Using Technological Innovation to Improve the Problem-Solving Skills of Middle School Students

Educators' Experiences with the LEGO Mindstorms Robotic Invention System

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In fall 1998, members of the mathematics department and the Institute for Interactive Technologies at Bloomsburg University met to discuss a problem of mutual concern: students' difficulty determining the best way to begin to solve a problem, even when it is derived from applications of simple mathematical concepts. Students often voiced feelings of frustration and confusion when approaching a word problem and didn't seem to fully understand the problem-solving process. In an attempt to find a nontraditional method to help students understand the importance of approaching problem solving as a process, the group applied for, and subsequently received, a grant from the Pennsylvania Department of Education. The grant was to support the creation of an innovative problem-solving course that would use a combination of logic, hands-on experience, and a modicum of trial and error to help students identify the processes behind effectively solving problems. The course was carefully designed for middle school students: students interested in innovative technology and, more important, at a critical point in the development of their attitude toward and aptitude for problem solving.

The group of Bloomsburg educators used the grant money to develop a course that could be taught to local middle school teachers. The key component of the course was the inclusion of a new product by the LEGO Corporation, called Mindstorms. The Mindstorms system is a programmable robotics kit that uses an interfaced computer program to enable students to design, construct, and manipulate their own robots. The idea was to introduce the system to middle school teachers, familiarize them with the system's operation and benefits, then encourage them to use it in their own classrooms. To that end, the university used a substantial portion of the grant to purchase ten Mindstorms systems and then donated them to the Central Susquehanna Intermediate Unit for classroom teachers to borrow.

During summer 1999, a group of eight middle school teachers from as many school districts enrolled in the resulting course, "Implementing LEGO Mindstorms in the Middle School Classroom." The course proved to be as innovative as the Mindstorms system itself. The first week (twenty hours) of the course involved familiarizing the classroom teachers with the Mindstorms system. Teachers were given a multitude of demonstrations, asked to experiment with the product, and provided with technical support when needed. The teachers were then brought together for a series of discussions concerning the educational value and practicality of the system. They discussed the benefits of using the product in the classroom and explored ways in which it could be introduced into the curriculum. The course was also designed to help teachers explore various problem-solving techniques as well as examine why students become frustrated and confused when presented with exercises that involve solving mathematical problems. Course participants also discussed ways in which the LEGO Mindstorms robotics invention system could foster heightened enthusiasm among students, encouraging them to examine their own thought processes as they approach problems. The course also examined the benefits of the system as it relates to cooperative learning and group problem solv-

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ing. The course addressed ways in which the LEGO Mindstorms robotics system could be most effectively implemented in the teachers' classrooms. Finally, the course provided the teachers with an opportunity to implement the program with a test group of students.

In the second week (thirty hours) of the course, forty gifted students in grades six, seven, and eight attended a one-week camp on the operation of LEGO Mindstorms. During the camp, the teachers enrolled in "Implementing LEGO Mindstorms in the Classroom" taught the middle school students how to use the Mindstorms system. The students were placed in groups of four and each member received a specific task. One student was a builder of the LEGO robot, another student programmed the robot, one student organized the LEGO pieces, and one student kept the group's journal. Each of the four group members took a turn with each task so each could experience the various roles integral to the project. For example, on Monday Shannon was a programmer, on Tuesday she was a constructor, and so on. The students began by building simple robots with designs they found in an instruction manual. By the end of the camp, the students created their own LEGO robots and had a competition to see which group's robot could push a golf ball across a floor for a given distance in the shortest amount of time.

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The teachers convened in the third week to discuss how they could integrate the system into their school curricula. The teachers made many observations and provided the university participants with valuable feedback. Some teachers expressed concerns that having four students in a problem-solving group left some students disengaged during the process. Teachers felt that three students would be ideal and believed that the role of the journal keeper could be eliminated. Teachers also agreed that the system could be more readily implemented in a classroom where the same students had the same robotics system each day for several weeks in a row. One teacher suggested that the robotics system could be installed in a school's computer laboratory.

The LEGO Mindstorms unit proved an excellent teaching tool for many reasons. Primarily, the system teaches students problem-solving skills because they are given the opportunity to design, develop, and test their own robot. Students seem happy to play with the robot to get it to perform the functions they want it to. Students know immediately when they have made a mistake because the robot will not move in the manner they expected. Such "failures" are a tremendous learning opportunity for the students. Because they generally perceive the reason for their failure as something they did or did not do, they can return to the computer program, examine it, and make changes they believe will solve the problem. Student groups can work through a number of problem-solving steps before teacher intervention becomes necessary.

Students remain highly engaged throughout the process because they visualize their robot as a toy. The robot becomes much more than a toy, however, as students gradually learn how to control it and command it to perform specific tasks. Working within their problem-solving groups assists students in the development of interpersonal, communication, and team-building skills. With every student an integral part of the team, students learn that constant, clear communication is a necessity. The development of those skills becomes valuable because while building the robot or writing the program the students often encounter a problem they cannot solve on their own.

Finally, the techniques and strategies that students use to fix their robots will help them when they encounter future problems. In working with the robotics system it is not always immediately clear why the robot fails to perform a specific function. Students learn to check both the program itself and the construction of the robot, as a problem in either area can render a robot motionless. The students also discover that sometimes a robot fails to perform as expected as a result of both the program and the robot's construction.

The robotics system shows promise in helping students not only with direct, hands-on problem solving, but with written problem solving as well. The robotics system teaches students that if their team is to solve a problem, they must be able not only to identify why the robot is not functioning correctly but to articulate the problem to their fellow group members. Many of the new tests of problem-solving capabilities require students both to provide a solution and to demonstrate the processes involved in determining the answer.

Although the new robotic invention product shows promise for the development of problem-solving skills, many questions have yet to be answered. The primary problem centers on cost and classroom implementation. The systems are fairly expensive; many school districts would find their cost prohibitive. In addition, the nature of the product requires a substantial commitment of time on the part of both students and teachers. Because most middle schools do not use block scheduling, teachers might struggle to find valuable time in which students could work without being constantly interrupted. Would interruptions lead students to be

less inclined to solve complex problems that necessitate experimentation? Finally, what promise does the system hold for those students not enrolled in courses for the gifted or for those students who are not mathematically oriented? Would the system prove more or less useful to them? Perhaps as the robotics invention system grows more popular in both homes and schools, those questions will be answered.

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