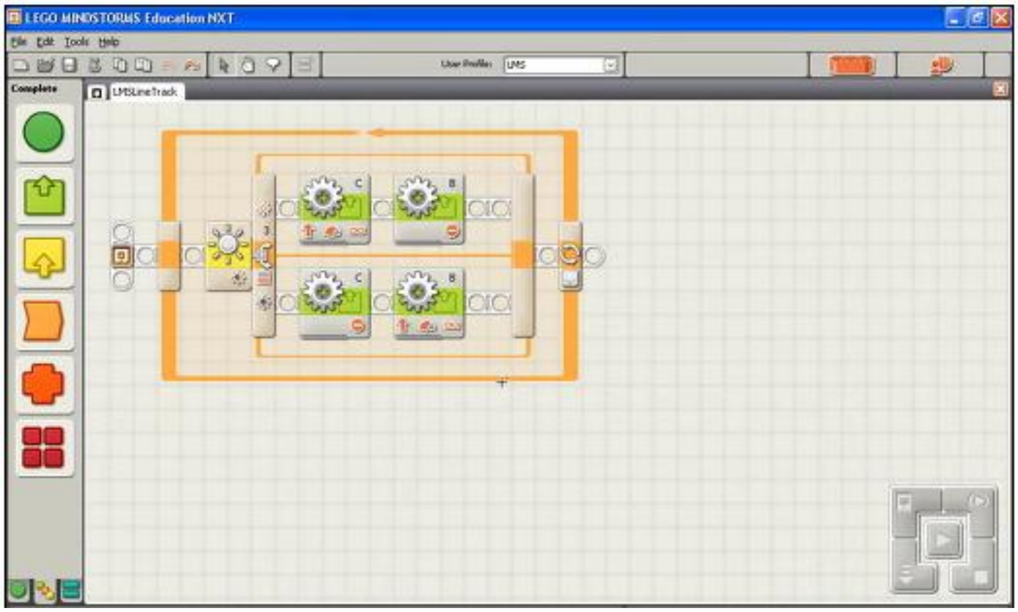


Figure 7. LEGO Mindstorms EDU NXT programming software line tracking program.

Pedagogical Approach

The implementation of the curriculum was coupled with a problem –based teaching strategy. Lessons usually start with a challenge that the students had to accomplish by the end of the class. Videos were presented to the class in which they were guided systematically in programming the basic behaviors necessary for the activity. Students then had to make revisions or combine multiple basic programs, thereby forcing them to apply knowledge they had learned in order to solve the challenge. Among the twelve (12) activities that are in the curriculum, only eight (8) were implemented prior to the administration of the posttest due to lack of sufficient time. The activities that were enacted in class are described below.

Lesson 1: Full Speed Ahead

In this lesson students learn to set-up the LEGO Mindstorms Edu NXT programming software, write a program, connect the robot to a computer and download programs to it, navigate and run programs on the NXT and to program the robot to move forward three rotations of the wheel and back with another three rotations.

Lesson 2: Wheels and Distance

This lesson is in inquiry format where students investigate the mathematical relationship between wheel size and distance traveled with a set number of motor rotations. First students review the basic concepts of a circle starting with the measurement of radius and diameter, emphasizing the importance of the diameter in calculating the circumference of a wheel. Students are then asked to compare the computed circumference of the wheel with the distance travelled by the robot in one rotation of the wheel in order to establish that the distance travelled of the robot in one rotation of the wheel is equal to its circumference.

Next, students learn the relationship of rotation to degrees. Since the robot can be programmed to run in units of degrees, it is essential that they understand how to convert motor rotations to degrees.

Understanding these concepts allow students to program the robot to run a specified distance. This is continually emphasized and practiced throughout the curriculum by providing practice problems as warm-ups during the start of the class. Below is a sample problem given as a warm-up:

> **Directions**: Please show all work, describe how you got the answer, and circle your final answer. If you use a calculator, say so, but also write out the calculations you did with the calculator.
>
> **The Problem**: The blue team used the big wheels on their robot and programmed it to go forward 720 degrees. The red team used the small wheels on their robot but programmed it to go forward 1440 degrees. Which team's robot, red or blue, will go further? (Note: The diameter of the big wheel is 5.5cm and the diameter of the small wheel is 3.0cm.)

Lesson 3: Right Face!

The lesson covers the basic programming required to make the robot turn, and then students investigate what is necessary to get the robot to turn to face a specific direction. The concept is first taught by modeling the robot's behavior using human actions. Students are

guided step-by-step through the process of building a program to make the robot do both left and right turns, as well as one wheel (“swing”) and in-place (“point”) turns.

Lesson 4: Measured Turns

In this investigation, students verify a hypothesis presented by a fellow roboticist that is presented in a video. They investigate the shape made by the robot as it turns, as well as a formula for calculating how many motor degrees are necessary to make the robot turn to face a specific direction. This is an activity that required a review of related math concepts like calculating circumference, balancing equations and solving for a variable.

In order to conduct the activity, a pen attachment was built and attached to the Taskbot. The robot was then made to run a swing turn and the circle that is formed was measured for its diameter, which was used to compute the circumference. From the computed circumference, students calculated the necessary number of motor degrees to make the robot turn 90 degrees to the right. The accuracy was then verified by running the robot for that number of degrees.

Lesson 5: Clap On, Clap Off

In addition to motors, robots also have sensors that they can use to gather information about their environment. In this activity, students were introduced to sensors and how to interpret the data readings, specifically from the sound sensor. Students calculated a threshold value (very much like an average) which was used to categorize other numbers into two simple categories: those less than the threshold, and those greater than the threshold. Thresholds are useful when robots must make decisions based on sensor input. Robots are then programmed to behave one way if its sensor reports values below the chosen threshold and behave another way if its sensor report values above chosen threshold. Using the thresholds, students wrote a program that made the robot go and stop using sound.

Lesson 6: Frequency and Amplitude

It is in this activity that students investigated the properties of sound waves and how the sound sensor works. Students collected data using the sound sensor and view mode on the NXT. They analyzed the data to determine what properties of a sound wave the sensor is most sensitive to. It is in this activity that students recorded, organized and analyzed data. They also visually presented the data in the form of a graph.

Lesson 7: Follow the Guidelines

This unit takes the students through the basics of line tracking, so that they can get their robots from one point to another without measuring the distance. Robots are able to do this by searching the ground for distinguishing marks and following those marks, or lines, to a goal.
In this activity, students continue to practice calculating the threshold value for light levels, then using that value they write a program that makes the robot track the side of a line.

Lesson 8: Faster Line Tracking

In the preceding activity, students learned how to program a robot to track a line slowly. In real world robotics projects, speed and efficiency are often important goals, so in this activity, students learn that programming and engineering can be used together to track a line faster without sacrificing accuracy. Specifically, they conducted an investigation in which they increased the motor speed and studied the effects of changing motor speed and light sensor placement on the tracking ability of the robot. In the end, students learn that there are tradeoffs and decisions in the design process.

PROCEDURE

Students were introduced to the Robotics Engineering curriculum by building the Taskbot. Next, the students learned to program the robot using the NXT-G programming software by viewing the instructional videos for each lesson on the curriculum CD. They advanced through the increasingly complex programming tasks and followed the curriculum closely in order to minimize any bias in this study.

Data Gathering

In order to measure the effectiveness of Robotics in promoting understanding in middle school science, the normalized gain from the pretest and the posttest scores of both groups were obtained. The normalized gain is determined using the formula below:

$$\text{Normalized Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{1 - \text{Pretest}}$$

Hake (1998) developed normalized learning gains because his research showed that absolute learning gains (posttest – pretest) provide an unfair advantage to classes with low pretest scores. Since the questionnaire did not include math related questions, the Math data were derived from the comprehensive pretest and posttest Benchmark assessment that was administered in August and May respectively.

Statistical Treatment

Welch's T-test was employed to determine if there were significant differences between posttest mean scores of the male and female students in the control and experimental groups. The same test was used in comparing the difference in the mean normalized learning gain scores of the male and female students in both groups. The Welch's T-test was used because the groups have unequal variances. This version of the independent group t-test takes into account the differences in variances and adjusts the p-value accordingly. Statistical tests were set to 95% confidence level.

RESULTS AND DISCUSSION

The results are divided as follows. The first section describes and analyzes the science pre and posttest scores and the normalized learning gains of students relative to gender. It also includes the comparison of the overall performance of the experimental and control groups. In the second section, the mean learning gains between the experimental and control groups for every GLE is analyzed. The third section compares and analyzes the performance of both groups in Math.

Science Assessment

Figure 8 shows the mean scores of the pre and posttest segregated by group and gender. The mean pretest scores of the female students (0.33 ± 0.03) and male students (0.34 ± 0.02) in the control group are statistically equal. The mean pretest scores of the experimental males (0.33 ± 0.03) and females (0.33 ± 0.02) are also equal. This establishes that all participants had the same pre-knowledge of the GLEs covered in the science assessment.

After 10 weeks of instruction, a posttest was given to both groups. All participants made a significant improvement from pretest to posttest (Figure 8). The male students in the control group attained a mean score of 0.47 ± 0.03 while the female students' mean posttest score was 0.44 ± 0.03 resulting to a combined mean score of 0.46 ± 0.02. The combined mean posttest score of the experimental group was 0.48 ± 0.02. When segregated between male and female students, the mean posttest score of the male students (0.52 ± 0.03) is marginally higher than that of the female students (0.43 ± 0.03).

The scores on the posttest vary widely. To determine if there is a significant difference between the performance of the males and females in each group, a one-tailed T-test was employed. Results are shown in Table 4.

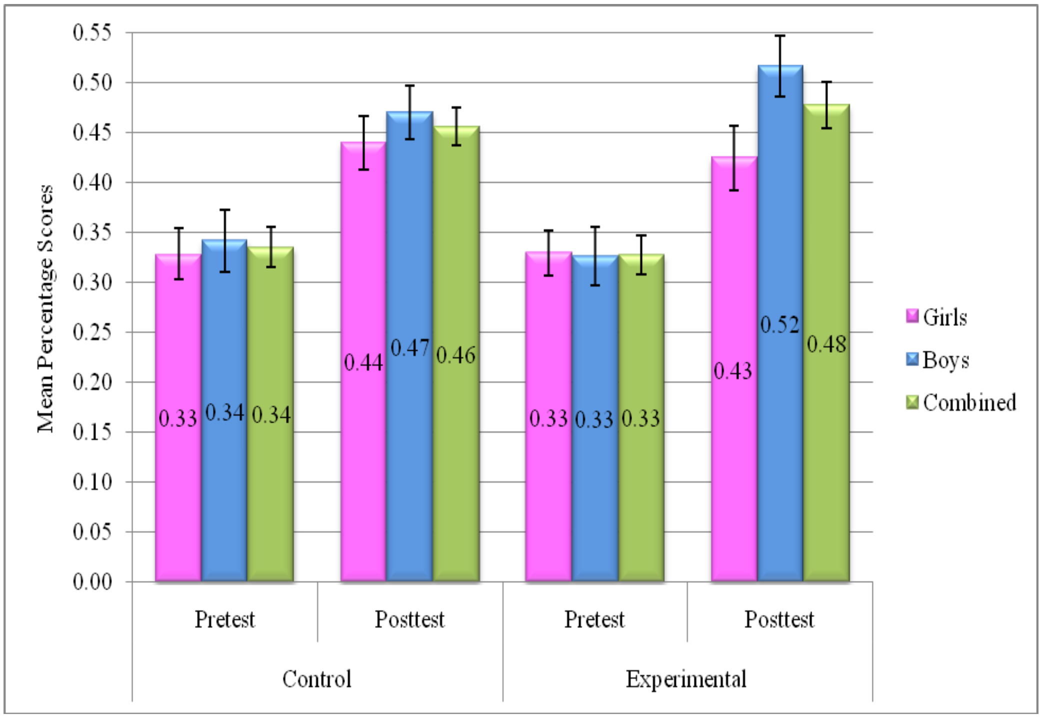


Figure 8. Comparison of the mean percentage scores of the pretest and posttest for both groups with gender segregation included.

T-test results show that with a *p* value of 0.2, there are no significant difference in the mean posttest score of the girls and boys in the control group. However, in the experimental group, the one-tailed T-test result (*p* = 0.02) show that the boys' posttest mean score is significantly higher than that of the girls. This finding suggests that there is a gender difference in the learning outcomes of students taking Robotics.

To determine the effectiveness of Robotics in improving science learning of students, the gain score of every student was normalized. The average normalized gain was calculated for every group. Figure 10 compares the normalized gain between males and females in each group.

The normalized learning gains of the students in the control group ranges from -0.8 to 0.8 as can be observed on Figure 11.a. Fifteen out of 61 students (21%) had a negative gain (8 of whom are girls) while 68 % of the group had a positive gain. This resulted to a normalized mean gain of 0.15.

Table 4. Welch's T-test results on the comparison of the mean posttest scores of male and female students in each group.

	Control N = 71		**Experimental** N = 61	
	Girls n = 33	**Boys** n = 38	**Girls** n = 26	**Boys** n = 35
Mean	0.44	0.47	0.43	0.52
Standard deviation	0.16	0.17	0.17	0.18
Error in the mean	0.03	0.03	0.03	0.03
T statistic	0.68		2.11	
One-tailed *p*	**0.21**		**0.02**	
Decision	**No significant difference**		**Significant difference**	

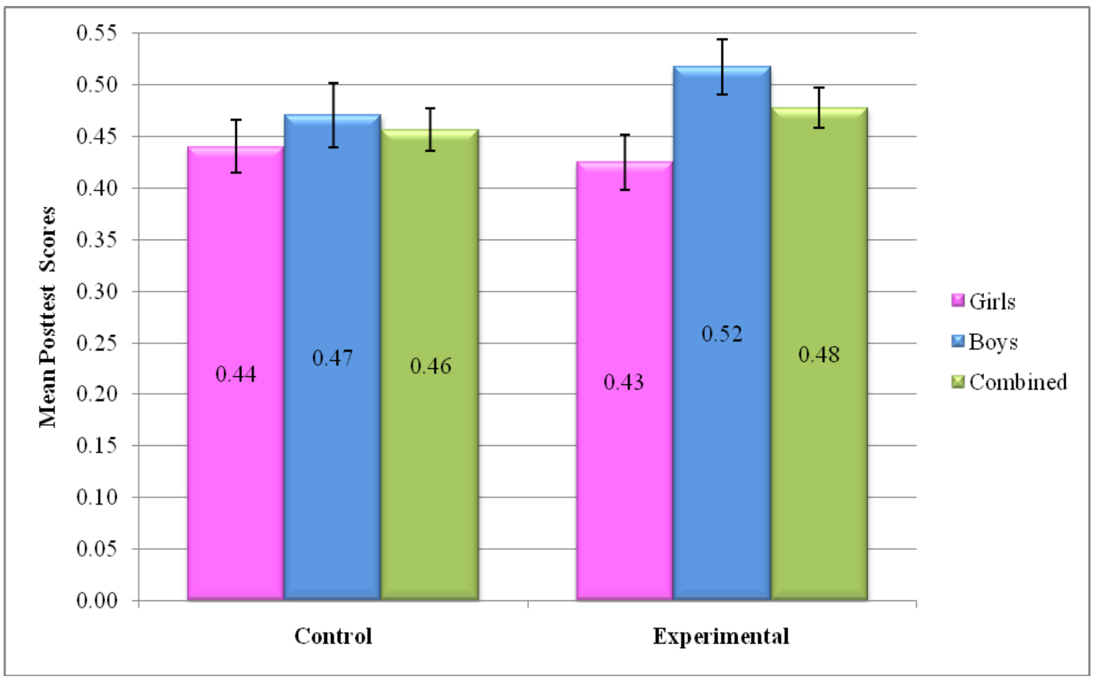


Figure 9. Comparison of the posttest scores of the male and female students in each group. The error bars of the experimental females and experimental males show a non-overlap which indicate that the difference may be significant (Cummings and Finch, 2005)

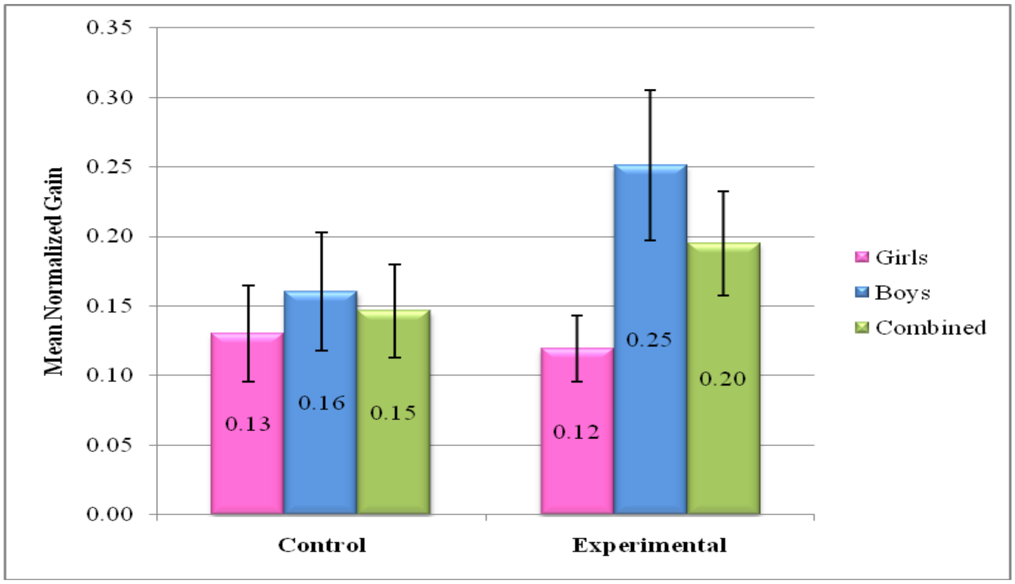
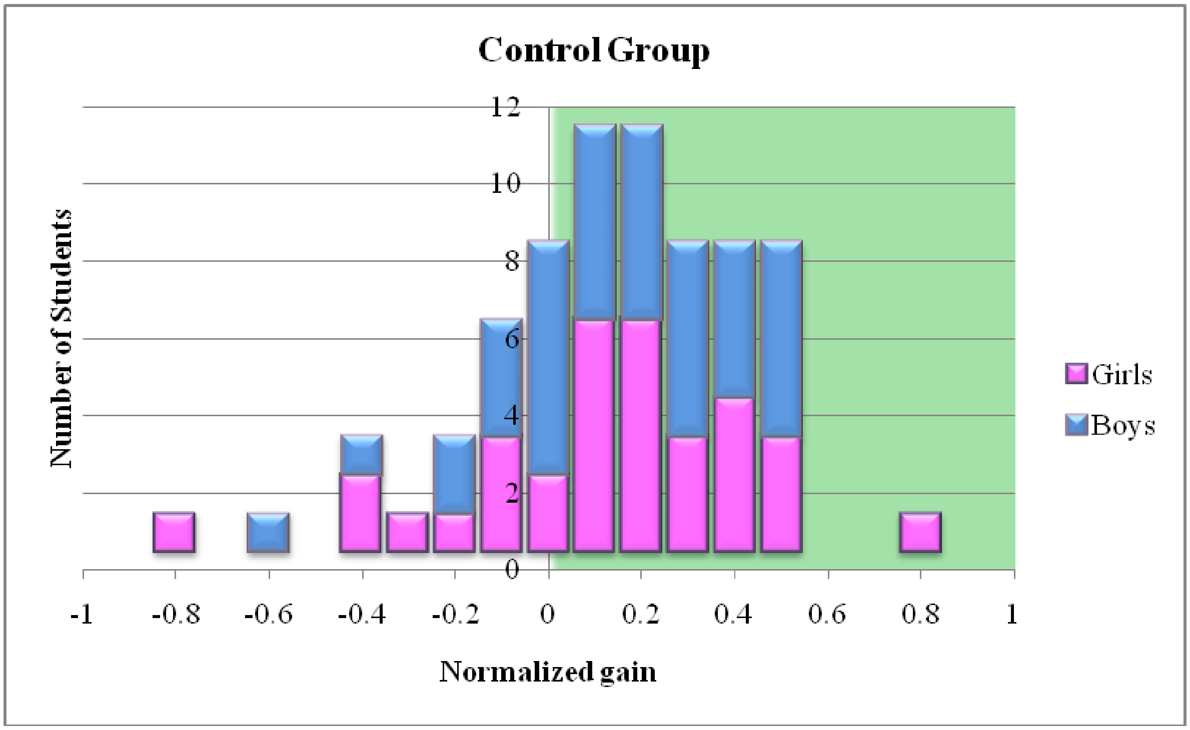


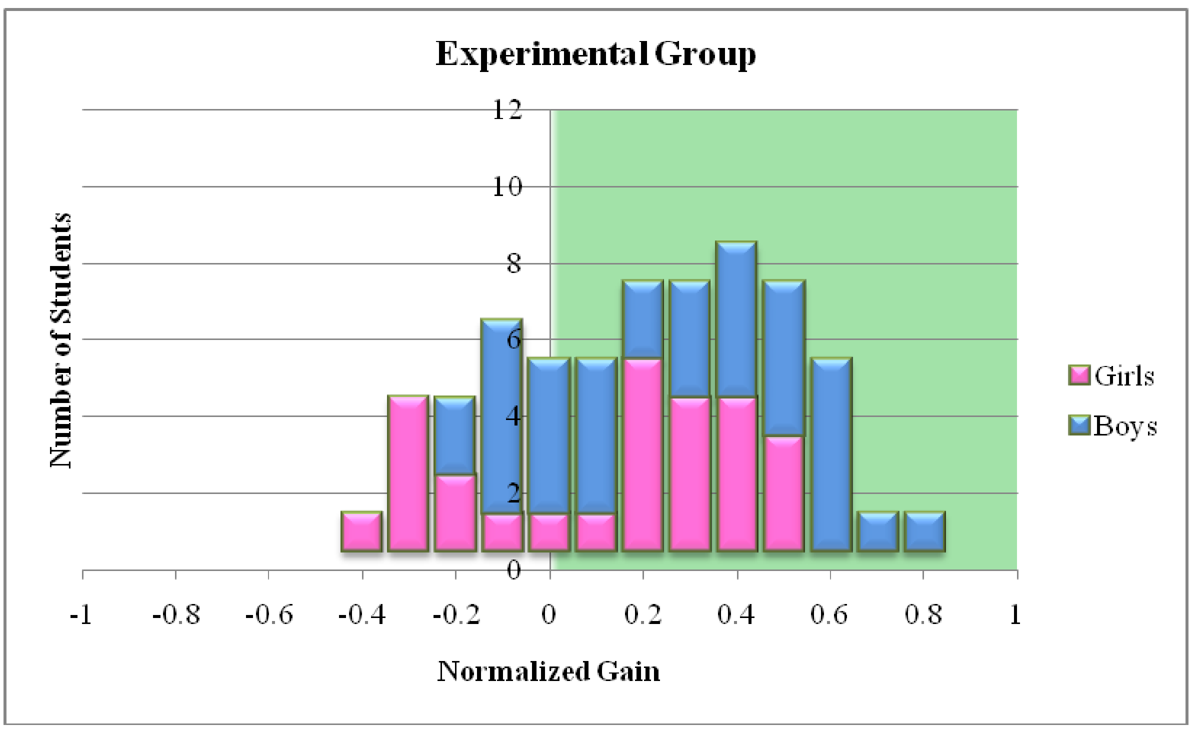
Figure 10. Comparison of the mean normalized gain between the male and female students in each group.

Table 5. Summary of the descriptive statistics for the normalized learning gains of both groups segregated by gender.

	Control N = 71			Experimental N = 61		
	Girls n = 33	Boys n = 38	Combined	Girls n = 26	Boys n = 35	Combined
Mean	0.13	0.16	0.15	0.12	0.25	0.20
Standard deviation	0.31	0.26	0.28	0.29	0.29	0.29
Standard error	0.05	0.04	0.03	0.06	0.05	0.04



(a)



(b)

Figure 11. Distribution of the science normalized learning gains of the students in the control group(a) and the experimental group (b) with segregation by gender. Points that fall on the shaded area have positive learning gains, whereas points that fall on the white area had negative learning gains.

Figure 11.b shows the normalized learning gains of the students in the experimental group. Despite the 11% (8 out of 61 students) negative learning gains from the female students, the greatest number (42 out of 61 or 68%) of the students showed positive learning gains with the boys of the experimental group showing the highest normalized mean gain of 0.20.

To examine if Robotics significantly increases the achievement scores of students in science, Welch's T-test was employed. The mean gain of the control group (0.15±0.03) was compared with the mean gain of the experimental group (0.20±0.04) and with a *p* value of 0.17 at 95% confidence level, the mean gain of the experimental group is not statistically different from that of the control group.

Table 6. Welch's t-test result comparing the science mean normalized learning gains of the control and experimental group.

	Control N = 71	**Experimental** N = 61
Mean	0.15	0.20
Standard deviation	0.28	0.29
Standard error	0.03	0.04
T statistic	0.97	
One-tailed *p*	**0.17**	
Decision	**No significant difference**	

However, the notably higher mean gain of the boys in the experimental group cannot be disregarded. A one-tailed T-test was conducted to compare the mean gain of the different gender groups. This test helps to determine the effect of gender on the impact of Robotics on the learning gain of the students. Table 5 shows the results of the analyses conducted.

Table 7. Comparison of the effects of gender on the learning gains of the experimental and control groups.

Comparison	df	t stat	One-tailed p-value	Decision
Control boys vs Control girls	63	0.44	**0.33**	**No significant difference**
Control boys vs Experimental girls	50	0.58	**0.28**	**No significant difference**
Experimental boys vs Control boys	69	1.41	**0.08**	**Marginal difference**
Experimental boys vs Control girls	65	1.67	**0.05**	**Marginal difference**
Experimental boys vs Experimental girls	54	1.78	**0.04**	**Significant difference**

These results reinforce the conclusion that only the males in experimental group showed significant gains.

One distinct attribute of Robotics in education is the immediate feedback it provides as students explore different variables in accomplishing the challenges during class. The iterative process of hypothesis generation, hypothesis testing and evaluation of solution appears to be more engaging for the boys as they explore different ways to solve the problems they encounter with the robotics activities. However, the immediate mastery of controlling the robots demonstrated by the boys hindered the learning of the girls in class. While the boys easily accomplished the tasks, the girls struggled and eventually just let the boys do the work. Apparently, their sense of accomplishment and willingness to take risks in seeking solutions diminished. This can lead to loss of interest in not only the activities but also a change of attitude towards science and math learning.

GLE assessment

The Science mean learning gains of both groups were also compared with each GLE (Figure 12).

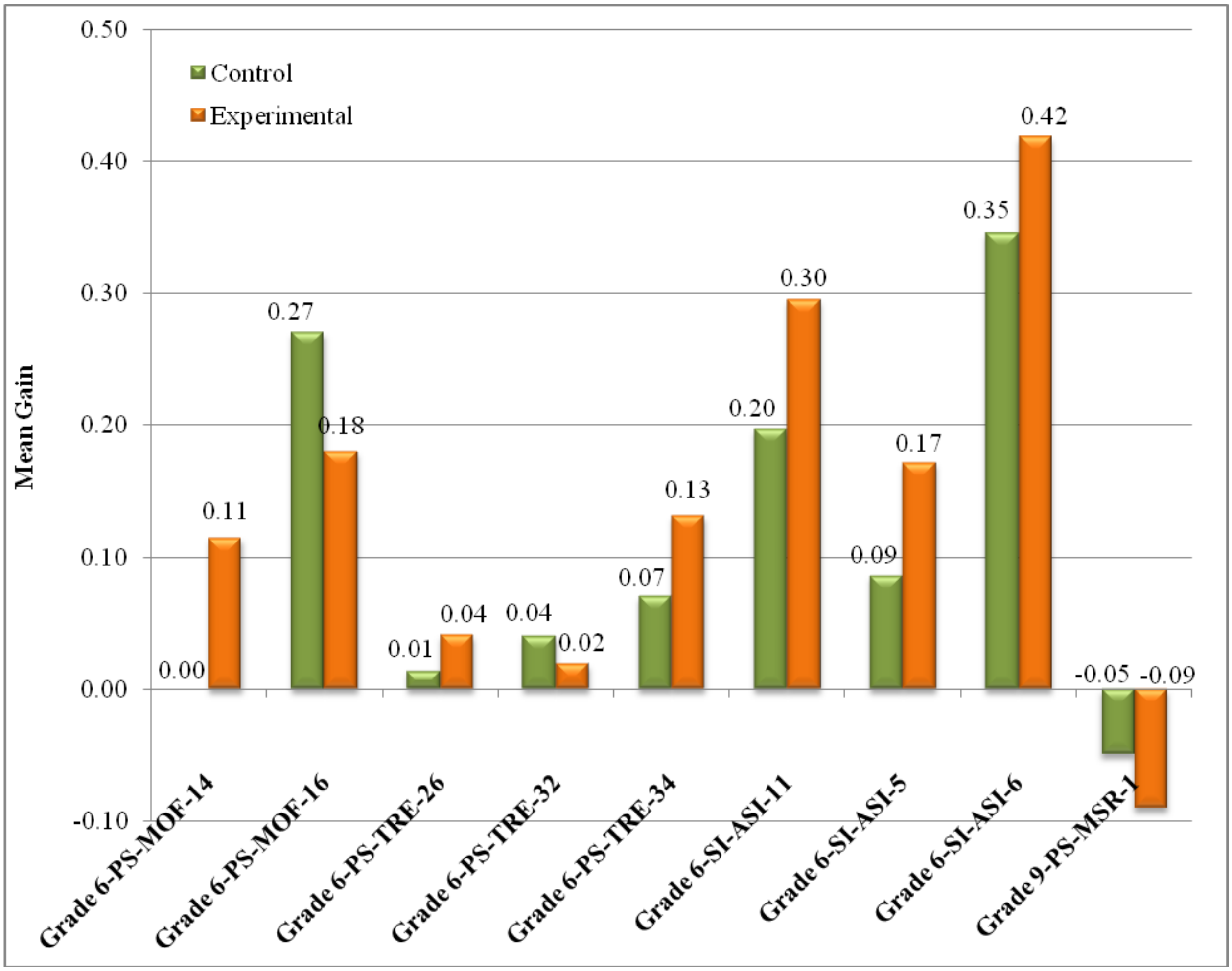


Figure 12. Comparison of the mean learning gains of both groups in every Science GLE.

In almost all of the Science GLE's covered in the test, the experimental group scored a higher learning gain, except on GLE MOF-16 (comparing line graphs of acceleration, constant speed, and deceleration) and GLE MSR -1 (measuring the physical properties of different forms of matter in metric system units). A closer scrutiny of Figure 12 makes it evident that the GLE ASI-11 has the greatest learning gain for the experimental group. This GLE involves

constructing, using and interpreting appropriate graphical representations to collect, record and report data. The mean gain on this GLE also shows the greatest difference between the two groups. The higher gain of the experimental group could be due to their exposure to the robotics engineering curriculum where they were required to gather data based on the behavior of the robots. The next two greatest differences in the mean gains are seen on GLE MOF-14, which involves constructing and analyzing graphs that represent one-dimensional motion, and on GLE ASI-5, which involves identifying independent, dependent and control variables in designing an experiment.

A one-tailed T-test was conducted to determine if the mean gain of the experimental group in each GLE was significantly higher than that of the control group. Results in Table 8 show that when GLE's are examined individually the experimental group did not have a significantly higher mean gain than the control group.

However, the notably higher mean gain of the experimental group on GLE's pertaining to scientific inquiry cannot be disregarded. and it suggests that robotics activities are ideal for teaching scientific inquiry skills. Robotics may provide an environment needed for students to identify and investigate problems, generate hypotheses, gather and analyze data, and to determine findings and interpret results as students go through the different challenges in class.

Math Assessment

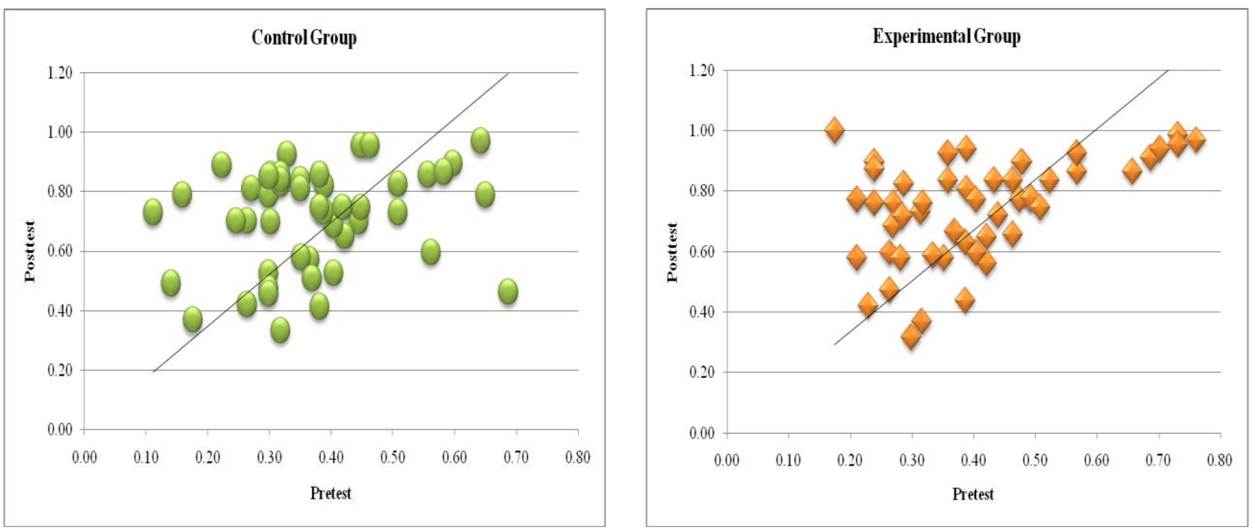
After finishing the Robotics curriculum, it was realized that students get to practice more Math than Science. Thus, further analysis was conducted to examine the students' learning gain in their Math Benchmark assessment for the school year 2009-2010. This required acquisition of the pretest and posttest scores of the students in all of the grade levels. The benchmark assessment was used in this part of the study because the test instrument only covered science GLE's.

Table 8. Welch's T-test results comparing the mean gain of both groups on each GLE.

GLE	Control mean gain	Experimental mean gain	t-statistic	DF	1-tailed *p*
GRADE 6-PS-MOF-14 (construct and analyze graph that represent one-dimensional motion)	0.00	0.11	1.03	130	**0.15**
GRADE 6-PS-MOF-16 (compare line graphs of acceleration, constant speed and deceleration)	0.27	0.18	0.78	126	**0.21**
GRADE 6-PS-TRE-26 (describe and summarize observations of the transmission, reflection and absorption of sound and light)	0.01	0.04	0.25	127	**0.40**
GRADE 6-PS-TRE-32 (identify and illustrate key characteristics of waves)	0.04	0.02	0.18	130	**0.43**
GRADE 6-PS-TRE-34 (apply the law of reflection and law of refraction to demonstrate everyday phenomena)	0.07	0.13	0.54	130	**0.30**
GRADE 6-PS-SI-ASI-11 (construct, use and interpret appropriate graphical representations to collect, record and report data)	0.20	0.30	0.90	124	**0.18**
GRADE 6-PS-SI-ASI-5 (identify independent, dependent and control variables in designing an experiment)	0.09	0.17	0.86	114	**0.20**
GRADE 6-PS-SI-ASI-6 (select and use appropriate aquipment, technology, tools and metric system units of measurement to make observations)	0.34	0.42	0.71	129	**0.23**
GRADE 9-PS-MSR-1 (measure the physical properties of different forms of matter in metric system units)	-0.05	-0.09	0.36	127	**0.36**

Since each grade level test contains a different number of items, the percentage of correct answers was taken for every student. Scores of students with a missing pretest or posttest were removed from the data.

On the Math pretest, the control group had a mean score of 0.36 ± 0.02 while the experimental group scored 0.40 ± 0.02. The scores of the control group ranged from 0.11-0.69, while the scores of the experimental group ranged from 0.17 -0.76. As seen in Figure 13, the pretest scores of the control group are more variable than that of the experimental group.



(a) (b)

Figure 13. Distribution of pretest and posttest scores of the (a) control group and (b) experimental group

The mean pretest scores of the control and experimental groups were compared using a one-tailed T-test. The result of the test is shown on Table 10. Since the *p*-value is 0.06, there is no significant difference in the Math pretest mean scores of the control and experimental groups. This further means that the students on both groups were statistically the same in terms of their Math competency prior to the start of the school year.

Table 10. Welch's T-test results for unequal variance in comparing the pretest scores of both groups on the Math state benchmark assessment.

t statistic	DF	1-tailed p	Decision
1.53	96	**0.06**	**No significant difference**

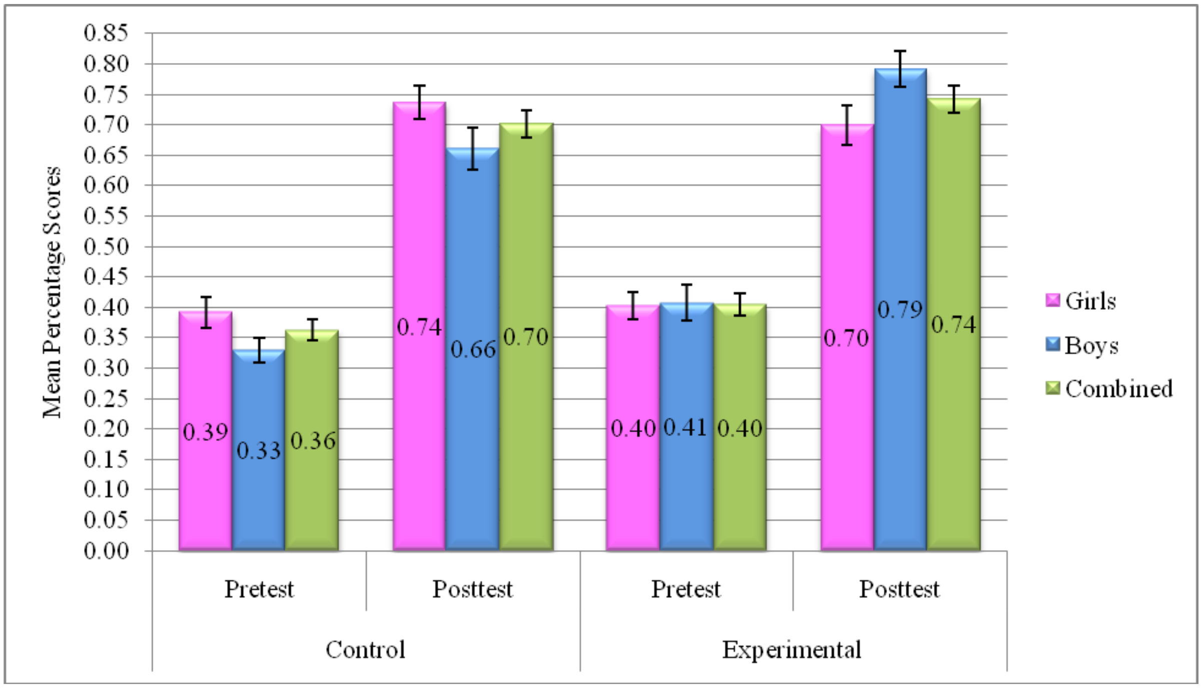


Figure 14. Comparison of the mean percentage scores of the Math pretest and posttest for both groups with gender segregation included.

Figure 13 show that students in both groups showed a significant improvement in their mathematics knowledge from pretest to posttest. It is then necessary to check if the improvement of the experimental group is significantly higher than that of the control group considering that their learning in math is supplemented by additional practice during robotics class.

To determine the effectiveness of Robotics in increasing the achievement scores of students in Math, the mean normalized gains of both groups were compared. Figure 14 shows that the control group had a mean normalized learning gain of 0.53± 0.04 while the experimental group had a mean normalized learning gain of 0.58± 0.03. With a *p*- value of 0.13, there is no significant difference.

Table 9. Summary of statistical values of the pretest, posttest and normalized learning gain in Math for both groups.

	Control n = 62			**Experimental n = 49**		
	Mean	**Standard Deviation**	**Error in mean**	**Mean**	**Standard Deviation**	**Error in mean**
Pretest	0.36	0.13	0.02	0.41	0.15	0.02
Posttest	0.70	0.13	0.02	0.74	0.17	0.02
Normalized gain	0.53	0.29	0.04	0.58	0.23	0.03

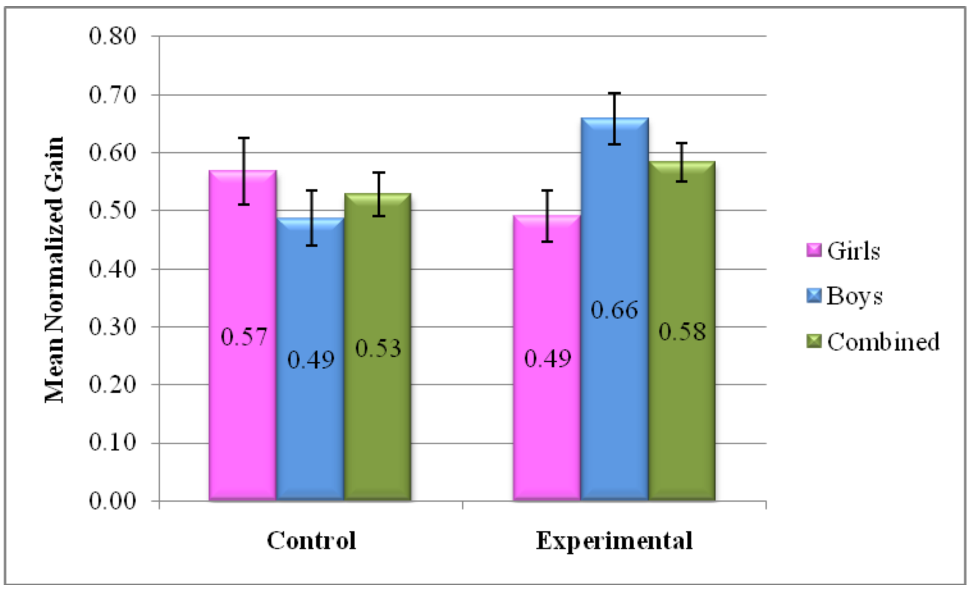


Figure 15. Comparison of the Math mean learning gain of both groups with error bars shown.

Table 11. Welch's T-test results for unequal variances on the normalized gain from the pretest and posttest on the Math state benchmark assessment.

t statistic	**DF**	**1-tailed p**	**Decision**
1.12	109	**0.13**	**No significant difference**

The results of this study indicate that the implementation of the Robotics curricula has no effect in increasing achievement scores of students in Math. One possible explanation for the lack of gain is that students got so involved in programming their robots to accomplish the challenge that they didn't devote time to consider the math concepts seriously. Instead, students resorted to trial and error to get the right settings for the robot. However, in a study conducted by Silk and Schunn (2009) in their analysis of the Robotics engineering curriculum, they claim that the activities cover so many math topics that it was difficult for students to master any one of them. They asserted that the lesson on wheels and distance alone covered topics like ratio and proportion, division of whole numbers, conversion, circumference, and number comparisons among others.

In conclusion, though the students used general math ideas as they engaged in the problem solving process during robotics activities, this research show that their knowledge of math is no different with those who did not take Robotics in terms of the specific topics they are tested on during high stakes testing.

SUMMARY AND CONCLUSIONS

This study aimed to determine the effectiveness of a Robotics engineering curriculum in increasing students' achievement in science and math. Specifically, it aimed to find out if the students taking the robotics class performed significantly higher in science and math than a control group.

The pretest results showed that the control and experimental groups had the same level of knowledge in terms of the concepts covered in each test prior to the Robotics engineering curriculum implementation. After 10 weeks of instruction, a science posttest, the same as the pretest, was administered to both groups and the normalized learning gains were determined. The mean normalized gains of the two groups in both science and math were then compared using t-tests. The results showed that, at the 0.05 level of significance, the science learning gains of the experimental group were not statistically higher than those of the control group.

The mean learning gains in every science GLE were also compared between the control and experimental groups, but t-test results showed no significant difference between the two groups over all the GLE's. It was, noted however, that the students in the experimental group had higher mean gains than the control on almost all of the GLE's. The top three GLE's where the experimental group had higher mean learning gains were: GLE ASI-11(construct, use, and interpret appropriate graphical representations to collect, record, and report data) ; GLE MOF-14 (construct and analyze graph that represent one-dimensional motion) ; and GLE-ASI 5 (identify dependent, independent and control variables in an experiment).

This finding suggest that the robotics engineering curriculum is effective in increasing student achievement only for certain science GLE's. It further suggests that the robotics classes have greatest impact on developing scientific inquiry skills of students which compose 40% of the questions tested during high-stakes testing.

Although the results of the analysis of the math data indicate that the implementation of the Robotics curricula has no effect in increasing achievement scores of students in Math and Science, the positive student and teacher interaction, the higher level of engagement of students (especially males) and their frequent use of math ideas in the problem solving process of the challenges suggests that there is a lot of potential in Robotics.

It is also important to note that Robotics provides an avenue for teachers to see students in a different perspective. Students that are considered to have behavior and learning problems in a regular classroom have been observed to demonstrate a high level of engagement as they work with the robots. The sense of achievement they derive in accomplishing the challenges during class reduces their frustration over poor academic performance.

Moreover, this study has identified an important factor affecting the learning outcomes in a Robotics class—gender. If Robotics is to be used in enticing students to pursue careers in science and technology, it is important to take into consideration the development of a gender-sensitive classroom setting wherein all students (girls and boys) learn at about the same pace or individualized activities are provided based on the learning ability of each student. Failure to do so may create a bias against females.

Indeed, if coupled with the right pedagogical approach, the impact of robotics could go well beyond the test scores on benchmark assessments, to include a long term process of skills development and motivation for a better education.

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APPENDIX A. ALIGNMENT OF THE NATIONAL STANDARDS ADDRESSED BY THE ROBOTICS ENGINEERING CURRICULUM WITH THE LOUISIANA GLE'S

Standard (A description of the standard or particular point of the standard that is addressed through robotics.)	**Robotics Link** (A description of how robotics in general and this curriculum in particular addresses the standard on the left.)	**Louisiana General Learning Expectations**
Science as Inquiry As a result of activities in all grades, all students should develop: • Abilities necessary to do scientific inquiry • Understanding about scientific inquiry Students should be engaged in activities that: • Begin with a question • Allow them to perform an investigation • Gather evidence • Formulate an answer to the original question • Communicate the investigative process and results	The guided investigations in Robotics Engineering are targeted at specific relevant questions about robotics technologies and concepts that lead to rich exploratory experiences. Some investigations focus on specific portions of the inquiry process, such as evidence-gathering or hypothesis evaluation. Others begin with a question and seek an answer using general inquiry processes. Explanation and evaluation are primary abilities applied in answering questions, not simply calculations or summarization.	**LAGLE--Science--Grade 6--PS--ASI—5** Identify independent variables, dependent variables, and variables that should be controlled in designing an experiment Questions number: 17, 21, 22, 23, 27 **LAGLE--Science--Grade 6—PS--ASI—11** Construct, use, and interpret appropriate graphical representations to collect, record, and report data (e.g., tables, charts, circle graphs, bar and line graphs, diagrams, scatter plots, symbols) Questions number: 26
Measurement • Understand measurable attributes of objects and the units, systems, and processes of measurement. • Apply appropriate techniques, tools and formulas to determine measurements.	Understanding the significance and meaning of measurements are central to the understanding of robotics: • Distance the robot travels (linear measurement, meter stick) • Amount a motor turns (angular measurement) • Directional change of the robot (angular measurement, protractor) • Speed of the robot (rate measurement, meter stick, built-in timer) • Physical quantities measured by sensors (touch, sound, light, distance)	**LAGLE--Science--Grade 9—PS--MSR—1** Measure the physical properties of different forms of matter in metric system units (e.g., length, mass, volume, temperature). Questions number: 1, 3 **LAGLE--Science--Grade 6--SI--ASI—6** Select and use appropriate equipment, technology, tools, and metric system units of measurement to make observations. Questions number: 8, 25

Physical Science As a result of activities in the middle grades, all students should develop an understanding of: • Properties and changes of properties in matter • Motions and forces • Transfer of energy By using simple objects, such as rolling balls and mechanical toys, students can move from qualitative to quantitative descriptions of moving objects and begin to describe the forces acting on the objects. Understanding of energy will include light, heat, sound, electricity, magnetism, and the motion of objects. Key Topics: Amplitude and frequency Light and reflectivity Color and perception Ultrasonic waves Simple machines Speed, distance & power	Robotics is able to demonstrate many applied physical concepts. Here are a few examples: • Mechanical advantage (gears) • Basic circuitry (sensor operation) • Digital and analog electronics (sensors) • Light (lamp, light sensor) • Sound (ultrasonic, sound sensors) • Speed (motors) • Friction (robot movement) Quantitative measurement is a staple of all investigations.	**LAGLE--Science--Grade 6--PS—TRE--32** Identify and illustrate key characteristics of waves (e.g., wavelength, frequency, amplitude) Questions number: 5, 12, 13
		LAGLE--Science--Grade 6--PS—TRE—26 Describe and summarize observations of the transmission, reflection, and absorption of sound, light, and heat energy. Questions number: 6, 19, 28
		LAGLE--Science--Grade 6--PS—TRE--36 Explain the relationship between an object's color and the wavelength of light reflected or transmitted to the viewer's eyes Questions number: 15
		LAGLE--Science--Grade 6--PS— TRE--27 Explain the relationship between work input and work output by using simple machines Questions number: 20
		LAGLE--Science--Grade 6--PS--MOF--14 Construct and analyze graphs that represent one-dimensional motion (i.e., motion in a straight line) and predict the future positions and speed of a moving object Questions number:2, 7, 18 **LAGLE--Science--Grade 6--PS--MOF--16** Compare line graphs of acceleration, constant speed, and deceleration. Questions number: 4, 9, 10, 16, 24 **LAGLE--Science--Grade 6--PS--MOF—17** Describe and demonstrate that friction is a force that acts whenever two surfaces or objects move past one another Questions number: 11, 14

APPENDIX B. HOW ROBOTICS ACHIEVES OUTCOMES

How Robotics Achieves Outcomes

Information Addressing how this Robotics Curriculum Addresses Content Standards

You will find information regarding how this curriculum addresses aspects of the various standards on the following pages:

How to Use this Document

This document is designed to link standards to the ways in which a robotics curriculum address those standards. Each standard or organizer is broken up into two sections, following the format below. The robotics link may refer to specific Activities and Investigations within the product, or it may refer to overarching ideas and general principles that are covered.

Standard Title or Description

Standard	Robotics Link
On the left is a description of the standard or particular point of the standard that is addressed through robotics.	*On the right* is a description of how robotics in general and this curriculum in particular addresses this standard.

Science Standards Addressed

From the National Science Education Standards (NSES)

Systems, Order and Organization

The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once.

A system is an organized group of related objects or components that form a whole.

The goal of this standard is to think and analyze in terms of systems.

Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable.

Prediction is the use of knowledge to identify and explain observation, or changes, in advance. The use of mathematics allows for greater or lesser certainty of predictions.

Order is the behavior of units of matter, objects, organisms or events in the universe – can be described mathematically.

Types and levels of organization provide useful ways of thinking about the world

Robots are excellent examples of systems, with many heterogeneous components interacting in organized, methodical ways to achieve results as a whole that they could not have achieved separately.

Examples include:

- Navigation systems (e.g. sensor tells the robot where it is, programmable controller tells the robot how to interpret this information, motors move in order to achieve the desired result)
- Sensing systems (electrical, mechanical, and programming elements of a sensor)
- Power & transmission systems (motor, axle, gear, wheel)
- Manipulator systems
- Lifting systems, vision systems, etc.

Each system can be broken down into subsystems.

Robotics technology is built upon a series of behaviors that can be measured mathematically and are understandable and predictable.

There are many examples that are easy for students to manipulate and understand:

- Gears and mechanical advantage
- Sensors and electronic control
- Wheel diameter and its effect on distance traveled
- Rotation sensor readings and robot path planning

Evidence, Models and Explanation

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows

The investigations included in this curriculum allow students to collect evidence to investigate scientific principles. Robots

individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations and computer simulations. Scientific explanations incorporate existing scientific knowledge and new evidence into logical statements. Terms like "hypothesis," "model," "law," "theory," and "paradigm" are used to describe various scientific explanations.	physically demonstrate many scientific concepts to make them more clear and understandable. Examples include: • Electronics and basic circuitry, which can be demonstrated using touch sensors and the NXT power supply • Gear trains, which demonstrate the ability to mathematically predict mechanical advantage and speed. • Light sensors, which can detect infrared as well as visible light

Constancy, Change and Measurement

Although most things are in the process of becoming different – changing – some properties of objects and processes are characterized by constancy; the speed of light, the charge of an electron, the total mass plus energy of the universe. Energy can be transmitted and matter can be changed. Nevertheless, when measured, the sum of energy and matter in the system, and, by extension, the universe, remains the same. Mathematics is essential for accurately measuring change. Different systems of measurement are used for different purposes. Scale includes understanding that different characteristics, properties, or relationships with a system might change as its dimensions are increased or decreased. Rate involves comparing one measured quantity with another measured quantity, for example, 60 meters per second.	Robots rely on the use of many innate constants in their basic operation. Ultrasonic sensors, for instance, calculate distance based around an assumed value for the speed of sound. In calculating the distance a robot travels per spin of its motor, fundamental mathematical relationships govern the elements of change and constancy between the different factors involved. For example, the ratio between the diameter and circumference of the wheel is constant ($C=\pi d$). On the other hand, a robot doesn't always need to use the same wheels – they can change – yet, no matter what the size of the wheel, the distance traveled per turn of the wheel remains proportional. Measurement is fundamental to all aspects of robotics, from matching dimensions of parts to ensure that they can connect properly, to measuring how far your robot went, to measuring how well a prediction matched a result.

Evolution and Equilibrium

Evolution is a series of changes, sometimes gradual and sporadic, that accounts for the present form and function of objects, natural systems and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions. For example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates.	Every robot design has a story. As they build and modify their robot designs, students can trace the evolution of their creation as they adapt it in different ways that allow it to complete different tasks, building upon lessons learned from their previous designs. Equilibrium appears in many different forms as a design factor that students will encounter in designing their robots. For example, a robot's top speed is an equilibrium point between the physical force of friction and the force generated by the motor.

Form and Function

Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world.	When designing robots, form always follows function. Whether the design decision involves using large versus small wheels, making the motor power high versus low, or selecting the sensing device the robot will use, all decisions are based on what the robot is expected to do: its function. All of these decisions will affect the final shape of the robot: its form.

Science as Inquiry – Content Standard "A"

As a result of activities in all grades, all students should develop: • Abilities necessary to do scientific inquiry • Understanding about scientific inquiry Students should be engaged in activities that: • Begin with a question • Allow them to perform an investigation • Gather evidence • Formulate an answer to the original question • Communicate the investigative process and results	The guided investigations in Robotics Engineering are targeted at specific relevant questions about robotics technologies and concepts that lead to rich exploratory experiences. Some investigations focus on specific portions of the inquiry process, such as evidence-gathering or hypothesis evaluation. Others begin with a question and seek an answer using general inquiry processes. Explanation and evaluation are primary abilities applied in answering questions, not simply calculations or summarization.

Physical Science – Content Standard "B"

As a result of activities in the middle grades, all students should develop an understanding of: • Properties and changes of properties in matter • Motions and forces • Transfer of energy By using simple objects, such as rolling balls and mechanical toys, students can move from qualitative to quantitative descriptions of moving objects and begin to describe the forces acting on the objects. Understanding of energy will include light, heat, sound, electricity, magnetism, and the motion of objects.	Robotics is able to demonstrate many applied physical concepts. Here are a few examples: • Mechanical advantage (gears) • Basic circuitry (sensor operation) • Digital and analog electronics (sensors) • Light (lamp, light sensor) • Sound (ultrasonic, sound sensors) • Speed (motors) • Friction (robot movement) Quantitative measurement is a staple of all investigations.

Science and Technology – Content Standard "E"

As a result of activities in all grades, all students should develop: • Abilities in technological design • Understandings about science and technology Students should begin to differentiate between science and technology. In the middle school years, scientific investigations can be completed by activities in which the purpose is to meet a human need, solve a problem, or develop a product rather than explore ideas about the natural world.	Robotics is the premier example of the marriage of science and technology, especially as related to the solving of problems or human needs. Every investigation students conduct with the robot is motivated by the need to advance the performance of the robot in order to meet performance criteria, connecting the "need to know" with the "ability to do".

Mathematics Standards Addressed

From the National Council of Teachers of Mathematics (NCTM) Standards

Numbers and Operations

• Understand numbers, ways of representing number, relationships among numbers and number systems. • Understand meaning of operations and how they relate to one another. • Compute fluently and make reasonable estimates.	Robotics uses numbers and operations in nearly all lessons, for example: • Calculating distance with rotational sensors (equations, equalities) • Gears, gear ratios and speed (ratios and proportions) • Light sensors and threshold (inequalities) • Wheel circumference, radius and diameter (geometric relationships)

Algebra

• Represent and analyze mathematical situations and structures using algebraic symbols. • Use mathematical models to represent and understand qualitative relationships. • Analyze change in various contexts.	Robotics lessons that involve algebra include the following: • Switch blocks (inequalities) • Programming sensors and thresholds (inequalities) • Measuring turns (equalities, solving equations) • Gears and speed (ratios, direct and indirect proportionality)

Geometry

• Precisely describe, classify, and understand relationships among types of two and three-dimensional objects using their defining properties. • Specify location and describe spatial relationships using coordinate geometry and other representational systems.	Robotics situations involving geometry include: • Wheel rotations and circumference (diameter, circumference) • Identifying locations in order to program a robot to move from point to point (connected path segments) • Interlocking gears and gear ratios (discrete combinations of radii)

Measurement

• Understand measurable attributes of objects and the units, systems, and processes of measurement. • Apply appropriate techniques, tools and formulas to determine measurements.	Understanding the significance and meaning of measurements are central to the understanding of robotics: • Distance the robot travels (linear measurement, meter stick) • Amount a motor turns (angular measurement) • Directional change of the robot (angular measurement, protractor) • Speed of the robot (rate measurement, meter stick, built-in timer) • Physical quantities measured by sensors (touch, sound, light, distance) • Detectable region of a sensor (ultrasonic sensor, meter stick, 2D graph paper)

Problem Solving

• Build new mathematical knowledge through problem solving. • Solve problems that arise in mathematics and other contexts. • Apply and adapt a variety of appropriate strategies to solve problems. • Monitor and reflect on the process of problem solving.	In the lessons, there are both guided and open-ended design problems that involve designing, building, and programming needed to create autonomous robots. • How do I get a robot to move a certain distance? (solved through measurement and the verification and use of a proportionality relationship) • What does the sound sensor measure? (solved by graphing the sensor readings with tones of varying volume and pitch, then seeing which one indicated an orderly relationship)

Reasoning and Proof

• Recognize reasoning and proof as fundamental aspects of mathematics. • Make and investigate mathematical conjectures. • Develop and evaluate mathematical arguments and proofs. • Select and use various types of reasoning and methods of proof.	Reasoning in robotics comes in many different forms, including the following: • Experimental reasoning, proof using measurements and physical evidence (Wheels and Distance) • Reasoning using equations, proof by solving (Measured Turns) • Reasoning about graphs, proof by observing trends (Frequency and Amplitude)

Communications

• Organize and consolidate their mathematical thinking through communications. • Communicate their mathematical thinking coherently and clearly to peers, teachers, and others. • Use the language of mathematics to express mathematical ideas precisely.	Each Activity and Investigation includes worksheet questions that require the student to reflect on what they have accomplished or experienced, and describe it or some aspect of it in their own words to someone else. Emphasis is placed upon explaining reasoning in addition to showing calculations. The End of Project Activities also include opportunities for students to communicate with their peers and teachers what they have learned and accomplished.

Connections

• Recognize and use connections among mathematical ideas. • Understand how mathematical ideas interconnect and build on one another to produce a coherent whole. • Recognize and apply mathematics in contexts outside of mathematics.	One of the strongest features of using robotics to teach math, science, engineering, technology and communications is its ability to make links between multiple disciplines. Students are able to take what they know and connect it to what they are learning, synthesizing new knowledge as they continue.

Technology Standards Addressed

From the International Technology Education Association (ITEA) Standards

The Nature of Technology

1. Students will develop an understanding of the characteristics and scope of technology. 2. Students will develop an understanding of the core concepts of technology. 3. Students will develop and understanding of the relationships among technologies and the connections between technology and other fields of study.	All robotics activities provide excellent hands-on exposure to technology in use and development. • "Connect" activities feature linkages to real-world robots that allow students to connect their designs to real-world needs and solutions • Successful robot operation revolves around the application of systems concepts to make sensors, actuators, and other components work together • Design processes take into account goals, resources, and trade-off factors to achieve optimal results • Technology exists in proper context alongside applications in science, math, and engineering • Several different technologies (e.g. desktop computer, USB/Bluetooth peripheral interface, mobile robotics controller, electromechanical sensors and actuators) are routinely used together in the operation of the NXT robot system, and all are necessary for it to work

Technology and Society

6. Students will develop an understanding of the role of society in the development and use of technology.	Activities are linked to real world robots that use similar technologies to accomplish tasks that fulfill a social and/or economic need in the real world. For example: • Follow the Guidelines (robot follows a line on the table; linked to AMTS real-world robot, which follows a pattern on a warehouse floor to transport materials autonomously) Some activities focus specifically on Human-Robot Interaction (HRI), an emerging field dealing specifically with psychological and design issues relating to the use of robots in human environments. • Hello! My Name Is… (students use sound and graphical elements to make the robot communicate with people) • Full Stop (emergency stop functionality for a runaway mobile robot)

Design

8. Students will develop an understanding of the attributes of design 9. Students will develop and understanding of engineering design 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem-solving.	Students gain first-hand experience with developing a functional robotic system in many activities, including: • Hello! My Name Is…(iterative – students design a robot to convey an emotion, then test their program with real users to see if they can correctly interpret the robot's actions) • Follow the Guidelines and Faster Line Tracking (guided – students first build a functional line-following robot, then improve its performance by modifying the design) • End of Project Housekeeping Challenge (goal-based open ended challenge – students in teams will develop their own robotic solutions to a board-based challenge)

Abilities for a Technological World

11. Students will develop the ability to apply the design process 12. Students will develop the ability to use and maintain technological products and systems	Students will apply design processes continually while working with and developing the robot. Here are some basic examples: • Full Speed Ahead (students learn the basics of making the robot move) • Obstacle Detection (students add a touch sensor and an ultrasonic rangefinder to help the robot avoid collisions) • Get in Gear (students adapt the robot's drive mechanism to make it faster or slower, weaker or stronger) In the course of working with the robot, students will be responsible for the maintenance of their robots: • Mechanical soundness (the robot needs to be kept in good enough condition to perform its tasks daily) • Organizing information (students must keep good enough records to know how to use systems they initially designed days or weeks earlier) • Troubleshooting (robots have problems–often–and students must be able to identify and solve these issues as they arise) Students will work with many important technologies as part of the operation of the NXT system: • Electronic microcontrollers (NXT) • Desktop/laptop computer and software (NXT Programming Software, word processor for writeups, spreadsheets for data graphs) • Peripheral interfaces (USB or Bluetooth wireless) • Electromechanical systems (touch, light, rotation, sound, ultrasonic sensors) • Electromechanical actuators (Interactive Servo Motors)

The Designed World

16. Students will develop an understanding of and be able to select and use energy and power technologies 17. Students will develop an understanding of and be able to select and use information and communications technologies 18. Students will develop an understanding of and be able to select and use transportation technologies 19. Students will develop an understanding of and be able to select and use manufacturing technologies	The NXT robot itself is an excellent example and integrator of many different designed technologies working together as a coordinated system. • Power sources (battery technologies – rechargeable Lithium-Ion vs. disposable alkaline) • Vehicle systems (all the robot's systems must work together in order to make it mobile, a viable platform for transportation of goods or as a platform to perform other work) • Manufacturing and prototyping (robot must be built and modified using appropriate materials, plans and tools) • Structural soundness and stability concepts are integral to the design of the robot's physical form. • Communication between system components (desktop to NXT, sensors to NXT, NXT to motors, NXT to NXT) • Communication technologies (USB vs. Bluetooth)

APPENDIX C. SCIENCE QUESTIONNAIRE USED FOR PRETEST AND POSTTEST ASSESSMENT

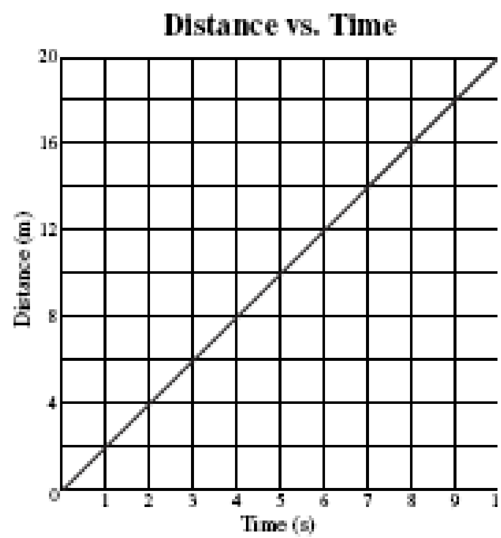
Use the illustration to answer question #1.

1. You are interested in determining how wide your robot is to see if it can fit through a maze that you set up. The problem is that you don't have a ruler around. You remember that 1 module (1M) is equal to 8 mm and then you observe that when you look at the back of your robot it is made up of one long 13M beam plus the wheels on both sides. You measure each wheel to be a width of about 4M. What would be the minimum width of the maze in order for your robot to fit?

    1. 175 mm
    2. 100 mm
    3. 42 mm
    4. 75 mm

2. The graph below relates distance and time for a moving object. What is the speed of the object represented below?

    A. 0.5 m/s
    B. 2 m/s
    C. 10 m/s
    D. 20 m/s

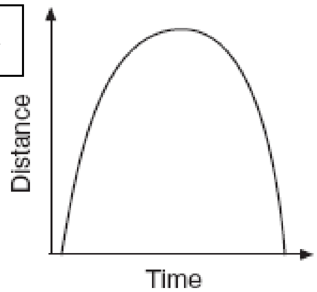


3. Shaun programmed his robot to go forward 5 rotations of the wheel. He used the big wheels that have a diameter of 5.5 cm. How far forward would you expect Shaun's robot to travel after running his program? (Recall that the circumference of a circle is equal to the diameter of the circle times pi [C= d * pi, where pi is equal to 3.14]

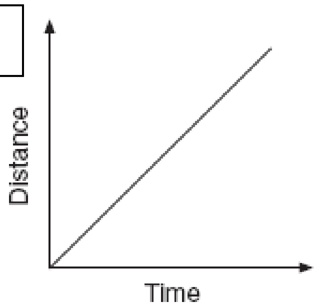
    A. 86.35 cm
    B. 27.5 cm
    C. 8.75 cm
    D. 68.35 cm

4. Which of the following graphs represents a train moving at constant speed?

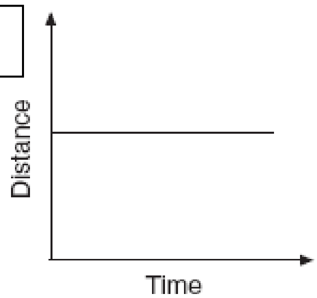
A.



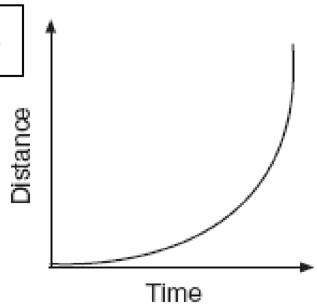
B.



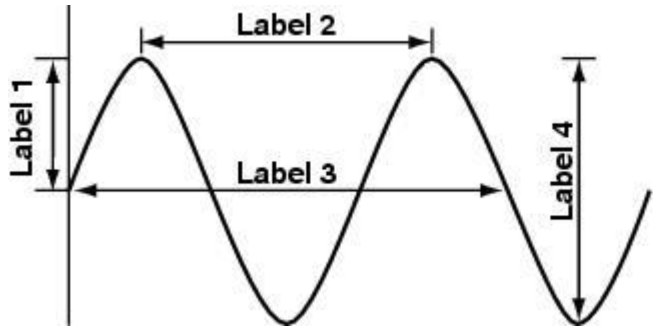
C.



D.



The diagram below is a graph of a light wave, use it to answer question #5.



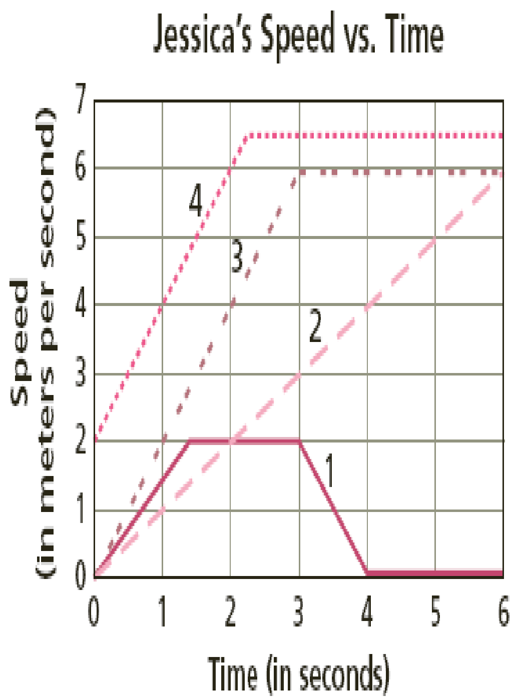
5. Which label identifies the measurement of the amplitude?

   A. Label 1
   B. Label 2
   C. Label 3
   D. Label 4

6. Pitch of a sound that you hear depends on the frequency of the sound wave. Humans can hear only a certain range of pitches. A sound that is too high for humans to hear is called

   A. infrasound
   B. decibel
   C. ultrasound
   D. rhythm

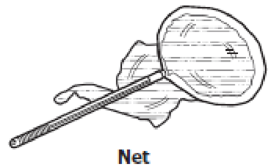
Use the graph below to answer question #7.

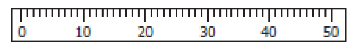


7. Justin-bot is a robot trainor. When practice race starts, Justin-bot can accelerate at the rate of 2 meters per second until he reaches a speed of 6 meters per second. Study the plot lines on the graph below. Which plot line correctly shows Justin-bot's acceleration and speed?

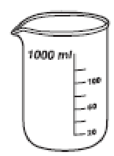
   A. Graph 1
   B. Graph 2
   C. Graph 3
   D. Graph 4

8. Which of these is the best tool to use when measuring the distance travelled by the robot?

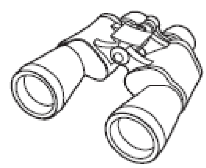
   A. 
   Net

   B. 

   Meter stick

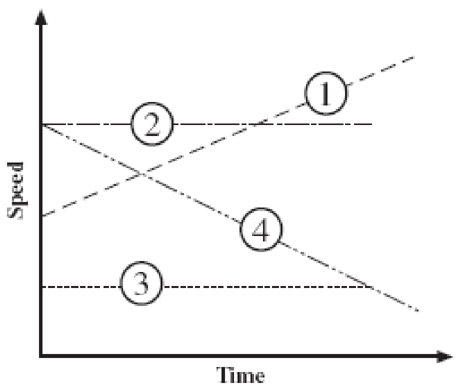
   C. 

   Beaker

   D. 
   Binoculars

Use the graph below to answer questions #9 and 10.

The graph relates speed and time of four cars (1, 2, 3, and 4) traveling along a straight highway.



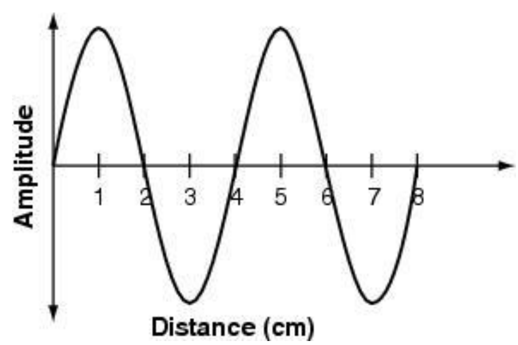
9. Which two cars move with zero acceleration?
   A. 1 and 4
   B. 2 and 3
   C. 1 and 2
   D. 3 and 4

10. Which car shows deceleration?
    A. Car 1
    B. Car 2
    C. Car 3
    D. Car 4

11. After a golf ball was hit, it landed on a flat grass surface and rolled for 25 meters before coming to a rest. Which of these caused the golf ball to stop rolling?

    A. the force of gravity
    B. the friction from the grass
    C. the decreasing mass of the golf ball
    D. the increasing energy of the golf ball

The graph below shows a soundwave use it to answer 12 and 13.



12. How many crests are shown in the graph above?

    A. 1
    B. 2
    C. 3
    D. 4

13. What is the measure of the wavelength in this graph?

    A. 2 cm
    B. 3 cm
    C. 4 cm
    D. 6 cm

14. The force of friction is **MOST** necessary to which of these technologies?

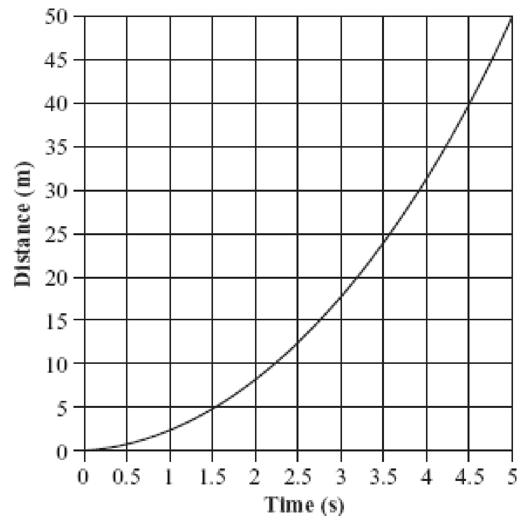
    A. television screen
    B. brakes on a bicycle
    C. glass in an electric bulb
    D. batteries in an electronic game

15. When light strikes an object, the light can be reflected, transmitted, or absorbed. In a robot's case, a light sensor measures the reflected light. The sensor has two small bulbs in the front, one is a Light Emitting Diode and the other is a photoresistor that converts the light energy that it receives into electrical impulses that it sends to the brain of the robot. A light-colored material or surface absorbs less light thus, gives a higher reading to the light sensor. Given this knowledge, identify the color that will give the robot a low reading:

    a. green
    b. black
    c. pink
    d. yellow

The distance vs. time graph below shows data collected as a robot moved across a level parking lot.

16. According to the graph, which of the following conclusions about the robot's motion is supported?



    A. The robot is accelerating.
    B. The robot is stopping and starting.
    C. The robot is traveling at a constant velocity.
    D. The robot is moving through an obstacle course.

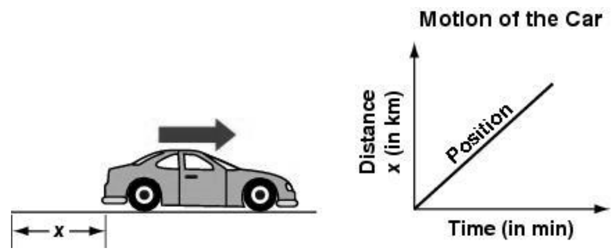
Use the information below to answer question #17.

Leah performed an experiment to study the effect of slope of a ramp on the speed of moving objects.

- She built three ramps from the same material, but with different slopes.
- She rolled a ball down each ramp.
- She measured the speed of the ball on each ramp.

17. What is the independent variable in this experiment?
    A. the speed of the ball
    B. the same material on all three ramps
    C. the different slopes on the ramps
    D. the type of balls used

Use the information below to answer question #18.
The distance traveled by a car on a highway and the time taken by the car are plotted on the graph shown below.

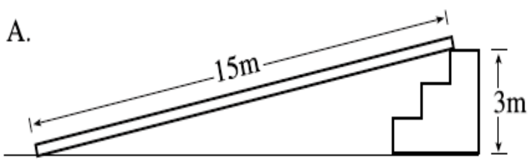


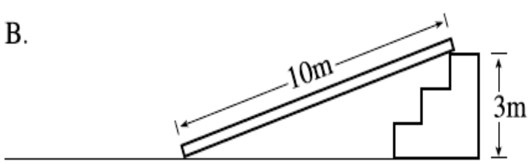
18. What can be concluded about the speed of the moving car?
    A. The speed of the car remains constant.
    B. The speed of the car increases with an increase in time.
    C. The speed of the car decreases with an increase in time.
    D. The speed of the car depends on the direction of motion.

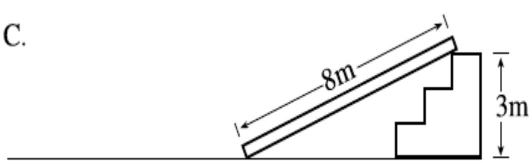
19. Mrs. Adams asks her students to name a place where sound waves will **NOT** travel. Which example should her students include in their answer?

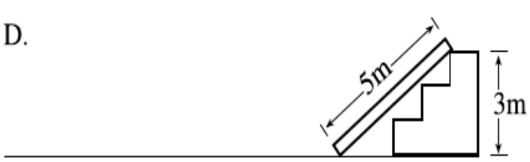
A. desert
B. glacier
C. sea
D. space

20. A robot must climb a stage that is 3 meters off the ground. Which of the ramps would require the **LEAST** amount of work by the robot?

A.


B.


C.


D.


A student wanted to know the effect of changing the power level of the robot to its speed. He programmed the robot to move forward for 5 rotations (equivalent to 88 cm) at different levels of power, then he took the time it took for the robot to complete 5 rotations.

22. What is the dependent variable?

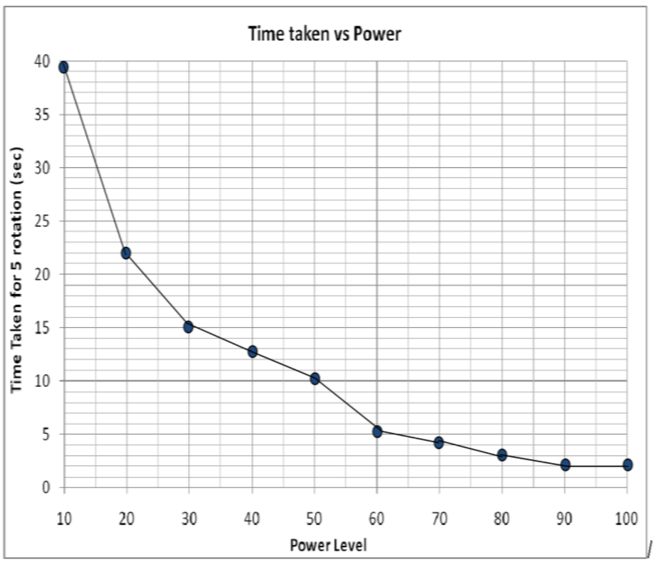
A. Direction
B. Rotation
C. Power level
D. Time

23. Identify a variable that was kept constant in the experiment.

A. Speed
B. Power level
C. Rotation
D. Time

Maria conducted an experiment to know the effect of changing the power level of the robot to its speed. She programmed the robot to move forward for 5 rotations (equivalent to 88 cm) at different levels of power, then she took the time it took for the robot to complete 5 rotations.

The graph below shows the data that she has gathered from the experiment.

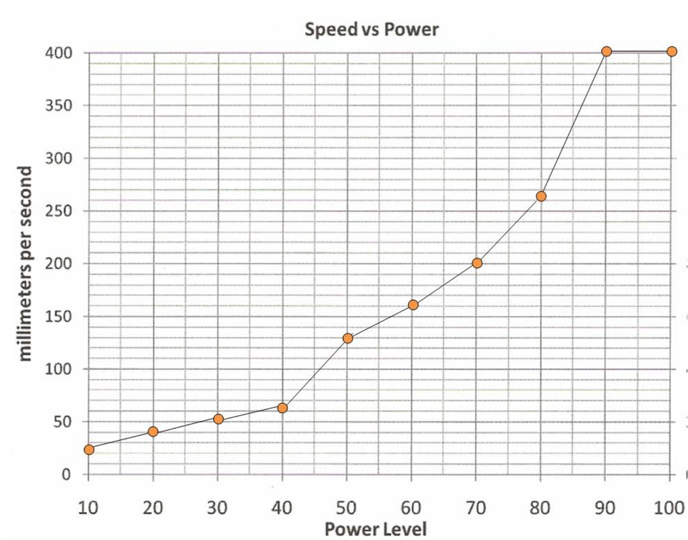


24. Based on the graph above, make a prediction as to how long it will take to do 5 rotations at 65% power.

    A. 5 sec
    B. 4 sec
    C. 10 sec
    D. 2 sec

25. Jordan asks the manager at the golf course about the length of the course. Which of the following units is most appropriate to use in reporting the length of the course?
    A. liters
    B. grams
    C. meters
    D. centimeters

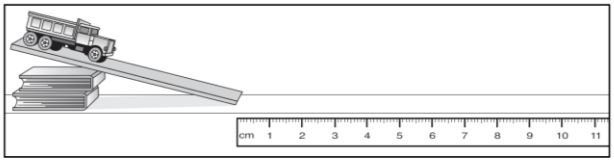
Use the information below to answer question #26.

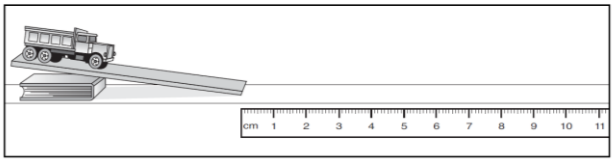


26. A robot needs to run in a sandy area and the only advisable speed to use is 180 mm/sec to prevent the robot from turning over. Based on the graph above, what power level will you recommend to set the robot.

    A. 65%
    B. 50%
    C. 70%
    D. 85%

Use the information below to answer question #27.





27. Madi let the truck go at the top of each ramp and measured the distance it traveled. Which of the following is **most likely** what she was trying to prove?

    A. A toy truck will roll down a ramp held up with books.
    B. A toy truck will move straight down a ramp whether the ramp is held up with one book or two books.
    C. A toy truck will roll about twice as far coming off a two-book ramp than a one-book ramp.
    D. A toy truck on a one-book ramp has half the force of gravity as a truck on a two-book ramp.

28. The Amplitude of a sound wave is perceived as:

    a. The volume of the tone
    b. The pitch of the tone
    c. The timbre of the tone
    d. The rhythm of the tone

Sources:

Massachusetts Department of Education Released Test Items: 1, 2, 10, 25 and 26

West Virginia Department of Education Released Test Items: 3, 4, 5, 6, and 7

Virginia Department of Education Released Test Item: 11

Ohio Department of Education Released Test Items: 12

Riverside: 13, 14, 15, 16, 18, 19, 20, and 21

EBR Test Writing Committee: 17, 22, 23, and 24

APPENDIX D. 6TH GRADE MATH COMPREHENSIVE BENCHMARK ASSESSMENT FOR SCHOOL YEAR 2009-10

Grade 6
Mathematics

Benchmark Assessment

August Pre-Test

2009-2010

East Baton Rouge Parish School System
Department of Accountability, Assessment and Evaluation

1. Which of the following is a prime factor of 38?

   A. 38

   B. 19

   C. 11

   D. 3

2. What are the common factors for 20 and 28?

   A. 4, 5, 10

   B. 1, 4, 7

   C. 2, 4, 5

   D. 1, 2, 4

3. Kathy and Patrick are making beaded necklaces. Each necklace has 18 beads on a single string. Kathy puts a blue bead every third bead. Patrick puts a blue bead every second bead. At which exact place on their necklaces will both Kathy and Patrick have a blue bead?

   A. The 3rd bead

   B. The 5th bead

   C. The 6th bead

   D. The 10th bead

4. What is the decimal equivalent to $\frac{1}{4}$?

   A. 0.04

   B. 0.25

   C. 0.40

   D. 0.75

5. Four students shared a pizza. The table below lists how much of the pizza was eaten by each student. Which student below ate the most pizza?

Student	Amount of Pizza Eaten by Student
1	0.10
2	$\frac{2}{5}$
3	$\frac{1}{3}$
4	$\frac{1}{10}$

A. Student 1

B. Student 2

C. Student 3

D. Student 4

6. Shannon cut her candy bar in fourths. She then cut each piece in $\frac{1}{2}$ again. What fraction of the whole candy bar is each final piece?

A. $\frac{1}{16}$

B. $\frac{1}{8}$

C. $\frac{1}{4}$

D. $\frac{1}{2}$

7. Jackson answered 73 out of 100 questions correctly on his science test. What is his score in decimal form?

A. 0.0073

B. 0.0730

C. 0.7300

D. 7.3000

8. Which of these numbers is the largest?

   A. –10

   B. –4

   C. 0.75

   D. $\frac{4}{8}$

9. What fraction below is TRUE?

   A. $\frac{1}{8} < \frac{1}{4}$

   B. $\frac{1}{4} > \frac{1}{2}$

   C. $\frac{2}{4} < \frac{1}{4}$

   D. $\frac{3}{8} = \frac{1}{4}$

10. What is the correct way to write seventy six and three thousandths?

    A. 7.6300

    B. 76.003

    C. 76.030

    D. 76.3000

11. What fraction of the total number of cans was collected by classes 3 and 4 together?

Class	Number of Cans
1	200
2	300
3	150
4	350

    A. $\frac{1}{2}$

    B. $\frac{1}{5}$

    C. $\frac{2}{3}$

    D. $\frac{5}{9}$

12. The following table shows the miles run by four students during a week.

Student	Miles Run
1	1.267
2	4.1
3	3.40
4	2.7325

What is the best estimate of the total miles run by all students to the nearest tenth?

A. 11.50

B. 11.40

C. 11.49

D. 11.45

13. What is 12.5 times 100?

A. 125

B. 250

C. 1,250

D. 12,500

14. What is 6,340 divided by 16?

A. 792.50

B. 397.50

C. 396.25

D. 300.00

15. 54 children are on a school bus with 18 seats. What is the ratio of children to seats?

A. $\frac{1}{3}$

B. 3:1

C. $\frac{3}{3}$

D. 3:3

16. Which of the following numbers is a perfect square?

A. 10

B. 18

C. 33

D. 81

17. Tyrone and Jakia met their friends to go bowling. They divided into 4 separate teams of 5 players each. Which equation could be used to calculate *f*, the total number of people bowling?

A. $f + 4 = 5$

B. $\frac{5}{f} = 4$

C. $\frac{f}{4} = 5$

D. $\frac{4}{5} = f$

18. A car lot had 30 cars for sale. There was exactly the same number of cars (*c*) in each of the following colors: red, blue, black, white and tan. Which equation below could help determine how many cars there were of each color?

A. $\frac{5}{c} = 30$

B. $\frac{30}{5} = c$

C. $\frac{c}{30} = 5$

D. $c + 5 = 30$

19. Steven has been saving his allowance to buy CDs. Each CD is \$14 and an additional \$2 for tax. Using the expression $14n + 2n$ (where n is the number of CDs), how much would 3 CDs cost?

A. \$48

B. \$44

C. \$42

D. \$16

20. The grocery store sells apples (a) for 50¢ each and pears (p) for \$2.00 each. Using the expression $0.50(a) + 2(p)$, how much money will be needed to buy 10 apples and 12 pears?

A. \$1.00

B. \$2.50

C. \$18.00

D. \$29.00

21. It takes 3 times longer to swim the length of the swimming pool as it does to swim the width of the pool. It takes 12 minutes total to swim both the width and length of the pool once. How long does it take to swim the length of the pool only? (Use the equation $3m + m = 12$, where m is equal to the number of minutes to swim the width of the pool only)

A. 3 minutes

B. 4 minutes

C. 9 minutes

D. 10 minutes

22. Sometimes Malik walks to his house after school and sometimes he walks to his friend's house. It is 15 blocks to his friend's house, which is 3 more than twice the number of blocks to his house. This can be represented by the equation $2b + 3 = 15$, where b is equal to the number of blocks to his house. How many blocks must Malik walk to his house from school?

A. 3

B. 6

C. 9

D. 12

23. Robert had 16 games to sell. He has 7 newer games and 9 older games. If he sold his newer games for \$5 each and his older games for \$3 each, how much money would he get from selling all 16 games?

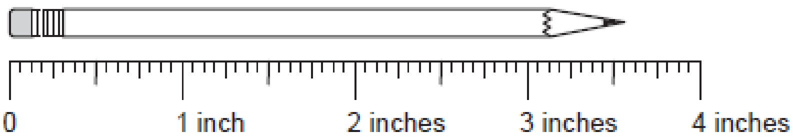
A. \$48

B. \$62

C. \$78

D. \$80

24. What is the length of the pencil to the nearest $\frac{1}{16}$ of an inch?



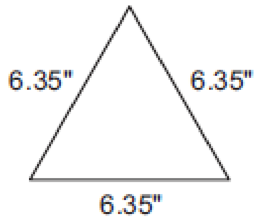
A. $\frac{9}{16}$

B. $3\frac{7}{16}$

C. $3\frac{9}{16}$

D. $3\frac{15}{16}$

25. What is the perimeter of the shape below?



A. 12.7”

B. 18”

C. 19.05”

D. 36”

26. The supermarket has bananas on sale. A shopper bought 3 pounds of bananas for \$2.07. What was the price per pound of the bananas?

A. 3¢

B. 69¢

C. \$2.07

D. \$6.21

27. Jeff is building a new table for his family. Which of the following is most likely the size of the top of the new table?

A. 6 feet × 4 feet

B. 10 yards × 3 yards

C. 6 inches × 12 inches

D. 12 centimeters × 140 centimeters

28. What is <u>most likely</u> the area of a classroom bulletin board?

A. 40 square inches

B. 40 square yards

C. 40 square miles

D. 40 square feet

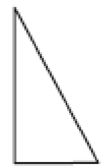
29. If Samantha is making a poster for her bedroom, which unit of measure would be the best to determine how big to make the poster?

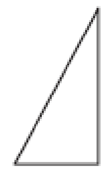
    A. Square mile
    B. Square inch
    C. Square kilometer
    D. Square millimeter

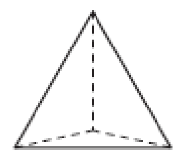
30. How many vertices does a rectangular prism have?

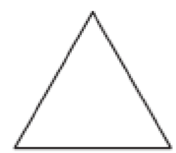
    A. 2
    B. 4
    C. 6
    D. 8

31. Which of the drawings is a polyhedra?

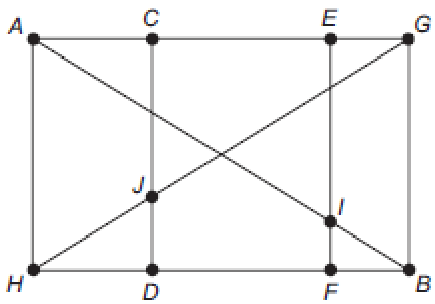
    A. 

    B. 

    C. 

    D. 

32. Jeff wants to find the exact center of a wall. Which 2 intersecting lines below would help him most directly determine the center?



A. $\overline{AB}$, $\overline{GH}$

B. $\overline{AB}$, $\overline{CD}$

C. $\overline{CD}$, $\overline{EF}$

D. $\overline{CD}$, $\overline{GH}$

33. Of the toys listed below, which would best represent the process of tessellation?

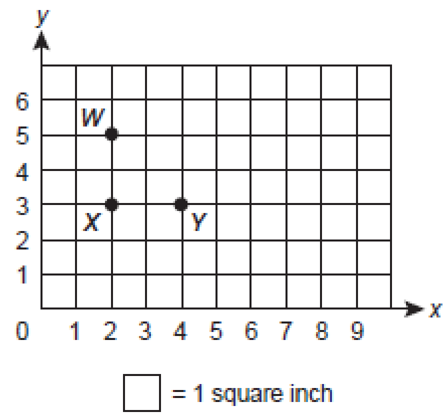
A. A yo-yo

B. A baseball glove

C. A stuffed animal

D. A checker board

34. A fourth point (Z) is added to the grid below to make square $WXYZ$. What will the coordinates be for point Z?



A. (2, 1)

B. (4, 1)

C. (4, 5)

D. (6, 3)

35. Lori's team played 6 games of basketball. Her team's scores are listed below in the stem and leaf plot.

Stem	Leaf
1	5 8
2	2 5 7
3	3

Of the 6 games played, how many times did Lori's team score <u>higher</u> than 21 points?

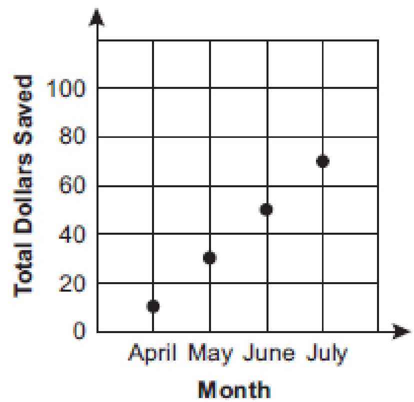
A. 3

B. 4

C. 5

D. 6

36. Marcus is saving for a new game. If he continues to save at the same rate, approximately how much will Marcus have saved by the end of August?



A. $80

B. $90

C. $100

D. $110

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Stem	Leaf
1	5 8
2	2 5 7
3	3

Of the 6 games played, how many times did Lori's team score <u>higher</u> than 21 points?

A. 3

B. 4

C. 5

D. 6

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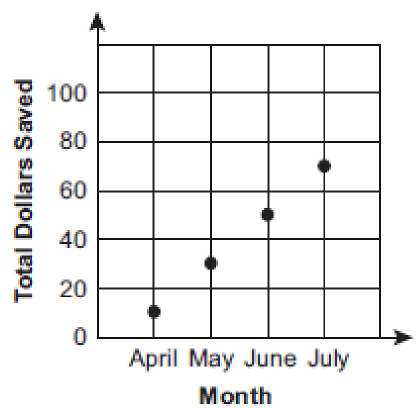


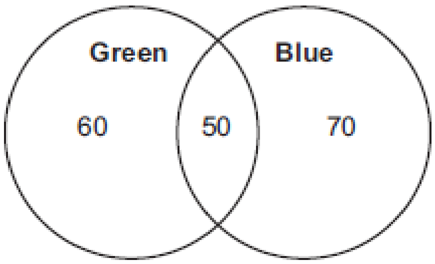
A. $80

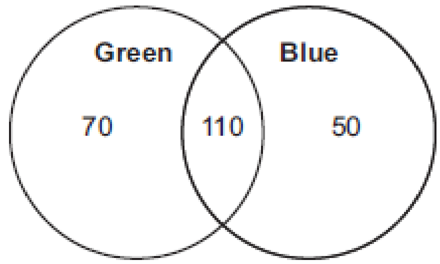
B. $90

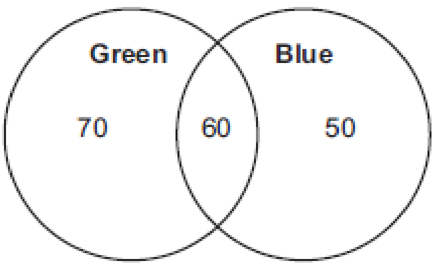
C. $100

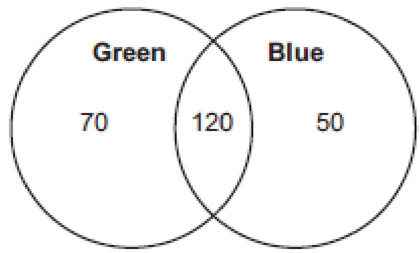
D. $110

39. The floor tile in Tameka's game room has 3 different colors. Seventy of the tiles are green, fifty of them are blue, and the remaining tiles are both green and blue. There are a total of 240 tiles. Which diagram correctly shows the type of tiles in Tameka's room?

A. 

C. 

B. 

D. 

40. A restaurant serves 12 flavors of cheesecake. With the cheesecake, the restaurant offers a choice of one of the following toppings to put on the cheesecake: whipped cream, fruit, or nuts. How many unique combinations of cheesecake and toppings are available?

    A. 12

    B. 15

    C. 36

    D. 48

41. If 62% of the class had been to Blue Bayou, what percentage had not been to Blue Bayou?

    A. 6.2%

    B. 31%

    C. 38%

    D. 124%

42. Matt put twelve blue, twelve red, and twelve yellow marbles in a bag and then shook it up. Without looking, he pulls out a marble, returns it, and pulls out another marble. How likely is he to pull a red marble first?

A. It is more likely that Matt will choose red.

B. It is less likely that Matt will choose red.

C. He has a 1 in 4 chance of choosing red.

D. It is equally likely that Matt will choose red.

43. What is the rule for the table below? Let n equal the input.

In	Out
3	7
4	9
5	11
7	15

A. $n + 4$

B. $2n - 1$

C. $2n + 1$

D. $3n - 3$

44. The ice cream truck came to Lindsey's neighborhood. Lindsey and her 2 friends decided to buy the same kind of ice cream.

Fudgesicle	50¢ each or 2 for 75¢
Dreamsicle	75¢ each or 2 for $1.25
Rainbow Pop	60¢ each or 2 for $1.10
Chocolate Pop	80¢ each or 2 for $1.50

If they each bought a dreamsicle, how much money would they need?

A. $2.00

B. $2.25

C. $2.50

D. $2.75

45. Aaron's mom took him to the park batting cage to practice his hitting. The batting cage charges the rates listed on the sign shown below.

Time	Cost
10 minutes	50¢
20 minutes	$1.00
30 minutes	$1.50
40 minutes	$2.00

How much would it cost for Aaron to practice for 60 minutes?

A. $1.00

B. $1.50

C. $2.00

D. $3.00

46. What would be the next number in the following sequence based on the pattern shown?

3, 4, 6, 9, 13, 18, 24, ___

A. 26

B. 27

C. 31

D. 32

APPENDIX E. 7TH GRADE MATH COMPREHENSIVE BENCHMARK ASSESSMENT FOR SCHOOL YEAR 2009-10

Grade 7
Mathematics

Benchmark Assessment

August Pre-Test

2009-2010

East Baton Rouge Parish School System
Department of Accountability, Assessment and Evaluation

1. Trey's parents want him to save $\frac{1}{5}$ of his allowance each week to help pay for swimming lessons. What percentage of his allowance did Trey's parents ask him to save?

   A. 20%

   B. 25%

   C. 40%

   D. 60%

2. Which answer shows numbers listed from least to greatest?

   A. 0.07 → 0.34 → 0.64 → 0.89

   B. 0.07 → 0.34 → 0.89 → 0.64

   C. 0.07 → 0.64 → 0.34 → 0.89

   D. 0.89 → 0.64 → 0.34 → 0.07

3. Which answer shows numbers listed from greatest to least?

   A. $\frac{1}{8}, \frac{1}{6}, \frac{1}{4}, \frac{1}{2}$

   B. $\frac{1}{6}, \frac{1}{4}, \frac{1}{8}, \frac{1}{2}$

   C. $\frac{1}{4}, \frac{1}{2}, \frac{1}{6}, \frac{1}{8}$

   D. $\frac{1}{2}, \frac{1}{4}, \frac{1}{6}, \frac{1}{8}$

4. What is the value of $(14 - 4) \times 3$?

   A. 2

   B. 18

   C. 21

   D. 30

5. Eric is mailing three envelopes. He must use one 24¢ stamp and one 17¢ stamp on each envelope. Choose the answer that uses the distributive property to determine how much it will cost Eric to mail all three envelopes.

   A. $3 \times 0.24 - 3 \times 0.17 = \$0.21$

   B. $3 \times 0.24 + 3 \times 0.17 = \$1.23$

   C. $0.24 \times 0.17 + 3 \times 3 = \$4.17$

   D. $0.24 \times 0.17 \times 3 = \$12.24$

6. Solve the following problem.

   $\frac{1}{9} \times \frac{1}{3}$

   A. $\frac{9}{3}$

   B. $\frac{1}{3}$

   C. $\frac{1}{12}$

   D. $\frac{1}{27}$

7. Solve the following problem.

   $0.25 \div 0.50$

   A. 0.125

   B. 0.25

   C. 0.50

   D. 0.75

8. An ant colony contains 20,000 ants in the fall. Only 10,000 of the ants remain at the end of the winter. What percent of the ants remained through the winter season?

   A. 5%

   B. 20%

   C. 25%

   D. 50%

9. Which expression can be used to solve the following problem?

   A restaurant charges \$100 per hour to rent a private room and \$21.50 per person for dinner. What is the total cost for a 2-hour dinner for 50 people?

   A. $2 \times 21.50 + 100 \times 50$

   B. $2 \times 50 + 100 \times 21.50$

   C. $2 \times 100 + 21.50 \times 50$

   D. $2 \times 100 + 21.50 + 50$

10. To price items for sale, a store multiplies the cost of the item by 1.4 and then adds 2 dollars. If an item costs the store \$20, at what price will the store sell this item?

   A. \$23.40

   B. \$28.00

   C. \$30.00

   D. \$42.40

11. In which situation would using estimation be <u>most</u> appropriate?

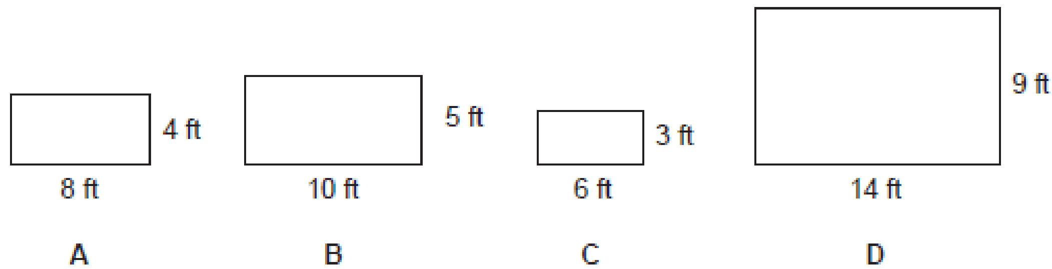
   A. Finding the dimensions of a door which will be replaced

   B. Determining the amount of money to pay the electric bill

   C. Calculating the amount of flour needed to bake a cake

   D. Finding the number of jelly beans it takes to fill a gallon jar

12. The dimensions of 4 rectangles are given below.



Which rectangle does not have the same ratio of length to width as the other three?

A. A

B. B

C. C

D. D

13. In a square, what is the ratio of the perimeter to the length of one side?

    A. 2:1

    B. 4:1

    C. 6:1

    D. 8:1

14. A car can go 30 miles per one gallon of gas. At this rate, how many gallons of gas will it need to go 600 miles?

    A. 12 gallons

    B. 20 gallons

    C. 50 gallons

    D. 80 gallons

15. The volume of a square pyramid can be found using the following formula where V = volume, s = length of base, and h = height:

    $$V = (s^2h) \div 3$$

    What is the volume of a square pyramid with $s = 3$ in. and $h = 5$ in.?

    A. 10 in.^{3}

    B. 15 in.^{3}

    C. 45 in.^{3}

    D. 135 in.^{3}

16. The volume of a cylinder can be found using the following formula where V = volume, r = radius, and h = height:

    $$V = 3.14 \times r^2h$$

    What is the volume of a cylinder with $r = 5$ cm and $h = 6$ cm?

    A. 30 cm^3

    B. 84.5 cm^3

    C. 188.4 cm^3

    D. 471 cm^3

17. The $\sqrt{130}$ would fall between which two whole numbers?

    A. 13 and 14

    B. 12 and 13

    C. 11 and 12

    D. 10 and 11

18. A kite was floating at a fixed height, *x*, above the ground. Then the kite rose 12 feet to a height of 20 feet above the ground. Which algebraic equation can be used to find the height, *x*, of the kite before it rose?

    A. $x - 12 = 20$

    B. $x + 12 = 20$

    C. $20 = 12x$

    D. $20x = 12$

19. Julie and Tameka collected canned food for a food drive. Julie collected 38 cans. This was about 3 times more than Tameka, *t*, collected. Which inequality represents this statement?

    A. $38 < t$

    B. $38 > t$

    C. $38 < 3 + t$

    D. $38 > t - 3$

20. Michelle plans to shop for candy for her party. She has \$25, but wants to save \$4 to pay for parking. Michelle knows that candy costs \$7 per bag and needs to determine how many bags of candy, *x*, she can buy. Which equation should she use to determine how many bags of candy she can buy?

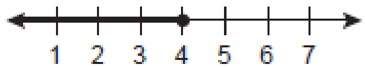
    A. $7x - 4 = 25$

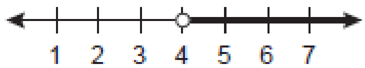
    B. $7x + 4 = 25$

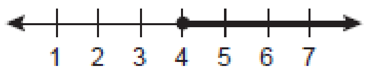
    C. $25 \times 4 = 7x$

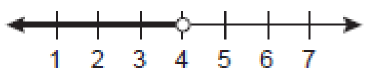
    D. $4x + 25 = 7$

21. Which of the following graphs shows the solution set of $x \leq 4$?

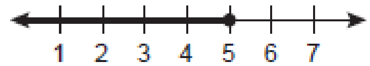
A. 

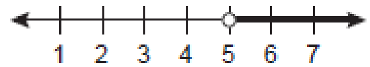
B. 

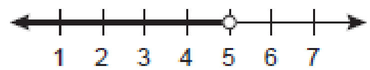
C. 

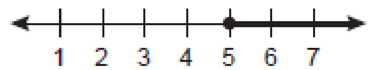
D. 

22. Which of the following graphs shows the solution set of $x > 5$?

A. 

B. 

C. 

D. 

23. The table below shows the number of lawns Abby mowed in May, June, and July.

Month	Number of Lawns Mowed
May	8
June	10
July	12

If this pattern continues, which expression can be used to find the number of lawns she will mow (s) in August?

A. $s = 12 + 2$

B. $s = 12 \times s$

C. $s = 12 - 2$

D. $s = 12 \div 2$

24. The table below shows how many words a secretary can type over time.

Minutes	Number of Words
1	60
8	480
16	960

If x represents the number of minutes, which rule represents the number of words the secretary can type in x minutes?

A. $60x$

B. $\frac{60}{x}$

C. $60x + 8$

D. $60x - 8$

25. What is the maximum area of a photo that can appear in a 5 in. × 7 in. frame?

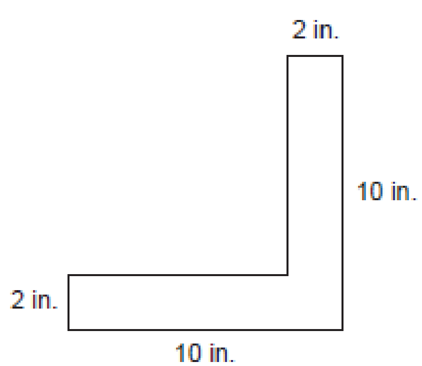
A. 5 in.^{2}

B. 7 in.^{2}

C. 35 in.^{2}

D. 226 in.^{2}

26. Find the perimeter of the following composite figure.



A. 24 in.

B. 40 in.

C. 89 in.

D. 150 in.

27. Lindsey bought four different kinds of meat at the store. The weight of each meat package is shown below in the table.

Item	Weight
Chicken	900 grams
Beef	1 kilogram
Pork	2.5 pounds
Fish	30 ounces

Which package of meat is the heaviest?

A. Chicken

B. Beef

C. Pork

D. Fish

28. Stephen weighs 40 kilograms. How many grams does he weigh?

    A. 40,000 grams

    B. 4,000 grams

    C. 400 grams

    D. 40 grams

29. Use the formula $F = (C \times 1.8) + 32$ where F = degrees Fahrenheit and C = degrees Celsius. If it is 50 degrees Fahrenheit, what is the temperature in degrees Celsius?

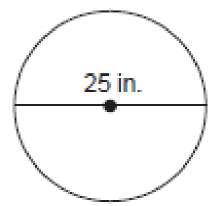
    A. 70 degrees Celsius

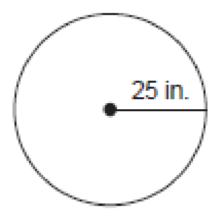
    B. 30 degrees Celsius

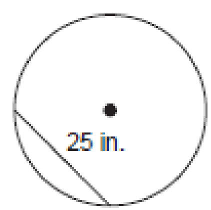
    C. 20 degrees Celsius

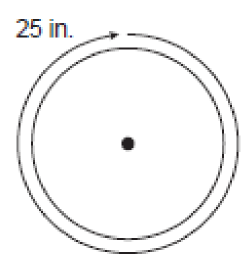
    D. 10 degrees Celsius

30. A piping company needs to choose a pipe that has a diameter of 25 inches. Which answer choice shows a pipe with a diameter of 25 inches?

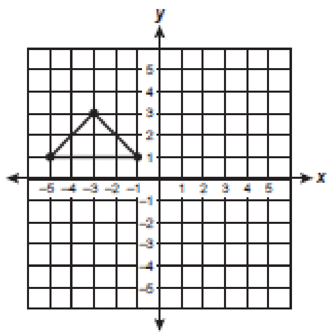
    A. 

    B. 

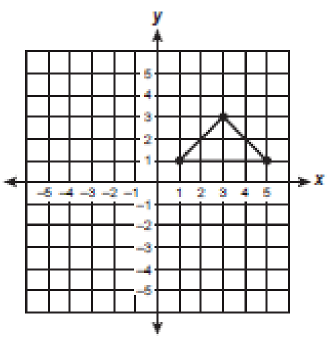
    C. 

    D. 

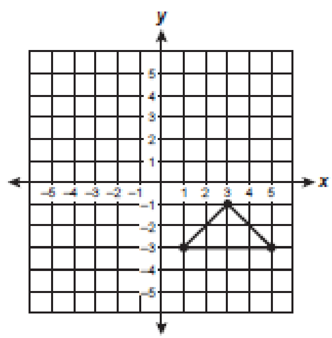
31. Choose the answer that shows the shape below reflected across the *y*-axis.



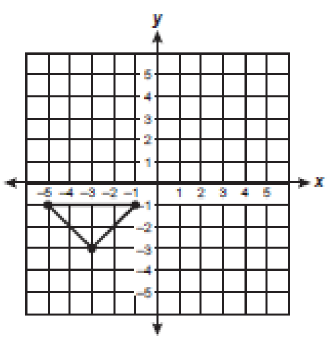
A.



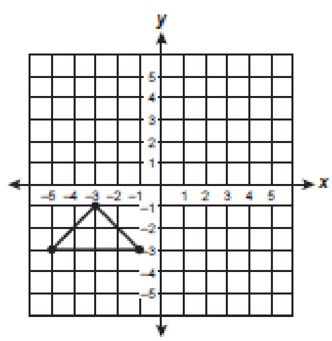
C.



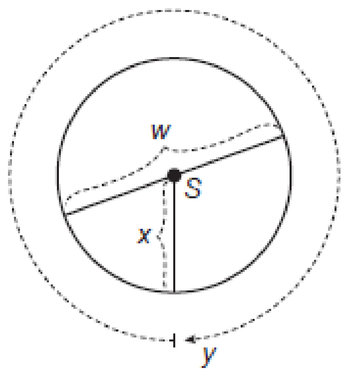
B.



D.



32. Different distances are labeled in the figure of the circle below. S is the center point of the circle.



The ratio of which two distances is used to calculate π?

A. $w : x$

B. $x : y$

C. $y : w$

D. $x : w$

33. The length of Phillip's current living room rug is 12 feet and the width is 8 feet. Phillip buys a new rug that is double the length of his current rug but the same width. How many square feet did he increase the area covered by the rug?

A. 192 square feet

B. 96 square feet

C. 24 square feet

D. 12 square feet

34. Joe is making a clock for a present. He wants the clock face to have a circumference of 5 feet. Which equation can he use to find r, the radius of the clock face?

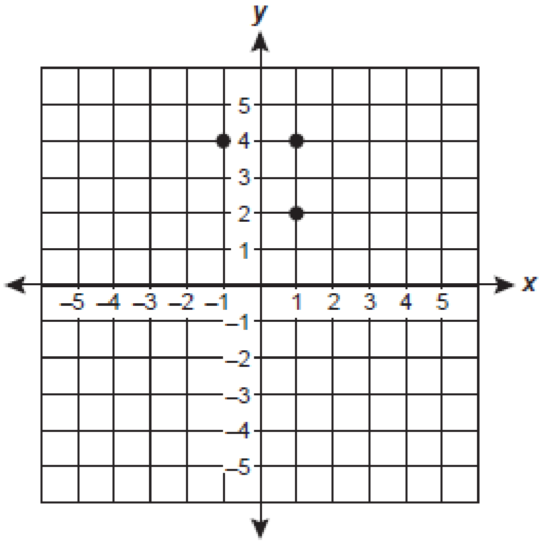
A. $r = 5 \div \pi$

B. $r = 10 \div \pi$

C. $r = 5 \div (2\pi)$

D. $r = 10 \div (2\pi)$

35. Whitney placed her square pencil box on a coordinate grid and marked the points of the corners. She accidentally forgot to mark the fourth corner.



What are the coordinates of the pencil box's fourth corner?

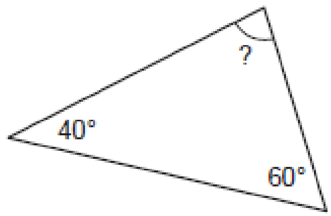
A. (–2, –1)

B. (–2, 2)

C. (–1, 2)

D. (2, –1)

36. What is the measure of the missing angle in the triangle below?



A. 60°

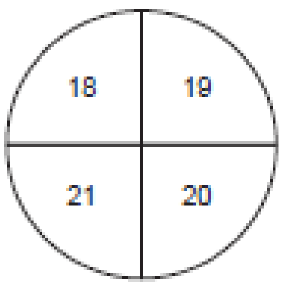
B. 80°

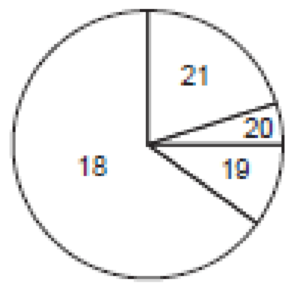
C. 90°

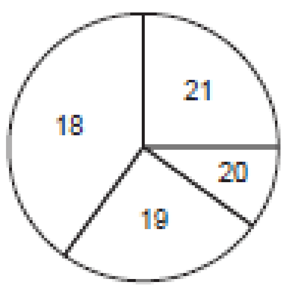
D. 100°

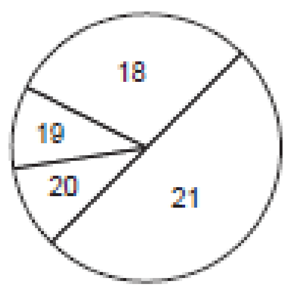
37. Which circle graph matches the data in the table below?

Age of First Time Voters	Percent
18	65%
19	10%
20	5%
21	20%

A.


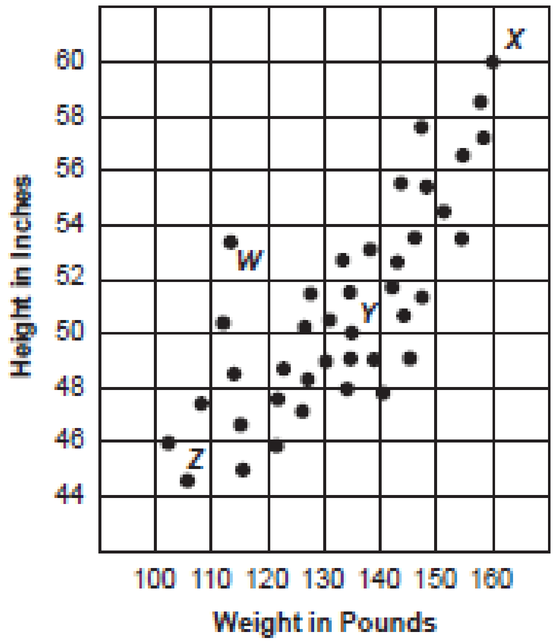
C.


B.


D.


38. 40 students recorded their height and weight.

    The scatterplot below summarizes the measurements.



Which statement is most supported by the data in the scatterplot?

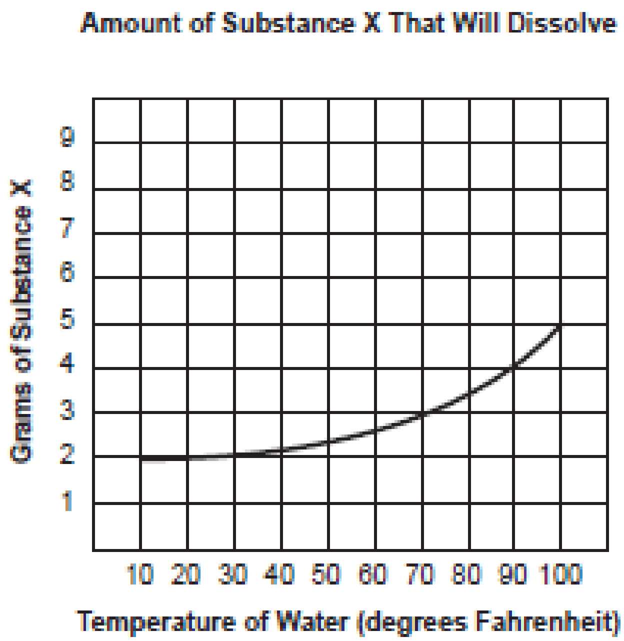
A. There is no relation between height and weight.

B. As height increases, weight tends to decrease.

C. The students start getting lighter after they reach 60 inches tall.

D. As weight increases, height tends to increase.

39. How many grams of substance X will dissolve in 1 quart of water at 100 degrees Fahrenheit?



A. 4 grams

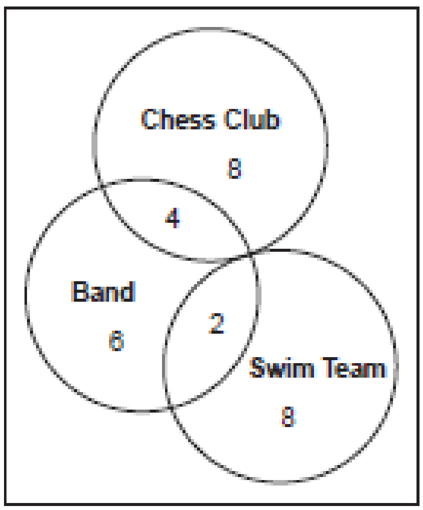
B. 5 grams

C. 50 grams

D. 100 grams

40. Use the Venn diagram below to determine how many total students were in chess club or band, but not both.

Organization Membership



A. 8

B. 10

C. 16

D. 20

41. A computer follows the instructions that are given below.

If $x > 0$, then print "x is positive."
If $x < 0$, then print "x is negative."

What will be printed if the number 9 is entered?

A. "x is positive"

B. "x is negative"

C. "x is equal to 0"

D. Nothing is printed.

42. Shannon is lost and is trying to find her friend's house. The house number she is looking for is 48. The house numbers she has passed are below.

According to the pattern above, in which house does Shannon's friend live?

A. A

B. B

C. C

D. D

43. Kierra knows that the probability of flipping a coin and getting heads is 50%. She flips a coin 25 times and finds the probability of heads is 46%. What explanation can explain this?

A. 46% is a mode.

B. She counted incorrectly.

C. 46% is a theoretical probability.

D. 46% is an experimental probability.

44. Determine the missing number in the sequence below.

$3^1, 3^2,$ ____, 3^4

A. 3

B. 3^0

C. 3^3

D. 3^5

45. What number comes next in the pattern shown below?

3, 9, 27, ____

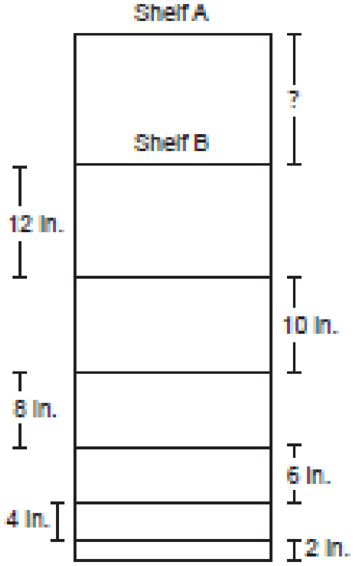
A. 9

B. 30

C. 32

D. 81

46. The spacing between library bookshelves is shown below.



If the pattern continues, how much space would there be between shelf A and shelf B?

A. 14 inches

B. 18 inches

C. 20 inches

D. 24 inches

47. Mark found the area of a rectangle to be 24 m^2. If only the length is multiplied by 3, how much does the area of the rectangle change?

A. The area of the rectangle is twice the area of the original.

B. The area of the rectangle is three times the area of the original.

C. The area of the rectangle changes by 24 m^2.

D. The area of the rectangle is 3 m more than the area of the original.

APPENDIX F. 8TH GRADE MATH COMPREHENSIVE BENCHMARK ASSESSMENT FOR SCHOOL YEAR 2009-10

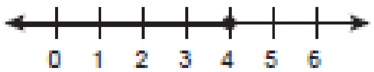
Grade 8
Mathematics

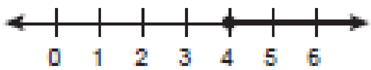
Benchmark
Assessment

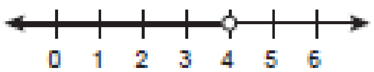
August Pre-Test
2009-2010

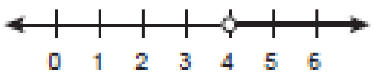
East Baton Rouge Parish School System
Department of Accountability, Assessment and Evaluation

1. Which graph represents $x \geq 4$?

A. 

B. 

C. 

D. 

2. Which symbol belongs in the circle to make the statement TRUE?

$12^0 \bigcirc 12^1$

A. =

B. ≤

C. >

D. <

3. Mary has money saved in 7 different bank accounts. She wants to know an estimate of how much she has total. Using the information in the table below, round each value to the nearest ten and find the sum.

Bank Account	Money
1	\$18
2	\$23
3	\$66
4	\$82
5	\$28
6	\$12
7	\$7

A. \$230

B. \$236

C. \$240

D. \$250

4. What is 10,721 in scientific notation?

   A. 0.1072×10^4

   B. 1.0721×10^4

   C. 10.721×10^4

   D. 10.721×10^3

5. Solve the following problem.

   $$66 \div 3 + (6 - 3) = ?$$

   A. 11

   B. 19

   C. 25

   D. 36

6. Solve the following problem.

   $$(5 - 3)^2 - 2 \times 4$$

   A. –4

   B. 4

   C. 8

   D. 12

7. The table below shows the results of Erin's survey of 3 classes of eighth-grade students about their favorite ice cream flavor.

Ice Cream Flavor	Number of Students
Vanilla	11
Strawberry	22
Chocolate	30
Lemon	17
TOTAL	80

   Based on these results, how many of the 400 eighth-grade students should Erin expect to prefer chocolate?

   A. 80

   B. 150

   C. 175

   D. 200

8. Denise answered 13 out of 16 questions correctly while playing a trivia game. About what percent of the questions she was asked did she answer correctly?

   A. 55%

   B. 60%

   C. 75%

   D. 80%

9. Car rentals cost \$19 per day plus a one-time cost of \$30. If Jeremy rents a car for d days, which equation represents Jeremy's total cost (c)?

   A. $c = 19d + 30$

   B. $c = 30d + 19$

   C. $c = 30d + 19d$

   D. $c = 30 + 19$

10. A carpet-cleaning company charges \$19.95 per room to clean the carpet. The customer can also get a protective coating for the carpet for 10¢ per square foot. Mrs. Segal had 4 rooms cleaned and had the protective coating applied to (n) square feet of carpet. Which equation can be used to find T, the total amount that she was charged?

    A. $T = 4n(19.95 + 0.10)$

    B. $T = 4(19.95n + 0.10)$

    C. $T = 0.10(19.95) + 4n$

    D. $T = \$19.95(4) + 0.10(n)$

11. Julie rents a boat for \$12 per hour. If she rents a boat for (h) hours, which expression shows her total cost (T)?

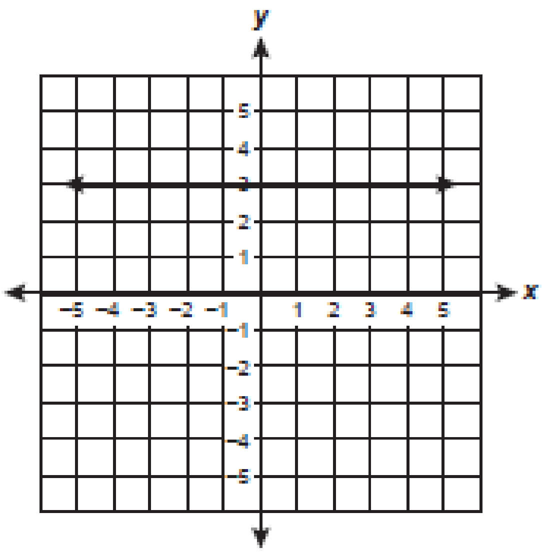
    A. $T = \$12 + h$

    B. $T = \$12 - h$

    C. $T = \$12 \times h$

    D. $T = \$12 \div h$

12. What is the equation of the line on the graph below?



A. $y = 3$

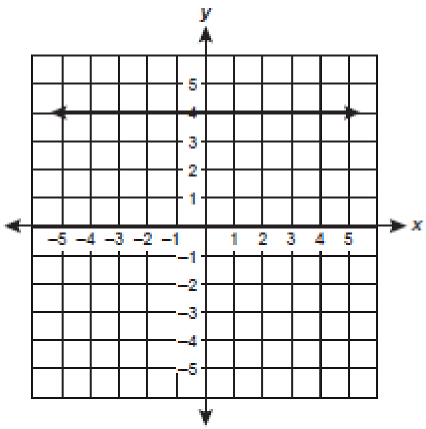
B. $y = 3x$

C. $y = x - 3$

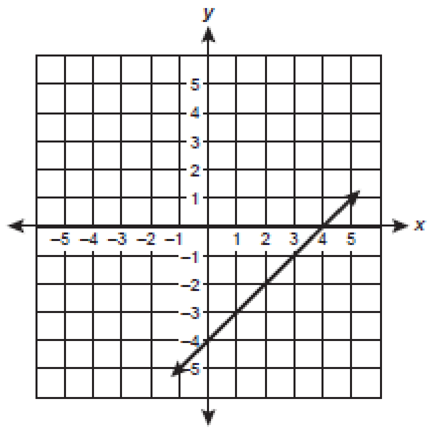
D. $y = x + 3$

13. Which graph shows $y = x + (-4)$?

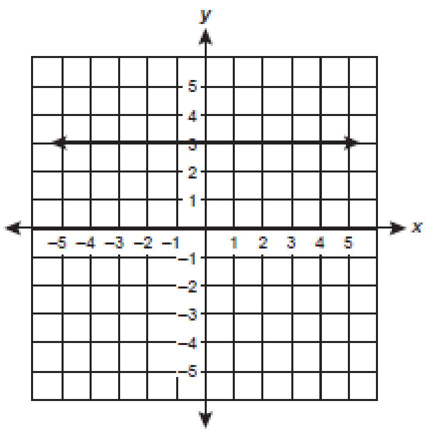
A.



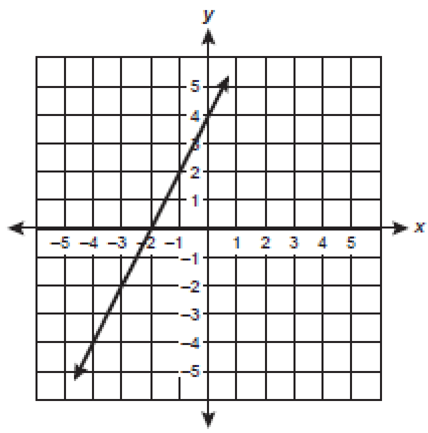
C.



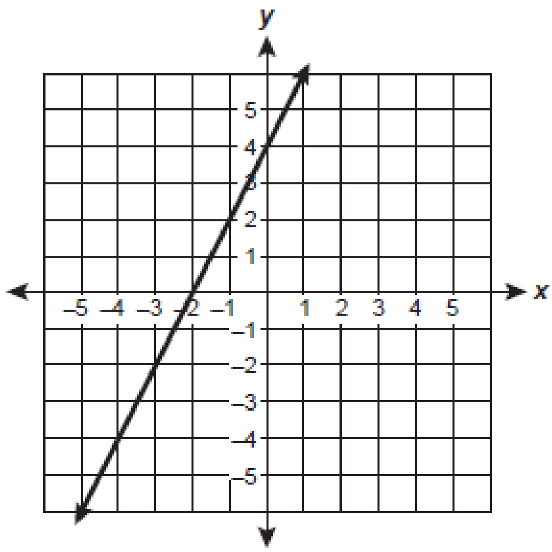
B.



D.



14. Which table contains only points on this line graph?



A.

x	4	6	2	–2
y	0	1	0	–3

B.

x	0	1	2	–2
y	4	6	0	–3

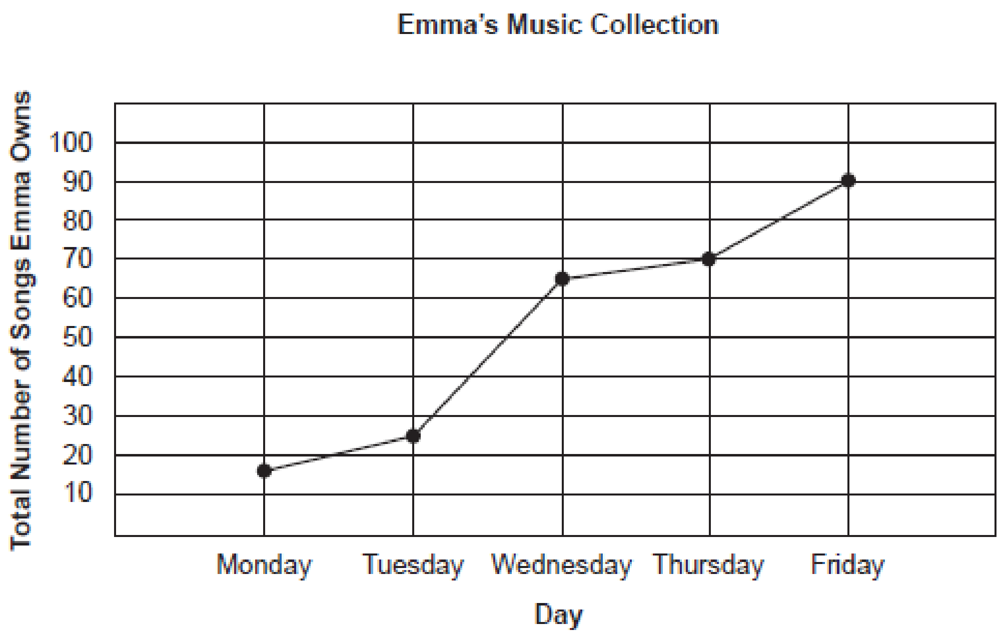
C.

x	0	1	–2	–3
y	4	6	0	–2

D.

x	–6	–3	0	1
y	1	2	4	6

15. Emma adds more songs to her music collection every day. The graph below shows the **total** number of songs Emma owns each day across five days.



On which day did Emma add the **most** songs?

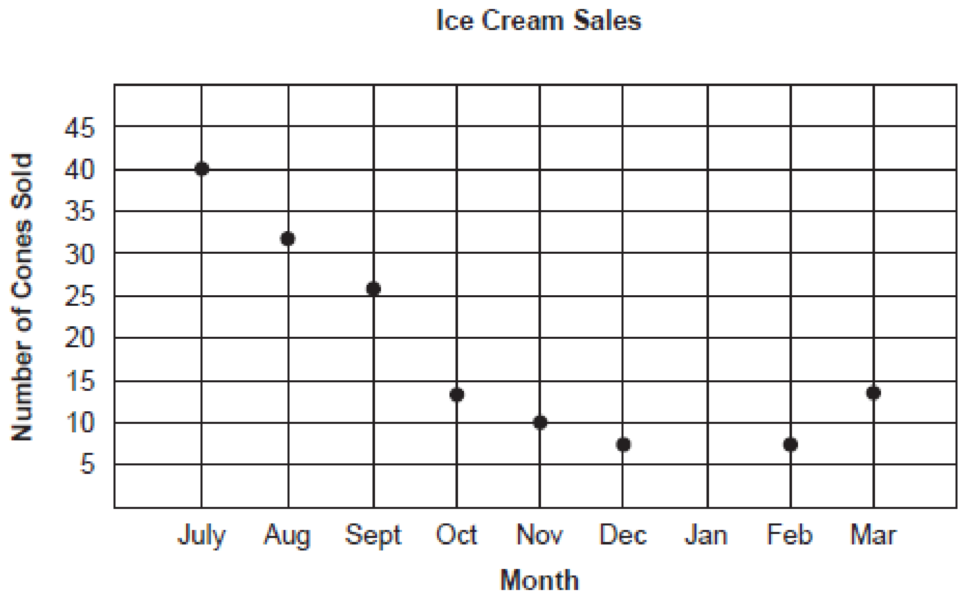
A. Monday

B. Wednesday

C. Thursday

D. Friday

16. Based on the information in the graph, predict the January sales for ice cream.



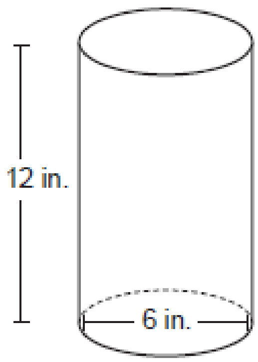
A. 5 cones

B. 15 cones

C. 36 cones

D. 60 cones

17. The formula for finding the volume of a cylinder is $\pi r^2 h$, where r = the radius of the base circle and h = the height of the cylinder. What is the volume of the cylinder below?



A. 339 cubic inches
B. 432 cubic inches
C. 1,357 cubic inches
D. 2,713 cubic inches

18. Calculate the density of an object with a mass of 8 grams and a volume of 4 cm^3.

Density = mass/volume

A. 2 g/cm^3
B. 8 g/cm^3
C. 16 g/cm^3
D. 128 g/cm^3

19. What is the volume of a typical soup bowl?

A. 10 gallons
B. 10 quarts
C. 10 fluid ounces
D. 10 milliliters

20. Which of the following units would be most appropriate for measuring the amount of water in a bath tub?

A. Pint
B. Gallon
C. Teaspoon
D. Fluid Ounce

21. Which unit from the metric system is the most similar in size to a quart?

    A. Pint
    B. Liter
    C. Meter
    D. Gallon

22. Raven's swimming pool has a volume of 12 cubic yards. What is the volume of her swimming pool in cubic feet? (1 cubic yard = 27 cubic feet)

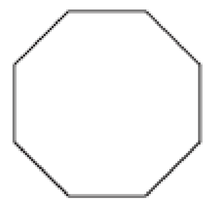
    A. 36 cubic feet
    B. 108 cubic feet
    C. 324 cubic feet
    D. 1,000 cubic feet

23. Which best defines the word bisect?

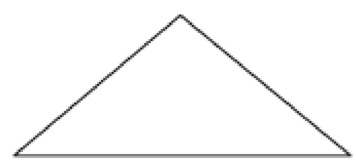
    A. Divide by 5
    B. Double the size
    C. Divide into two equal parts
    D. Divide into three equal parts

24. Which figure has exactly 2 lines of symmetry?

    A. 

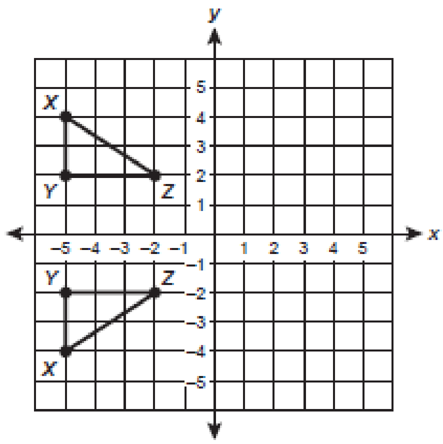
    B. 

    C. 

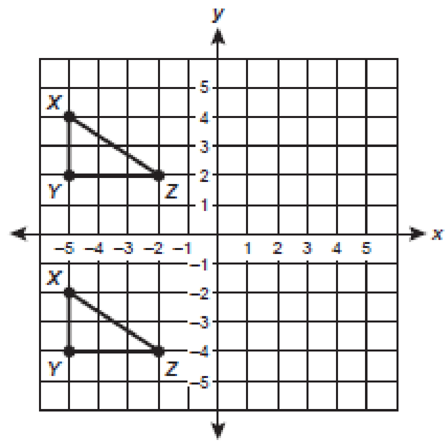
    D. 

25. Which graph shows ΔXYZ reflected across the y-axis?

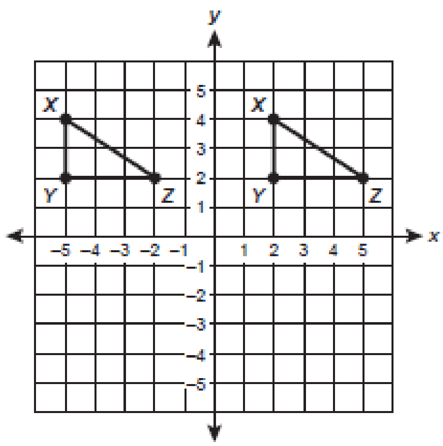
A.



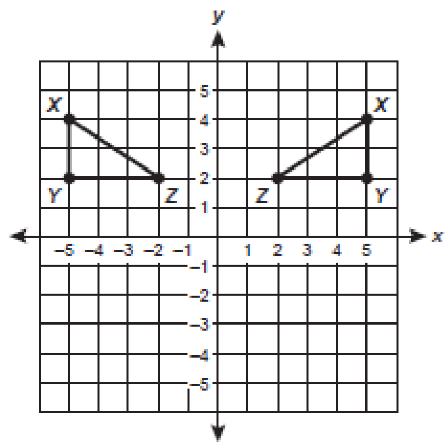
C.



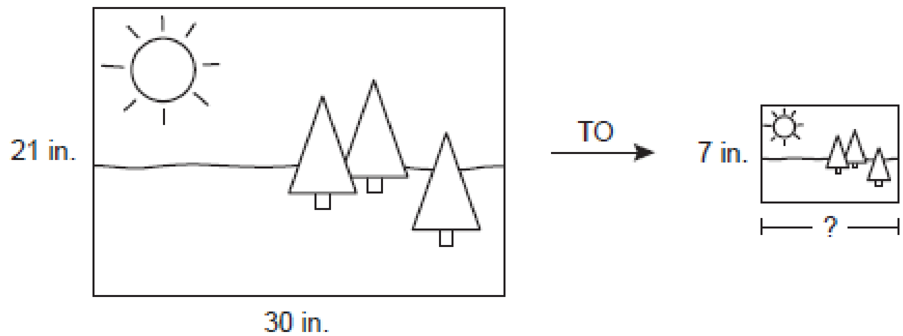
B.



D.



26. Nathan reduced a 21 x 30 photograph to a similar but smaller version.



What is the width of the new picture?

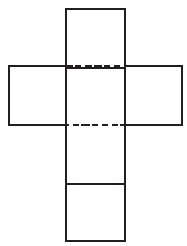
A. 7 in.

B. 10 in.

C. 21 in.

D. 30 in.

27. If the figure shown below was folded on the dotted lines, what shape would it make?



A. A cube

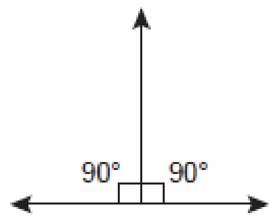
B A triangle

C. A hexagon

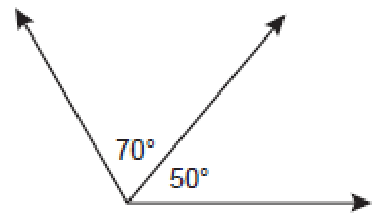
D. A pentagon

28. Which picture shows complementary angles?

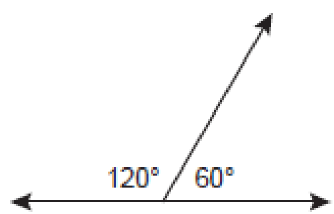
A.



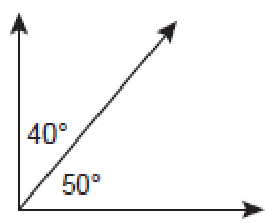
B.



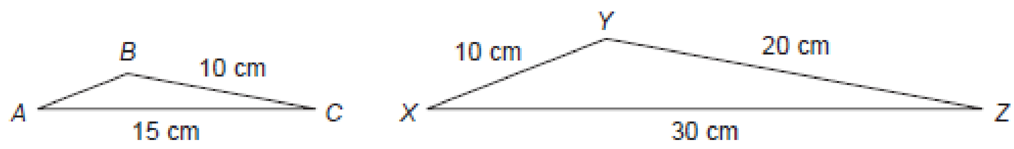
C.



D.



29. ΔABC and ΔXYZ are similar triangles.



What is the length of $\overline{AB}$?

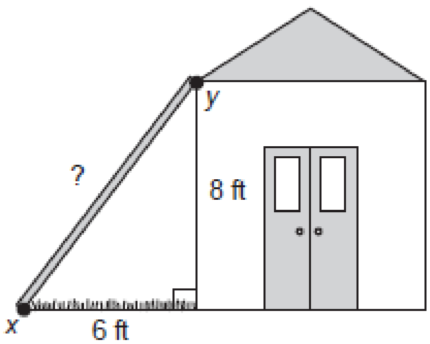
A. 5 cm

B. 10 cm

C. 15 cm

D. 30 cm

30. Based on the information in the picture below, what is the minimum length a ladder must be in order to reach from *x* to *y*?



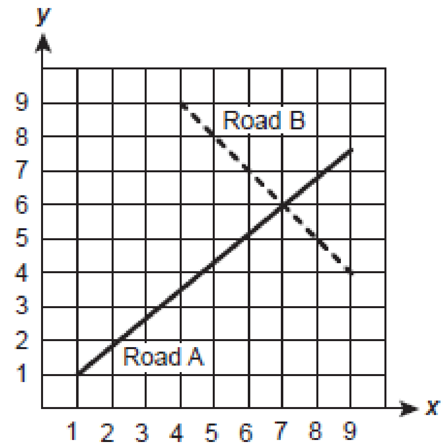
A. 6 feet

B. 8 feet

C. 10 feet

D. 100 feet

31. Determine the coordinates of the point where the two roads intersect.



A. (1, 1)

B. (4, 9)

C. (6, 7)

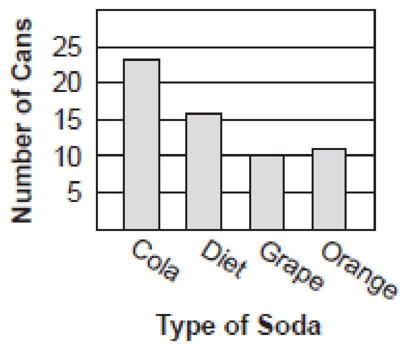
D. (7, 6)

32. A vending machine is filled with 60 cans of soda. The table shows the number of cans of each type of soda in the machine.

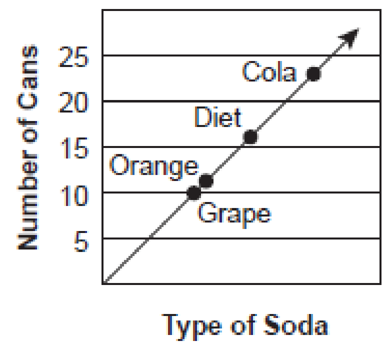
	Cola	Diet	Grape	Orange
Number of Cans	23	16	10	11

Which graph best represents the data in the table?

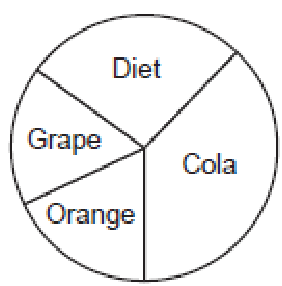
A.



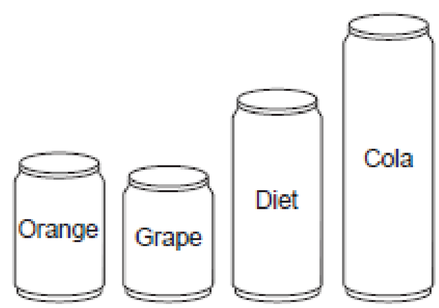
C.



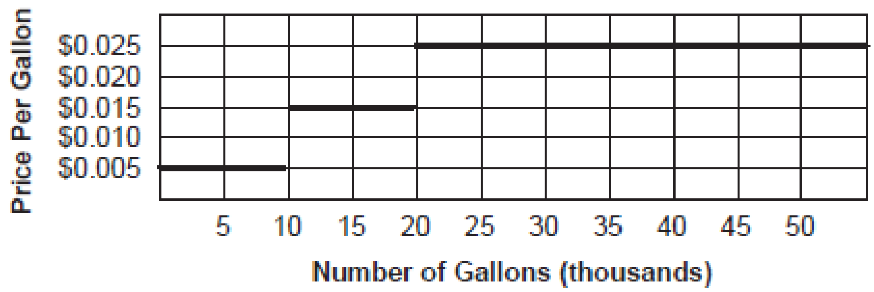
B.



D.



33. The graph shows the rates that customers are charged for water used in Parish A.



Which table best represents the same information?

A.

Number of Gallons	Price Per Gallon
0 - 1,000	$0.005
1,000 - 10,000	$0.015
Over 10,000	$0.025

C.

Number of Gallons	Price Per Gallon
0 - 9,999	$0.005
10,000 - 19,999	$0.015
20,000 and up	$0.025

B.

Number of Gallons	Price Per Gallon
0 - 9,999	$0.025
10,000 - 19,999	$0.015
20,000 and up	$0.005

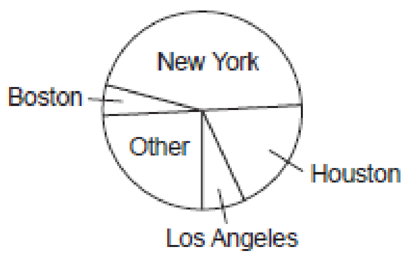
D.

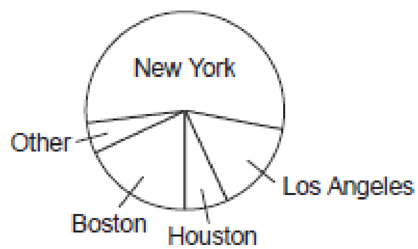
Number of Gallons	Price Per Gallon
0 - 9	$0.005
10 - 19	$0.015
Over 19	$0.025

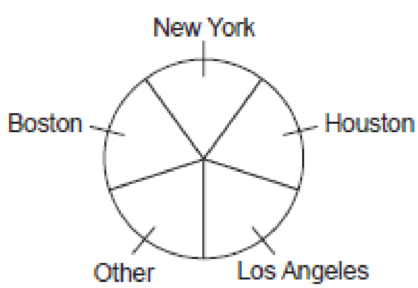
34. Tara asked her classmates where they went for vacation over the summer. The table below shows the results.

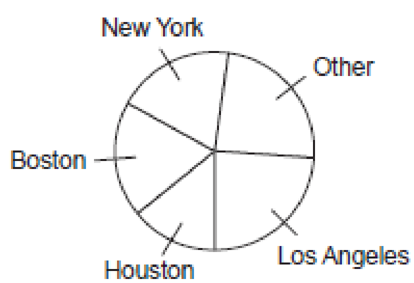
Cities	Number of Students
Los Angeles	3
Houston	8
New York	19
Boston	2
Other	10

Which graph best represents the same information?

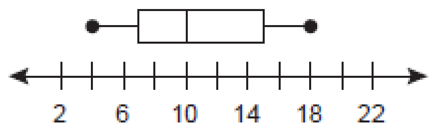
A. 

C. 

B. 

D. 

35. The box-and-whisker plot below shows the amount of time students in the 8th grade spend studying each week.



What is the range of time students spend studying?

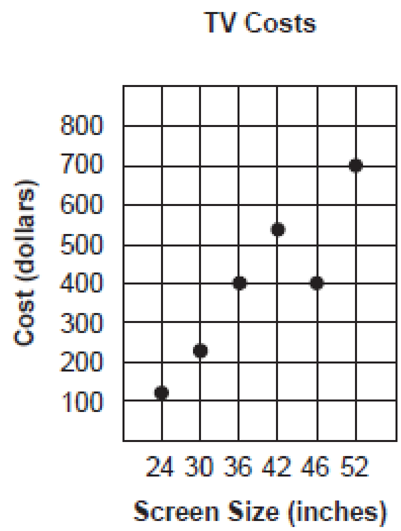
A. 4 hours

B. 10 hours

C. 14 hours

D. 18 hours

36. The scatterplot below shows the cost of 6 different televisions and their screen size in inches.



Which best describes the trend shown in the scatterplot?

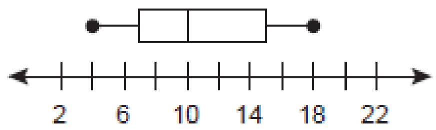
A. Negative trend

B. Positive trend

C. Mean trend

D. No trend

35. The box-and-whisker plot below shows the amount of time students in the 8th grade spend studying each week.



What is the range of time students spend studying?

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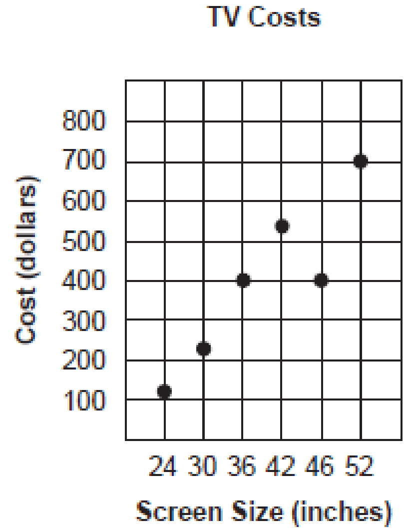
36. The scatterplot below shows the cost of 6 different televisions and their screen size in inches.



Which best describes the trend shown in the scatterplot?

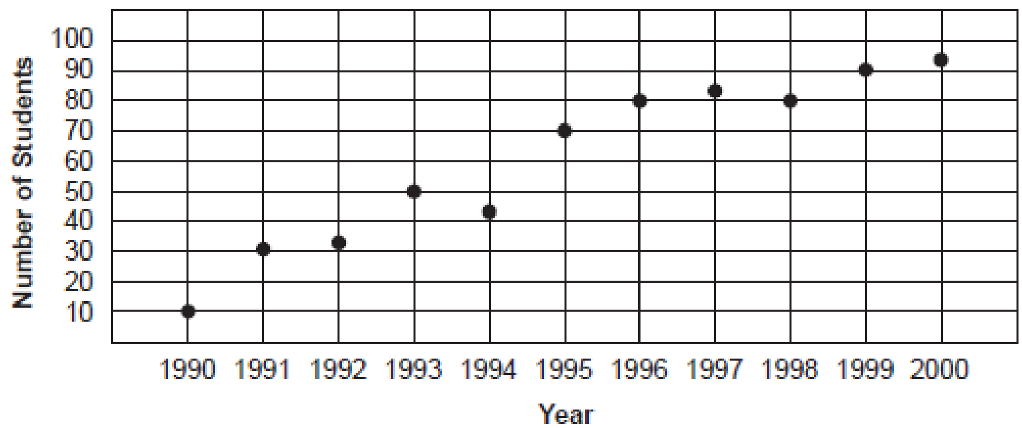
A. Negative trend

B. Positive trend

C. Mean trend

D. No trend

37. The graph shows the number of eighth-grade students who have participated in the talent show between the years 1990 and 2000.



Using the trends presented by the graph, approximately how many eighth-graders will participate in the talent show in the year 2001?

A. 90

B. 60

C. 50

D. 30

41. A restaurant advertises that it offers exactly 16 unique sandwich and soda combinations. Which menu reflects the restaurant's advertisement?

A.

Sandwiches	Sodas
• Hamburger • Cheeseburger • Turkey • Ham • Hot Dog	• Orange • Cola • Lemon-lime • Fruit • Grape • Cherry

C.

Sandwiches	Sodas
• Hamburger • Hot Dog • Cheeseburger • Ham • Turkey • PBJ	• Orange • Cherry • Grape • Cola • Lemon-lime • Fruit

B.

Sandwiches	Sodas
• Hamburger • Hot Dog • Cheeseburger	• Orange • Cola • Grape • Cherry

D.

Sandwiches	Sodas
• Cheeseburger • Hot Dog • Ham • Turkey	• Orange • Cola • Grape • Cherry

42. A student spins a spinner separated into 4 equal sections 50 times. The results are given in the table below.

Color	Number of Spins
Red	10
Blue	12
Green	20
Yellow	8

What is the probability the spinner will land on green on the next spin?

A. $\frac{1}{10}$

B. $\frac{1}{5}$

C. $\frac{2}{5}$

D. $\frac{1}{2}$

43. Mrs. Kemp has a bag with 6 red, 8 green, 5 blue, 9 yellow, and 2 white marbles that are all the same size and shape. What is the probability of randomly choosing a white marble on the first pick, putting it back, and then choosing a blue marble on the second pick?

A. $\frac{1}{90}$

B. $\frac{1}{87}$

C. $\frac{1}{15}$

D. $\frac{1}{6}$

44. The following pattern is an example of which category of pattern?

2, 4, 8, 16, 32

A. Linear

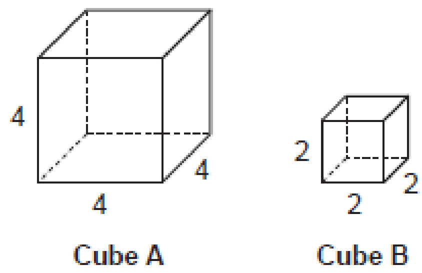
B. Circular

C. Repeating

D. Geometric

Please go to the next page

45. Which of the following correctly describes the volume of cube A compared to cube B?



A. The volume of cube A is 2 times the volume of cube B.

B. The volume of cube A is 4 times the volume of cube B.

C. The volume of cube A is 6 times the volume of cube B.

D. The volume of cube A is 8 times the volume of cube B.

APPENDIX G. APPLICATION FOR EXEMPTION FROM INSTITUTIONAL OVERSIGHT

Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or samples or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

LSU

Institutional Review Board
Dr. Robert Mathews, Chair
203 B-1 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu | lsu.edu/irb

- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://www.lsu.edu/irb/screeningmembers.shtml
- A Complete Application Includes All of the Following:
  - **(A)** Two copies of this completed form and two copies of parts B thru E.
  - **(B)** A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  - **(C)** Copies of all instruments to be used.
    - •If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
  - **(D)** The consent form that you will use in the study (see part 3 for more information.)
  - **(E)** Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB.
    Training link: (http://phrp.nihtraining.com/users/login.php.)

1) Principal Investigator: Ingrid Cruz **Rank:** Graduate Student **Student*? Y/N** Y

Dept.: Natural Sciences **Ph:** (213)610-4120 **E-mail:** icruz1@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each
* If student, please identify and name supervising professor in this space
none

3) Project Title: "Using Robotics in Teaching Math Concepts in a Middle School Setting"

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 9-20-2012

4) LSU Proposal?(yes or no) No **If Yes, LSU Proposal Number** ______
Also, if YES, either ○ **This application completely matches the scope of work in the grant**
OR
○ **More IRB Applications will be filed later**

IRB# E4641 LSU Proposal# ______
☑ Complete Application
☑ Human Subjects Training

5) Subject pool (e.g. Psychology Students) Middle school students ages 9-14
•Circle any **"vulnerable populations"** to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature ______ ** **Date** 9-19-09 (no per signatures)
**I certify my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ✓ Not Exempted ___ Category/Paragraph 1
Reviewer Mathews Signature ______ Date 9/21/09

APPENDIX H. LETTER OF PERMISSION FROM LEGO

Dear Ingrid

Ingrid, we are very flattered that you chose to use our LEGO® MINDSTORMS® NXT 2.0 product as part of your college project. We appreciate that you contacted us for permission to use some of the images as seen in the User Guide for that product,#8547.

The LEGO Group owns the copyrights to its building instructions, publications and to the photographs used in our catalogs and on our packages. Nevertheless, at the present time the LEGO Group does not object to scanning of limited extracts of these materials in unaltered form for non-commercial purposes of exchange of information or good faith commentary. Using them for educational purposes as you described in your phone call certainly falls under these acceptable perameters. However, if at any point your manuscript gets published you would need to contact us again so we can review any additional guidelines with you. We would ask that the photographs be scanned without distortion or overemphasis of the LEGO logo. A disclaimer and notice must appear indicating that the copyrights are owned by the LEGO Group (e.g. LEGO Group.

We hope that these guidelines will address the most frequently asked questions about using the LEGO trademarks and copyrights. We know that the public wants to respect these rights, but are not always certain about what is permissible. We appreciate the interest which has been expressed about our company and our products and hope that this continuing dialog will enhance the exuberance we try to create with our products.

I also have to tell you about a few other guidelines:

1) Please always spell the word LEGO using capital letters and use it only as an adjective not a noun. For example you can write "Model built with LEGO bricks" but not "Model built with Legos".

2) The first time you use the word LEGO please follow it with a "®" which shows everybody it's a registered trademark.

3) You can't use the red LEGO logo.

If you'd like to find out more about our rules please go to www.LEGO.com/fairplay, or get loads more LEGO Group information by going to www.LEGO.com/aboutus

Best of luck with your manuscript and project. Please contact us at 1 800 835 -4386 if you need any further information.

Karen
LEGO Direct Consumer Services

VITA

Ingrid Lorelei Jomento-Cruz was born in Quezon City, Philippines on May 13, 1979 to Samuel Jomento and Julieta Rubio-Jomento. She got a bachelors degree in Biology major in Genetics from the University of the Philippines in April 2000. She has taught for 6 years both in collegiate and middle school level. She received her training in LEGO Robotics from Southern University and Robotics Academy of Carnegie Mellon University. She currently teaches Robotics Engineering at Scotlandville Middle Pre-Engineering Magnet in Baton Rouge. Her passion is in sharing knowledge in science and Robotics to kids of all ages. She entered the Graduate School at Louisiana State University Agricultural and Mechanical College in June 2008 and is expected to earn the degree of Master of Natural Sciences in December 2010.