Practices of Teaching Problem Solving Skills in Robotics Education

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Practices of Teaching Problem Solving Skills in Robotics Education

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The present paper presents the practices of teaching problem solving skills in robotics education using LEGO® MINDSTORMS® NXT at a college level. The fundamentals, the components, and the main course design were introduced in the paper. Problem solving log data were collected from 16 undergraduate students enrolled in this course during the first eight weeks of the course. The data showed that lack of knowledge/understanding was the main cause of problems students encountered. Students most frequently used technical manuals to gather information, and used analysis to process knowledge, and mainly used trial and error to solve problems when they encountered them. Practical applications and implications were included.

INTRODUCTION

In the 21st century, emerging technologies are advancing the development of human civilization more than ever before. While technologies bring enormous benefits to workplaces and daily lives, people also incur many challenges. Problem solving is fundamental to all technological challenges (Tidewater Technology Associates, 1986; ITEA, 2000). How people can learn to solve technological problems efficiently has become an important issue in formal and informal education environments from K-12 to adult continuing education.

The purpose of this paper is to present the practices of teaching problem solving skills in a Robotics Education course in a university over an extended period time. Instructional objectives of the course are to enable students to have the following:

1) Demonstrate technological problem solving skills;

2) Apply the technological problem solving process to design automated systems using selected electronic and mechanical components and devices;

3) Interface computers to external devices and program computers for open loop and closed loop control of electro-mechanical devices;

4) Interpret technical manuals to operate and program robot design and invention systems;

5) Design, construct, and program a fully functional autonomous robot to solve a real world need or issue.

PRACTICE INNOVATION

In this paper, current practices in teaching Robotics Education to improve students' problem solving skills were discussed. Data were collected in an actual classroom in a university in the southeastern United States. The participants were undergraduate students enrolled in the robotics education courses.

Teaching strategies included classroom and online discussions, e-journaling, group and online lab work, reflection, electronic communication, inquiry activities, design/problem solving activities, and engineering log books. Educational technologies included but were not limited to:

- Moodle Learning Management System
- VoiceThread e-presentation software
- Blackboard Collaborate
- Tumblr blog
- LEGO™ Digital Designer 3D Solid Modeling Software

Fundamentals of LEGO® MINDSTORMS® NXT robots

Basic content information of the robotics education course that might typically be presented in a classroom setting was posted in the online course management space - Moodle. The lessons align/coincided with lab activities related to any given topic. No lab time was used for lecture presentations, providing students more time to work on their robot projects. The lab met six hours per week for 15 weeks.

On the first day of the lab class, students chose a partner to work with for the first half of the semester and were assigned a LEGO® MINDSTORMS® NXT Education design and invention kit (see Figure 1). Each pair inventoried their kits and replaced missing pieces and/or removed extra pieces. Using a chart matching each LEGO® piece with an image, students learned the names of the pieces as they counted each one. For example, wheels were also used as pulleys. Beams, axles, and connectors had specific names and sizes, etc. The purpose of this exercise was to build a knowledge base and skill set particular to LEGO® robots. Information related to the major components of the robot was presented online and students were quizzed and asked to participate in discussion threads during class time. Major components of the robot kit included but were not limited to:

- Sensors: Light, sound, touch, and ultrasonic
- NXT intelligent brick (microprocessor)
- NXT interactive servo motors

The inventory generally took 60 minutes to complete at which time students began building the basic robot as detailed in the prescribed manual.

Figure 1. Parts in a LEGO® MINDSTORMS® NXT Education Design and Invention Kit

Students must interpret 3D graphics construction directions. There were no written instructions. Throughout this initial activity, students were introduced to construction basics, motor and sensor functions, and how each function was controlled by the brick. When the class was built, students input commands to move the structure forward, reverse, and then added loop and stopped commands to the program. Programming directly in the brick allowed for only five command blocks and was therefore limited.

Figure 2. A LEGO® NXT Brick with Ultrasonic Sensor

Using the same basic robot, students moved on to computer programming using the NXT-G programming software. They learned commands to drag and drop in to the programming work area. Each time a command block was dragged from the palette and dropped in the work area, a configuration panel opens at the bottom of the screen. Students may set motor output ports, sensor input ports, change motor power, or any other parameter required to satisfy the behavior or function of a particular command block.

Once proficient, measured by the successful outcome of a specific task, students were introduced to the Robot C (see Figure 3) for NXT programming software. During this learning experience, each pair of students may choose to alter an existing robot design or create their own. Either way, they must incorporate a sensor with which they have not yet worked (i.e. magnetic compass sensor, gyroscopic sensor, temperature probe, and more). It was at this point that students began to take ownership of their robots and programs.

```
// Motor port 3 forward with 100% power

task main()
{

  /*
    Port 3 forward with 100% power
    Do this for 3 seconds
   */

   motor[port3] = 127;
   wait1Msec(3000);
```

Figure 3. Robot C Programing Language

Technological Problem Solving Components: The Problem Solving Log

DeLuca (1992) developed and validated a *Problem Solving Log* form based on his 14 years of technological teaching. This 2-page problem-solving log was one of the most important teaching strategies used in this course. It was an explicit method to learn how people approach the process of solving problems. A problem was defined as a situation that prevents students from completing their tasks. Each time a student encountered a problem that was not solved directly, they were asked to fill out a problem solving log. First, they briefly described the issue and then tracked and recorded the process through which they solved the problem. The expectation was for students to *think* about the way they solved problems by following the problem solving process to find the resources needed to solve a problem.

Each of the following categories includes a brief description of several components of the log.

Problem Area. Students were asked to describe the specific task or event when the problem was encountered. This was to identify the problem using ones' own words.

Cause of the problem. The responses for "cause of the problem" included lack of knowledge/understanding, lack of technical skills, equipment problem, and other.

Thinking processes. In-depth thinking skills involved the process of retrieving information in memory and reconstructing knowledge. Five categories of thinking skills were identified by Presseisen (1985) to describe people's mental process of changing the form and function of knowledge (see Table 1). This section of the log also allowed students to record how they gathered information, recalled relevant information, and processed knowledge.

Problem-solving processes. The process of problem solving was regarded as sequential mental activities (Anderson, 1980). Researchers have proposed several problem solving models (for a review, see Varnado & Deluca, 2007). Problem solving process options included trial and error, troubleshooting/debugging, experimentation, design, research and development, and management. Definitions and results of data collection were presented in Table 2.

Final Design Project

At mid-semester, students were selected to work in teams of three to four members. In these groups, students identified a real world need or problem, and used the LEGO® design and invention system to prototype a unique robotic system that resolves the issue.

Following the problem solving process, each team must identify and conduct initial research on five different problems/issues, carry out brainstorming sessions, and in their design log, document each of their ideas. Documentation of this segment of the assignment must be detailed, organized, and summarized. What the robot will do and a rough sketch of what it may look like must also be included. Having considered each idea, each team chooses what they believe to be the most practical design to present to the instructor. They advocated for that idea based on thorough research and justified their reasoning for choosing that particular selection.

Evaluation of this project was based on the *functional* prototype, documentation of the process (an electronic engineering design log), a final technical report, a presentation (including a trifold display, brochure, video, and other multimedia requirements), and peer evaluation.

FINDINGS

For the first half of the fall 2012 semester, 16 students filled out 35 problem solving logs when they were learning the basics of LEGO robots.

Among 43 causes of the problem, the majority (n = 17; 40%) were due to lack of knowledge/understanding, which was far more than equipment problems (n = 12; 28%) and lack of technical skills (n = 11; 26%), and other (e.g., carelessness; n = 3; 7%).

Regarding thinking processes, most students gathered information from manuals (n = 26), and then classmates (n = 15) and Internet or other sources (n = 10), and then finally the instructor (n = 9). This was what the instructor expected since she wanted the students to explore by themselves first and consult the instructor as their final resource.

Regarding approaches to recall relevant information, more participants used relating or associating knowledge items (n = 19) than brainstorming (n = 16) and other approaches (e.g., Internet; n = 11).

Processing knowledge included five methods: qualifying, analyzing, transforming, relating, and classifying. Analyzing was used most frequently (Table 1). Students were allowed to make as many choices that applied to solving a problem.

Table 1 Methods of Processing Knowledge

N	Methods	Definition
24	Analyzing	Establish cause and effect, assessment: predictions, inferences, judgments, and evaluations;
13	Qualifying	Find unique characteristics: definitions, facts, problem/task recognition, units of basic identity;
12	Relating	Detect regular operations: patterns, sequence and order, logical inductions, parts and wholes, analysis and synthesis;
5	Classifying	Determine common qualities: Grouping and sorting, similarities and differences, comparisons, either/or distinctions;
4	Transforming	Relate known to unknown characteristics, create meanings: Analogies, metaphors, logical inductions.

Regarding the problem-solving processes, trial and error was the most frequently used process (Table 2).

Table 2 Problem Solving Process Results

N	Process	Definition
25	Trial and error	Try probable solution and then determine if it works.
20	Trouble-shooting/de-bugging	Isolate the problem, identify possible causes, test components, implement the solution, and then evaluate the solution;
14	Experiment-ation	Observation, hypothesis development, experimentation, draw conclusions
9	Design	Ideate/brainstorm, identify possible solution, prototype, finalize design;
6	Research and development	Conceptualize the project, select research procedure, finalize research design, develop proposal, conduct research, analyze results, report results, evaluate research project
3	Management	Identify project goals, identify tasks to reach goals, develop a plan to accomplish the task, implement the plan, and then evaluate the plan.

DISCUSSION

Cause of the Problem

Lack of knowledge and understanding was the most frequent problem cause. Given that the majority of the students did not have experience with LEGO robots before, the LEGO parts, microprocessor, and programing were new to the students. At the beginning level of learning, it was normal to have difficulty due to lack of knowledge and understanding of the machine. It is possible that people might have different types of problem causes at different stages of the process.

Thinking Process

The thinking process included gathering information, recalling relevant information, and processing information.

Gathering information from the technical manuals was the most frequent. Most of the manuals provided systematic instructions for building the robots and they were always available to the students. When they tried and failed to find the answer on the manuals, they turned to classmates and internet for a quick answer. The preference of information source needs further investigation and whether seeking information on ones' own or turning to classmates for handy assistance helps better with problem solving skill improvement also needs further investigation. After searching for information all around, there were still cases where the problem is still not solved and the instructor has the authority to give the enlightening guidance. The instructor explained that the process of searching information is a key part of problem solving process regardless of whether the students were able to solve the problem by themselves or not. When they finally got the answer, they could know what worked, what did not, and why.

Recalling relevant information is closely related to gathering information. It is important to reconstruct the information gathered and think outside of the box to trigger more information, According to Bloom's taxonomy (Krathwohl, 2002), the levels of thinking and problem solving are in the order of remembering, understanding, applying, analyzing, evaluating, and creating.

Problem-solving Process

According to the problem solving processes data, most students employed trial and error. This happened during the first eight weeks of training of the basics of robots, including the building blocks, various sensors, and programming, etc. In other words, they were still in the process of learning to get familiar with the fundamental parts of the robotics. All the problem solving processes (i.e., trial and error, troubleshooting/debugging, experimentation, design, research and development, management) are supposed to be important (Deluca, 1992). The reason why they heavily relied on the basic trial and error process may need to be explored.

Practical Value and Further Direction

The design of the robotics course provided a great opportunity to learn robotics knowledge, problem solving skills, and creativity. The use of reflective journals and problem-solving logs helped measuring and enhancing their problem solving skills.

When it came to problems, the thinking process data indicated that student heavily relied on rudimentary trial and error, which might be because the students did not understand the other problem solving process, or maybe they did not have enough chance to use the higher-level problem solving processes. If the teaching goal is to teach students all these problem solving processes, then appropriate tasks that require higher-level problems –solving processes should be included in the curriculum. Other human factors method like focus group, thinking aloud, etc. will be used to validate the problem solving log, and further facilitate the teaching of problem solving skills.

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