3-3-2008

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Recommended Citation
Bruciati, A. (2008). Robots that Teach: Developing an Integrated Curriculum for Middle School Math. In K. McFerrin et al. (Eds.), Proceedings of Society for Information Technology & Teacher Education International Conference 2008 (pp. 4423-4428). Chesapeake, VA: AACE.

Robots that Teach: Developing an Integrated Curriculum for Middle School Math

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Abstract: Keeping middle school students interested in mathematics and motivating them to succeed are challenges that continually present themselves to even the most seasoned teachers. Students will be drawn to mathematics if they are able to connect it to exciting careers. This paper describes a research-based curriculum model for teachers, grant writers, and others interested in incorporating Lego robotics technologies into an existing middle school mathematics curriculum. The model is based on data gathered from a three year research study in which approximately 150 sixth grade students per year and their teachers collaborated with a middle school Math Coordinator, a school Numeracy Coach, and university-level educational technology professors.

Introduction

Classroom learning environments must foster student achievement through the alignment of standards, research-based teaching and learning practices, and emerging technologies to prepare our students to enter the 21st century workforce. Mathematically literate citizens, who are equipped with the skills and knowledge for solving complex problems, are critical for sustaining and improving the quality of life, enhancing democratic societies, and maintaining the global knowledge economy.

Keeping middle school students engaged in mathematics and motivating them to succeed are challenges that continually present themselves to even the most seasoned teachers. According to the National Council of Teachers of Mathematics (NCTM) (2000-2004), middle school students will be drawn to the subject if they are challenged and supported in their mathematics classes. As students reach middle school, influences such as peer acceptance and self-perceptions impact their level of classroom engagement. These students are less likely to take risks and engage themselves fully in activities at which they are not sure they will succeed.

Robotics Technologies

The use of robotics has become commonplace in our society. Robotic vacuums and lawn mowers perform household chores. Bomb disposal or search and rescue robots are used by law enforcement and military personnel to perform hazardous duties. Industrial robots perform a variety of tasks with speed and accuracy that include: painting, welding, and material handling, among others. Edutainment robots that perform simple tasks such as picking up objects or dancing have become popular among young people.

Robotic technologies enable teachers to connect curricular knowledge to real-world workplace skills and competencies. Robotics products such as Lego Mindstorms for Schools (Lego Group, 2007a) or Mindstorms NXT (Lego Group, 2007) have been used by students to design, build, and program a variety of entry-level robots. Robots are controlled through the use of an icon-based programming language. An icon is a graphic image that represents a computer function or control. Through the use of RoboLab (Lego Group, 2007b) or NXT software (Lego Group, 2007) graphic representations of programming code can be dragged and assembled into strings at the center of the computer screen. Strings of icon commands can be assembled that represent robotic actions such as move forward and turn. An infrared (IR) tower allows the completed program code to be transmitted from a PC or MAC to the robot's RCX microprocessor. The simplicity of this process enables teachers and their students to master computer programming concepts without the need for advanced computer science training. However, students who are participating in computer science classes can also learn to control their robots through additional high level programming languages such as Visual Basic and Java.

Project DISCOVER

D.I.S.C.O.V.E.R. the Future with Robotics (Discoveries In Sciences Change Our Views: Equality, Respectability) is an interdistrict educational program funded through a grant from the Connecticut State Board of Education. The Interdistrict Cooperative Grant (ICG) Program established under Connecticut General Statutes Section 10-74d is a competitive grant program that provides funding for programs that "(A) increase student achievement, and (B) reduce racial, ethnic and economic isolation" (Connecticut State Department of Education, 2002-2007). Sixth grade classroom teachers from Hillcrest Middle School in Trumbull (Cyberized Solutions, 2007) and Hall School in Bridgeport (Hall School, 2001-2007) work collaboratively with a middle school Math Coordinator, a school Numeracy Coach, and educational technology professors from Sacred Heart University (2007) in Fairfield, Connecticut. In collaborative partnerships, students design, build, and program robots using LEGO RoboLab software (Lego Group, 2007b). Students meet with professionals in the field of robotics and educational technology to explore a variety of career opportunities. Hands-on project-based activities encourage students to make discoveries about each other, their communities, and the world in which they live. These activities emphasize Connecticut Mastery Test (CMT) mathematics skills (Connecticut State Department of Education, 2002-2007a). The CMT is a standardized test administered to Connecticut students in grades 3 through 8.

Resources and Classroom Management

Fifty-five robotic kits were purchased for Project DISCOVER. One Lego robotics kit is recommended for each group of 2-3 students provided that: 1) a large group of students will be using the kits simultaneously, 2) teachers include robotic construction as a lesson objective, and 3) sufficient funding is available. For those on a limited budget, fewer kits can be shared among more students if the large group of students is divided into smaller sub-groups such as Groups A, B, and C. These smaller groups could meet on different days or times. For example, a large group of 60 students could be divided into 3 smaller groups of 20 students each. Groups would meet on a rotating schedule such as every third Monday after school. The smaller group of 20 students would be further divided into 10 sub-groups containing 2 students each. Ten robot kits would be needed for this type of program. Robots would be constructed ahead of time by student "helpers" and numbered from 1-10 using a black permanent marker. During the class session, each group of 2 students would be assigned a robot according to number. The focus of the lessons would be on programming and not emphasize construction. It is important to note that, although the Project DISCOVER Program included robotic construction as a preliminary activity, only 18 of the 55 pre-constructed robots were used during the programming lessons. These robots were shared among the sub-groups as they met on a rotating schedule.

Six batteries are required to power each robot's RCX microprocessor. Due to the large number of robotic kits (55) purchased for the Project DISCOVER participants, 2 rolling carts were used to organize and/or transport the kits between the school storage closet and the media center. Two laptop carts were also available for student use. One wireless laptop was assigned to each group of 2-3 students and used to transfer program code to the robot.

The school media center was the primary meeting place for all group sessions. However, students occasionally used the school computer lab due to scheduling conflicts or the need to print files. Miscellaneous office and art supplies were also used such as mural paper, markers, printer paper and ink.

Curriculum Design

An integrated math curriculum was developed as the result of the Project DISCOVER collaborative effort. Curriculum objectives focus on the development of mathematical literacy for students in Grade 6 through the use of Lego Mindstorms for Schools (Lego Group, 2007b). Instructional goals, objectives, and inquiry-based, collaborative learning activities are aligned with National Council of Teachers of Mathematics (NCTM) standards that include;

Measurement, Numbers and Operations, Geometry, and Connections, among others (NCTM, 2000-2004). The curriculum is divided into instructional units or *Missions* that can be modified to meet the needs of students with a variety of special needs and learning styles.

Pre-Mission activities include surveys and questionnaires that measure student attitudes, motivation, and the ability to work as part of collaborative teams. A Venn diagram serves as an introductory activity that enables groups of 3 students to compare and contrast different likes, dislikes, and backgrounds. A pretest activity benchmarks student math skills prior to interacting with the curriculum.

In Mission 1, groups of students conduct an Internet search for background information related to the use of robotics in society. PowerPoint presentations are then created and shared with the class. In a later mission, students are introduced to Cartesian coordinates. During this activity, students must program their robots to navigate paired coordinates on a grid of 4 x 4 inch squares. As an optional Mission 1 activity, student groups can draw their grids on large mural paper (see Figure 1.). Teachers can create cross-curricular ties to other subject areas by asking students to design their grids according to specific themes such as ancient Egypt, the rainforest, the solar system, or others.

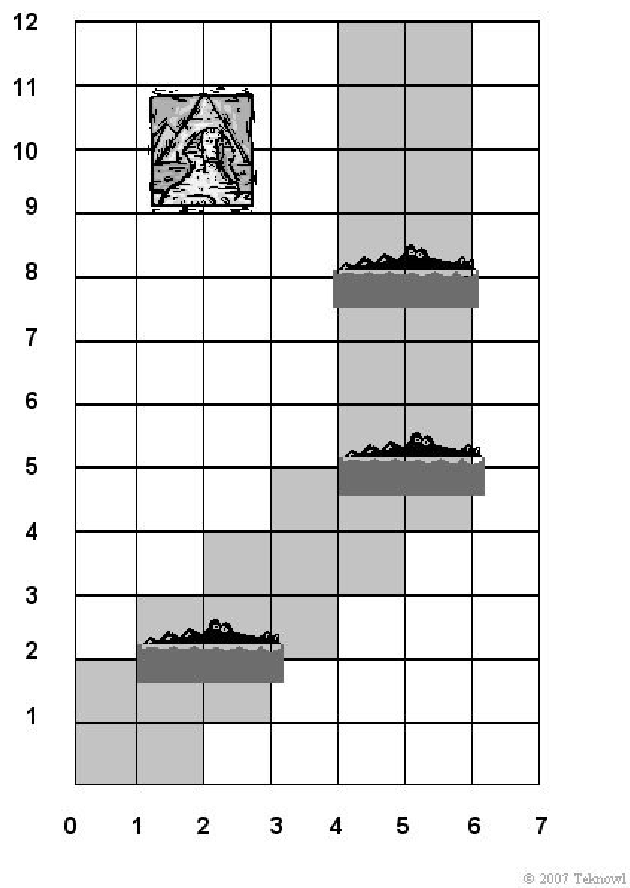


Figure 1: Coordinate Grid Activity – Ancient Egypt

Mission 2 introduces students to robot construction, the measurable attributes of objects, and the relationships between numeric operations. Worksheets are used to divide the robot into sub-assemblies. These worksheets enable students to categorize different parts of their robot according to metric and customary measures. Through this activity, each student in the group measures and locates the parts required for his/her sub-assembly. Groups of students then collaborate by constructing their robot after all of the sub-assembly parts have been identified, categorized, and placed on the worksheets.

An introduction to basic programming is the focus of Mission 3. Students begin by learning how to use the computer and RoboLab (Lego Group, 2007b) software to create a simple string of commands such as “Move the robot forward for two seconds and stop”. The IR tower transfers these commands from the computer to the robot’s RCX microprocessor. This process enables the robots to move autonomously within the classroom. Worksheets reinforce the mathematical skills learned in Mission 2 and also require students to convert measures within the same measurement system (customary and metric) based on the relationships between units. During this activity, students program their robot to move forward for different amounts of time. The distance traveled is measured in either inches and yards or centimeters and meters. An optional activity requires students to calculate the average distance traveled for each unit of measure.

In Mission 4, students demonstrate their ability to use coordinate geometry to represent and examine the properties of geometric shapes. They also connect mathematics to everyday experiences, investigations in other disciplines, and activities in and outside of school. Students begin by mastering advanced programming concepts that enable their robots to navigate through points on a coordinate grid using ordered pairs of non-negative rational numbers (see Figure 1). In the second part of this mission, students program their robots to solve real-world problems such as programming a robot that can guard the perimeter of a building (see Appendix).

Mission 5 consists of an “Ultimate Robot Challenge” in which groups of students compete in a variety of Olympics-style programming and mathematics activities. School media centers, playgrounds, or gymnasiums can be used as a staging area. Programming activities demonstrate the ability of students to race their robots around the circumference of a circle and navigate through obstacles on the coordinate grid. The final math activity consists of a posttest assessment that enables teachers to benchmark and document student mastery of the math concepts that have been introduced in previous missions.

Mission 6 is used for reflection and closure. Whole class activities require students to compose a reflective essay describing what they have learned from their experience. Class discussion follows this activity and award certificates are distributed to each student participant.

Conclusion and Future Research

Math teachers must strengthen a student’s conceptual understanding of the subject while emphasizing the mastery of basic skills. Opportunities that enable students to connect math skills to exciting careers in the field of robotics have been shown to increase motivation and engagement. Traditionally, the integration of robotics into the middle school curriculum has been aligned with science and engineering standards. Specific robotics activities that are directly linked to mathematics standards will engage students in finding and imposing structure, conjecturing and verifying, thinking hypothetically, comprehending cause and effect, and engaging in abstraction and generalization. Individual work, small group collaboration, and whole-class discussions are additional instructional strategies that can be used for guiding the development of a student’s conceptual understandings and abilities.

During the next year, research will focus on the development and pilot-testing of additional Missions that expand the mathematics curriculum currently in use. It is also the intent of this researcher to create cross-curricular ties between the field of robotics and other middle school subject areas.

References

Connecticut State Department of Education (2002-2007). *Interdistrict Cooperative Grant*. Retrieved January 15, 2008 from http://www.sde.ct.gov/sde/cwp/view.asp?a=2681&q=320446.

Connecticut State Department of Education (2002-2007a). *Mathematics information*. Retrieved January 12, 2008 from http://www.sde.ct.gov/sde/cwp/view.asp?a=2618&q=320872.

Hall School (2001-2007). *Home page.* Retrieved January 12, 2008 from http://bridgeport.ct.schoolwebpages.com/education/school/school.php?sectionid=3.

Cyberized Solutions (2007). *Hillcrest home*. Retrieved January 12, 2008 from http://www.trumbullps.org/hms/.

Lego Group (2007). *Lego Mindstorms for schools*. Retrieved January 15, 2008 from http://www.lego.com/eng/education/mindstorms/default.asp.

Lego Group (2007a). Lego NXT. Retrieved October January 17, 2008 from http://www.legoeducation.com/.

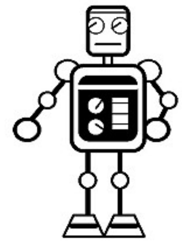
Lego Group (2007b). *Robolab software*. Retrieved January 3, 2008 from http://www.legoeducation.com/store/detail.aspx?CategoryID=177&by=9&ID=270&c=2&t=0&l=0.

National Council of Teachers of Mathematics (2000-2004). *Overview: Standards for grades 6-8*. Retrieved January 15, 2008 from http://standards.nctm.org/document/chapter6/index.htm.

Sacred Heart University (2007). *Home page*. Retrieved January 15, 2008 from http://www.sacredheart.edu/.

Acknowledgements

This project was made possible through an Interdistrict Cooperative Grant from the Connecticut State Department of Education. The opinions expressed are those of the author.



Mission 4 – Advanced Programming Challenge
Pilot Level 4

Name ______________________________ Group ___________

Directions Part 1 –

Use Lego RoboLab Pilot Level 4 to create the Perimeter Patrol program below.
When you are finished, create a screen capture of your program and paste it under the directions.
Save this worksheet to your computer desktop or USB key.

Program 1: Perimeter Patrol

Setup - Before you begin Program 1 –
Connect your motors to Ports A and C if you have more than one motor connected to your robot.
Attach the touch sensor to Port 1.
Attach the light bulb brick to Port 2.
Attach the light sensor to Port 3.

Part 1 - Write a multi-step program in Pilot Level 4 that enables your robot to patrol a perimeter of approximately 3x3 feet. Your robot must move in a clockwise direction. The light bulb must be on.

Part 2 - Program the robot to stop where it began.

Part 3 - Calculate the square footage of the 3x3 area that your robot is patrolling.

Write your answer here ____________ (HINT - Multiply length times width.)

Example –