AC 2010-317: PROMOTING TECHNOLOGICAL LITERACY AMONG MATHEMATICS, SCIENCE AND TECHNOLOGY TEACHERS: A GRADUATE STUDIES COURSE

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Promoting Technological Literacy among Mathematics, Science and Technology Teachers: A Graduate Studies Course

Abstract

This paper addresses a graduate course aimed at fostering technological literacy among K-12 mathematics, science and technology teachers. The course includes: 1) discussing broad questions, such as what is technology and how technology relates to other fields, for example, mathematics, science and engineering; 2) learning a specific subject in technology, for example, basic concepts in control systems; and 3) experiencing the process of designing, constructing and improving a technological system, for example, robotics. Students' performance in the course and their very positive reflections on this experience indicate that individuals having a background in exact sciences are frequently interested in learning technological concepts and are capable of handling relatively challenging technological tasks in a short time. Based on our experience, it is suggested to adapt the following guidelines in designing programs aimed at fostering technological literacy: linking what is learned in the class to participants' daily lives or professional interests; learning through hands-on activities in a rich technological environment; fostering peer-learning and collaboration in the class; and encouraging participants to reflect on their learning.

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Introduction

Subjects such as mathematics, science and technology are currently being instructed in school as separate disciplines, and teachers often teach specific subject matter and have only little knowledge about subjects not within their area of expertise. Only few teachers understand broad terms such as technology and technological literacy. In the Department for Science and Education at, we feel it is important to promote technological literacy among mathematics, science and technology teachers in order to enhance their understanding of technology and open routes for incorporating technology and engineering concepts into teaching other school subjects. This is the rationale behind the technology course we are offering our graduate students, as described in this paper.

The "Aspects of Teaching Technology and Science" Course

The "Aspects of Teaching Technology and Science" course is delivered to K-12 mathematics, science and technology teachers studying for MSc or PhD degrees in science and technology education. About 20 students take this course every year during one semester (13 weeks, three hours a week). The course is comprised of the following three main parts: 1) discussing broad questions such as what is technology and how technology relates to other fields, for example, science and engineering; 2) learning a specific subject in technology, for example, basic concepts in control systems; and 3) experiencing the process of designing, constructing and improving a technological system, for example, robotics. The following section of this paper will describe in more detail what the students learn throughout the course. Implications of this course on education are also discussed.

What is Technology?

The term technology is not defined exactly and people understand it in many different ways. Therefore, the course starts by addressing issues such as: what is technology; the role of technology in the development of humankind, society, culture and the economy; the relationship between technology, engineering and science; etc. We deal with various approaches or models of teaching technology and fostering technological literacy in K-12 schooling existing in different countries worldwide. For example, technology as a craft, technology as engineering, technology as design, technology as the application of science, technology as computers and integrated programs for teaching mathematics, science and technology [1] [2]. Mitcham [3] discusses technology as artifacts, as knowledge, as processes, and as volition. The bottom line is that we adapted the approach proposed by Marc de Vries [4] in his book Teaching about technology: An introduction to the philosophy of technology for non-philosophers, in which he describes technology as "the human activity that transforms the natural environment to make it fit better with human needs, thereby using various kinds of information and knowledge, various kinds of natural (material, energy) and cultural resources (money, social relationships, etc.)."

Learning Technological Concepts

In the second part of the course, the students learn two to three major technological subjects, for example, the basics of digital systems, image processing, control systems, robotics or communication systems. We addressed the latter three subjects in the current academic year (2009-2010). Let us see how two of these subjects, control systems and robotics, are learned in the class.

Control systems

The chapter on control systems includes learning terms and concepts such as systems, control and feedback. For example, a system is defined as an assembly of inter-related elements, the sum of which exhibits behavior not localized in its constituent parts. That is, "the whole is more than the sum of its parts" [5] [6]. A system can be physical, biological, technological, social or symbolic, or it can comprise more than one of these. The concepts of control and feedback are discussed in the context of simple examples that individuals having no background in engineering can understand, such as temperature control using a thermostat (closed-loop, on-off control) and manual control of needle speed in a sewing machine (open-loop, continuous-control), as illustrated in Figure 1. These examples are significant because they help explain the difference between on-off versus continuous control, and demonstrate that control is not always closed-loop.

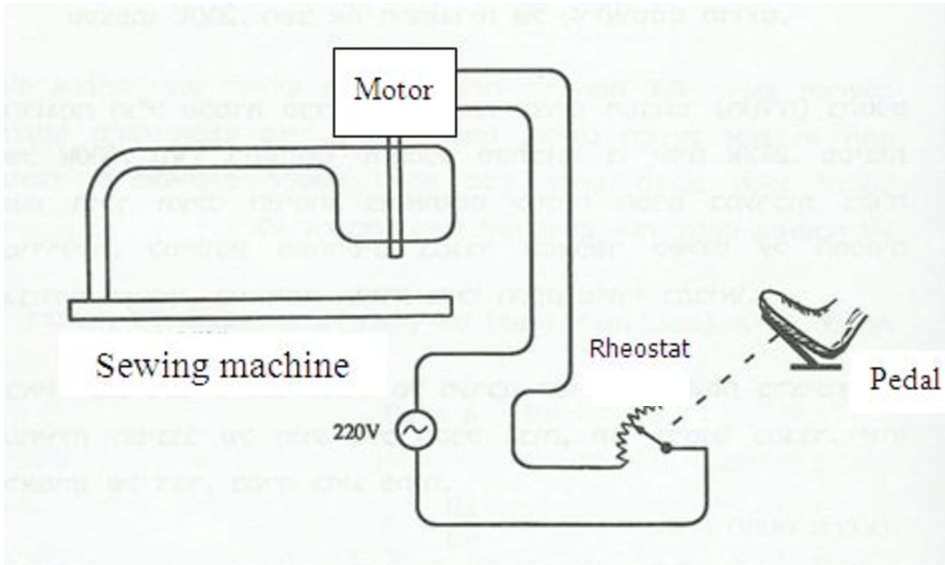


Figure 1: An example of open-loop, continuous-control: manually regulating needle speed in a sewing machine.

In one assignment the students prepare in the course, they must learn about a feedback control system on their own, for example, at home or in a car. The student must explain the system he/she chooses using sketches, pictures and a block diagram. An example of a student's work, a mathematics teacher, is shown in Figures 2 and 3 (published with the students' consent).

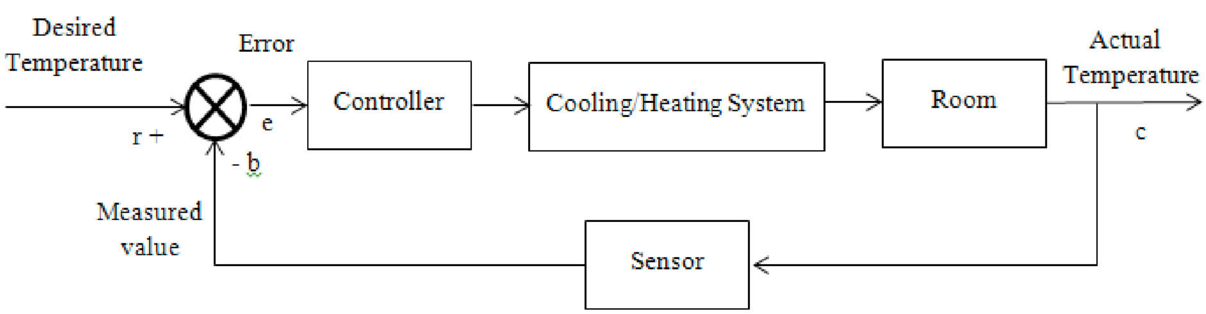


Figure 2: Block diagram of an air-conditioner's temperature control.

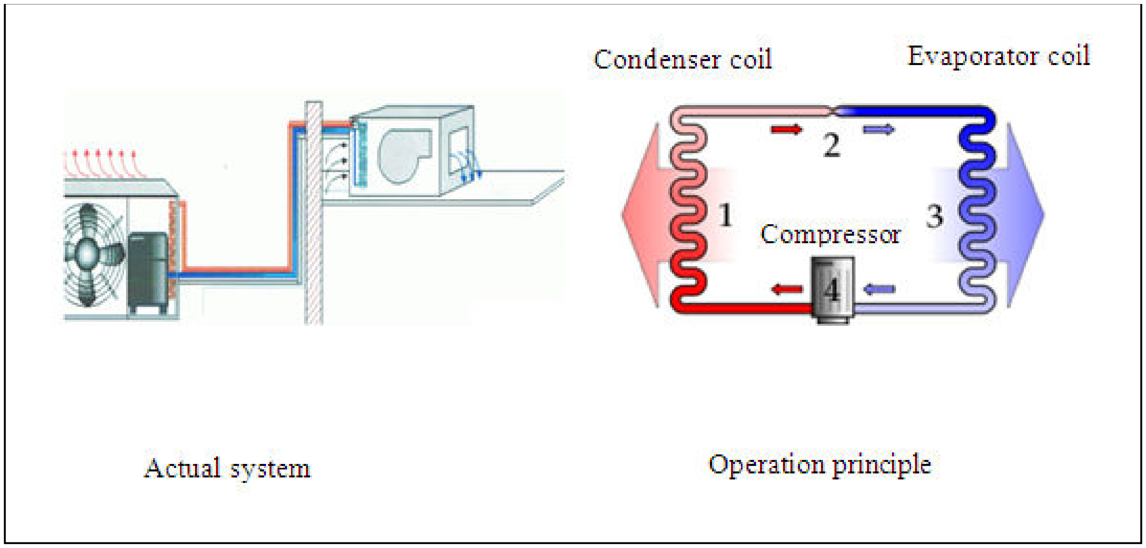


Figure 3: Air-conditioning system.

Other examples of work prepared by students in the course are cruise control and Anti-lock Braking System (ABS) in cars, and water level control in a washing machine. It is important to note that most of the students had no background in technology or engineering, and they learned the above-mentioned subjects from books, catalogs and other resources available on the Internet.

Robotics

This part of the course starts with a short introduction to robotics, for example, what is a robot and how a robot differs from other automatic systems. The learning takes place in a robotics laboratory in which the students construct and program small portable robots using the Lego NXT robotics environment. The robot comprises a digital controller, motors and sensors, as illustrated in Figure 4.

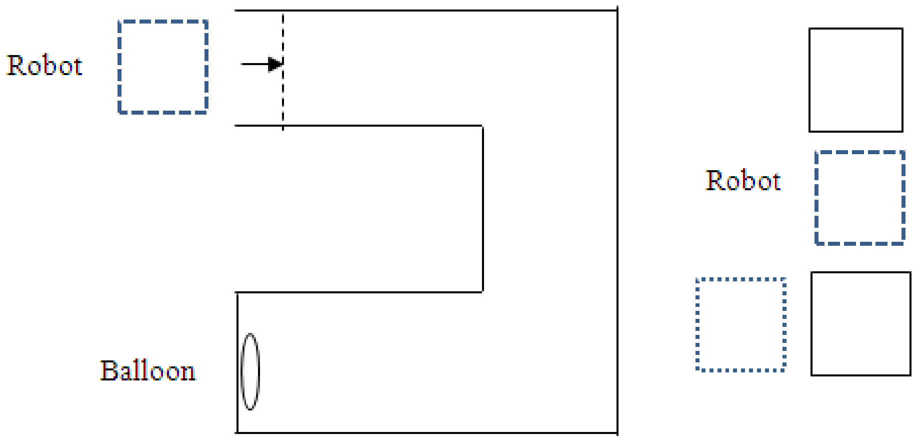
Figure 4: Lego NXT robot.

The students use an icon-based programming language that enables full control of each motor. Figure 5 presents a simple command in which robot motors A and B perform 2.31 rotations at 75% full power.

Figure 5: An example of an icon-based programming environment for the robot.

The students deal with a series of tasks in the lab, including:

- Measuring a robot's velocity on the floor as a function of motor power
- Making the robot move in a labyrinth and burst a balloon at the end of its path using sensors (Fig. 6)
- Programming the robot to park between two cars (Fig. 6)
- Programming the robot to move along a given geometrical course, for example, a square, triangle or circle



A robot in a labyrinth

A robot parks between two cars

Figure 6: Robotics assignments.

In handling the above-mentioned tasks, the students must learn how to make the robot move in a specific direction or turn at a given angle around its center. To this end, they must find, for example, the relationship between the number of wheel rotations **N** and the angle the robot turns **Θ**, as illustrated in Figure 7. The distance between the robot's wheels **L** and the wheel diameter **D** are important parameters in calculating the robot's movement.

One can show that $N = \frac{D}{L} \cdot \frac{\Theta}{360}$

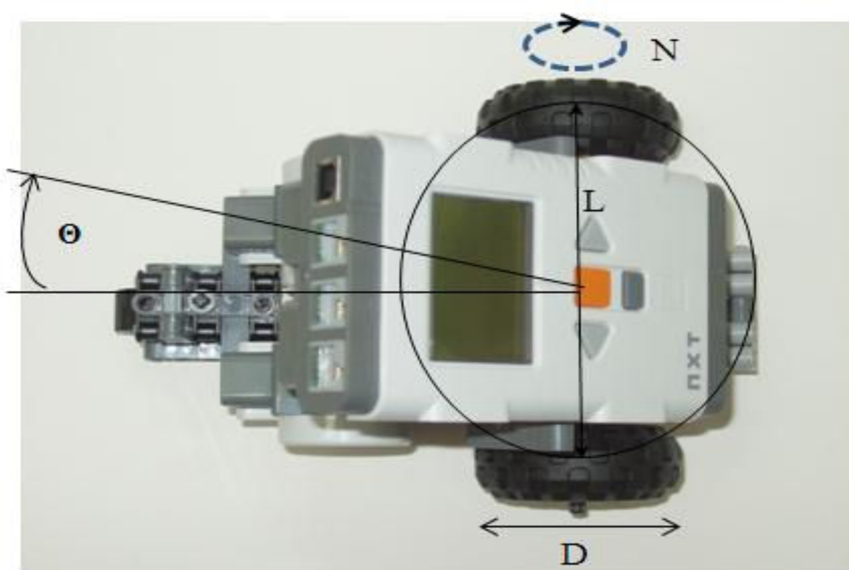


Figure 7: Rotating the robot around its center

One of the tasks the students deal with is programming the robot to move around a circle, as shown in Figure 8. This is a quite a challenging task because the students must find a general algorithm that divides the circle into n small steps and controls the robot's movement from one point to another.

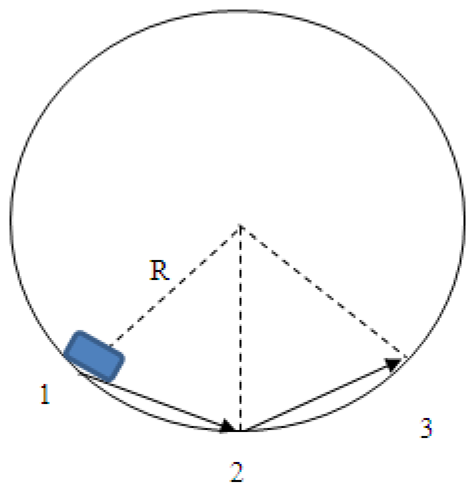


Figure 8: A robot moving around a circle.

To conclude, we can see that although the robotics activity in the course is rather short – only about nine hours – the students perform a series of tasks of increasing complexity. These tasks were designed to not only encourage higher-level thinking, problem-solving and creativity in the class, but also to show the students how robotics relates to physics and mathematics – subjects in which many of them have expertise and teach in school.

Student's Reflection on the Course

During the course, the students are asked to prepare individually a summative reflection on what they have learned. Following are some examples from students' notes during the past academic year.

Students' comments on the control chapter of the course included:

"It is important that every citizen knows how technological systems we use at home *work…"*

"Now I'll understand much better what *I'll be buying*, for example, an oven or a washing machine."

The students wrote the following regarding the robotics activity:

"I enjoyed the robotics lessons very much. The subject was absolutely new to me. I was impressed with the integration between the theoretical knowledge and practice, including mathematics and physics, besides technological innovations. This knowledge is certainly interdisciplinary."

"In the robotics activity I learned to design new things... *learn*ed new software... applied mathematics and geometry knowledge... applied process thinking... *use*d algorithms."

"We learned to consider space, the surrounding conditions, the fact that the robot is not *always an exact machine*... it needs *sensors*... this activity required that we use creativity in problem-solving."

"It is well known that feedback is an important part of learning. During the robotics lessons, we programmed the robot, tested it, received immediate feedback from its performance and went back to improving our design. This was an opportunity to actually experience receiving feedback through learning."

"My students (in school) often ask me why we learn algebra or geometry. Now I can show them how these subjects relate to robotics."

Many students emphasized the aspect of teamwork in working on the robotics tasks. For example:

"The robotics activity contributed to me because of the chance of collaborating with *other students... this was a very enjoyable teamwork* experience."

"I enjoined the collaboration not only with members in our group but also with other groups in the class."

Summary

As previously mentioned, the main objective of the course described in this paper is to promote technological literacy among mathematics, science and technology teachers. Beyond discussing general questions such as the nature of technology and how technology relates to other exact sciences, the course gives the student a chance to learn major technological subjects and experience the process of technological design and problem-solving.

We chose to engage students in learning subjects such as control systems and robotics because these fields deal with fostering an individual's systems thinking as well as scientific and technological literacy [7]. The American Benchmarks for Science Literacy [8], for example, stresses that all pupils should learn the concept of a system and develop their understanding of systems as they progress in school. The National Science Education Standards [9] identified systems as being a unifying concept that can provide pupils with the "big picture" of scientific ideas as a context for learning scientific concepts and principles.

Conclusions

The quality of the assignments prepared by the students in this course and their very positive reflections on the course content and method indicates that individuals having a background in the exact sciences are frequently interested in learning technological concepts and are capable of handling relatively challenging technological tasks in a short time. Based on our experience, it is suggested to adapt the following guidelines in designing programs aimed at fostering technical literacy:

1. Linking what is learned in the class to participants' daily lives or professional interests.
2. Learning through hands-on activities in a rich technological environment.
3. Fostering peer-learning and collaboration in the class.
4. Encouraging participants to reflect on their learning.

In compliance with these principles, we consider extending the course in the future to also include additional technological subjects as well as project-based learning in the course.

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