An Approach to the Challenge Line Problem in a Mechatronics Engineering Course

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Abstract - *Experience gained from a course in Mechatronics Engineering is used to illustrate an approach to the Challenge Line Problem, a problem that relates to a key pedagogical issue that underlies most engineering courses. The issue is how to achieve the optimum balance between two extremes. The first extreme provides students with highly constrained problems in which there is a clearly defined solution. The other extreme provides students with open ended problems that have multiple potential solutions and includes the possibility that there is no viable solution. After several years of experience, it is believed that a course has been established that moves in stages from the highly constrained extreme to the open ended extreme of the Challenge Line Problem and yet provides both a broad and stimulating learning experience for the students.*

Index Terms - *active learning, project-based, laboratory-based, mechatronics engineering*

INTRODUCTION

The Challenge Line Problem is a pedagogical issue that underlies most engineering courses. The issue is about how to achieve the optimum balance between two extremes. The first extreme provides students with highly constrained problems in which there is a clearly defined solution. The other extreme provides students with open ended problems that have multiple potential solutions and includes the possibility that there is no viable solution. An illustration of the Challenge Line is given as Figure 1.

The course which is the subject of this paper is laboratory-based and technology-oriented course in Mechatronics Systems Design. However, the Challenge Line is an issue that underlies any course. The broad pedagogical issue is how to achieve the optimum balance between narrowly defined problems and open ended problems. In the context of a mechatronics course, questions that must be addressed include what technology to use, what support to provide, what tasks to set and how to evaluate student performance. This issue of the Challenge Line is closely tied to that of Active Learning in engineering education.

Active Learning is said to be the true key to education. Goff paraphrased Piaget and said "… in order for a student to understand something, she must construct it herself, she must re-invent it." [1]. He went on to observe that students who are engaged in the learning process master the material. Students who are not engaged generally do not succeed. The best way to engage students is to create an exciting active learning environment. In engineering, a hands-on project-based or laboratory based course lends itself naturally to the creation of an active learning environment, be it at the undergraduate [2] or graduate levels [3]. Experience with the Queen's course in mechatronics has amply demonstrated a well known drawback to the laboratory or project based active learning environment; the problem is resources and time [4]. Such courses need specialized physical resources and can consume excessive amounts of both student and instructor time. The Challenge Line problem also impacts directly on student time, which in turn impacts on the level of frustration that a student can experience in self-directed tasks. Again, the issue is finding the balance between two extremes.

In the context of a mobile robot-based mechatronics course, one extreme is to provide students with a ready made robot which does exactly what is expected when it is turned on. The other extreme requires the students to obtain the electronic parts, assemble the sensor array, program, test, revise and determine if the robot will perform the assigned task within the given constraints. After several years of experience, it is believed that a course has been established that moves in stages from the highly constrained extreme to the open ended extreme of the Challenge Line Problem and yet provides both a broad and stimulating learning experience for the students. It does so through a combination of lectures, tutorials and laboratories that culminate in a team design project that requires the students to assemble and program a team of robots to perform a given cooperative task.

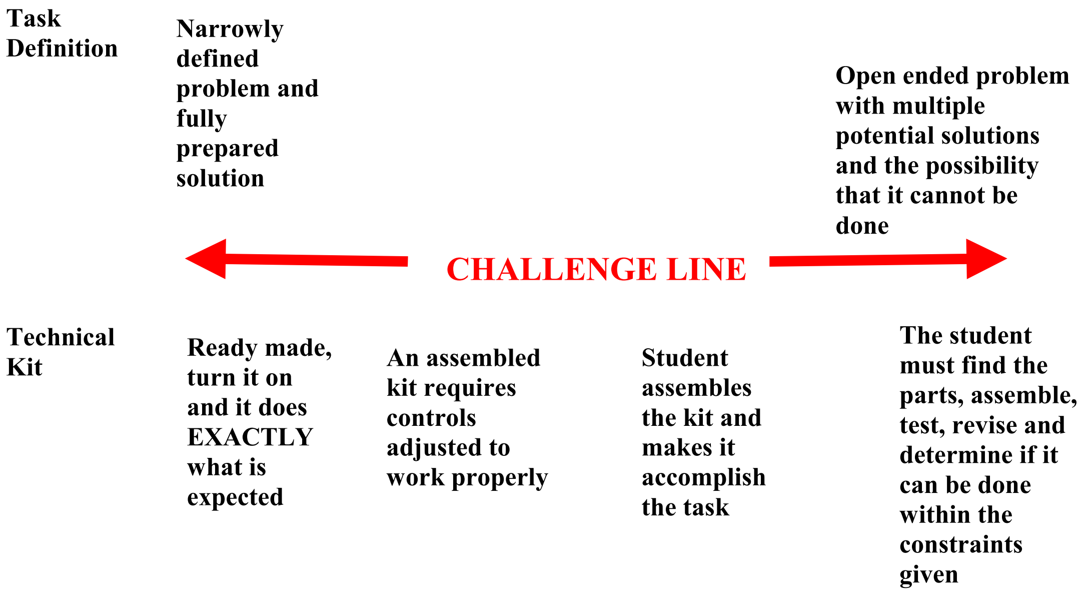

FIGURE 1
THE CHALLENGE LINE

AN APPROACH TO MECHATRONICS

The Queen's approach to mechatronics is to focus on the application of electronics and microcontrollers to mechanical systems. The course is designed around a series of tasks that involve a mobile robot and a prototyping board with a microcontroller, as illustrated in Figure 2 and Figure 3, respectively. The "MechBOT" mobile robot, which was designed in-house, has a highly flexible platform on which sensors, actuators and associated circuits are mounted. None of the commercially available educational mobile robots provided enough space to accommodate the range of sensors and actuators that were originally envisioned for the course.

FIGURE 2
STUDENT PAIR WORKING ON THEIR ROBOT IN THE MECHATRONICS LABORATORY

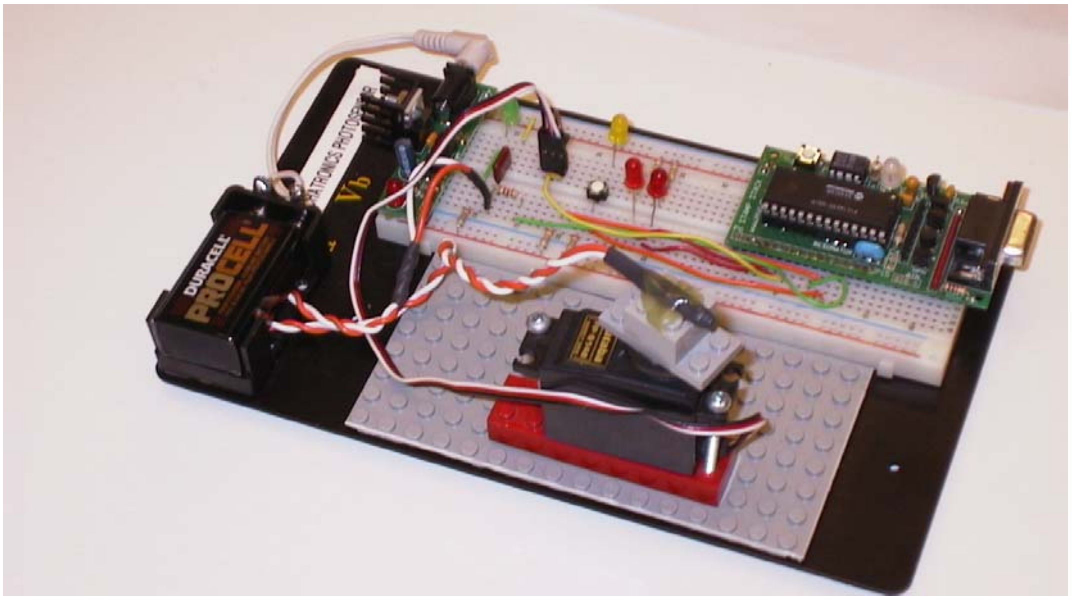

FIGURE 3
PROTOBOARD BASED NAVIGATION BY LIGHT LABORATORY (LAB #3)

It is acknowledged that just as mechatronics courses are commonly laboratory-based, the mobile robot has been effectively adopted as a standard educational tool [5]. Although mobile robots have regularly been used as a tool in electrical engineering programs, mechatronics has provided an opportunity to introduce such devices to non-electrical, and, in particular, mechanical engineering students [6].

A series of eight laboratories was used to introduce the students to the technology, alternating between the application of the technology to the prototyping board in one week, and then the application to the mobile robot in the following week:

- Lab #1 and Lab #2, navigation by contact sensing (limit switches)
- Lab #3 and Lab #4, navigation by light sensing (photoresistors), as illustrated in Figure 3 (protoboard based) and Figure 4 (robot based), respectively
- Lab #5 and Lab #6, navigation by ranging (infrared sensor), with Lab #6 illustrated in Figure 5 (class discussion with testing area shown)
- Lab #7 and Lab #8, navigation by RF (wireless communication)

These laboratories were conventional in the sense that they were structured. A handout detailed the procedure and every group dealt with the same hardware. Variation between groups came about due to the software programming and in the handling of the sensors, actuators and associated circuits. The laboratories could be viewed as one part applied electronics, and one part introductory microcontrollers, with a mobile robot as the application.

For the laboratories, students worked in pairs and this occupied the first eight weeks of the course. In the final four weeks of the course, the experience and knowledge gained in the laboratories was applied to a team design project. In this case, "team" meant eight students working together with four robots. The most recent project was on a problem that mimicked a team of autonomous robots trying to find and isolate a landmine (represented as lights). Further details on the design project and the task based nature of the marking scheme for the course can be found in [7].

In reference to Figure 1, it is important to repeat the observation that the course progressed left to right along the Challenge Line, from the structured small group laboratories (same procedure and hardware but different software solutions possible) in the first eight weeks to the unstructured team design project (with multiple and creative hardware ***and*** software solutions). The laboratories were carefully organized to introduce the technology needed in the design project as well as expose the students to implementation problems with individual elements. This reduced the frustration factor when it came to the systems integration problem presented by the design project. The frustration factor was also immunized by introducing new sensor technology at the protoboard level (for example Figure 3) before applying the technology at the level of the mobile robot (for example Figure 4). Student interest can be used to offset student frustration. Table 1 summarizes this alternate interpretation of the Challenge Line.

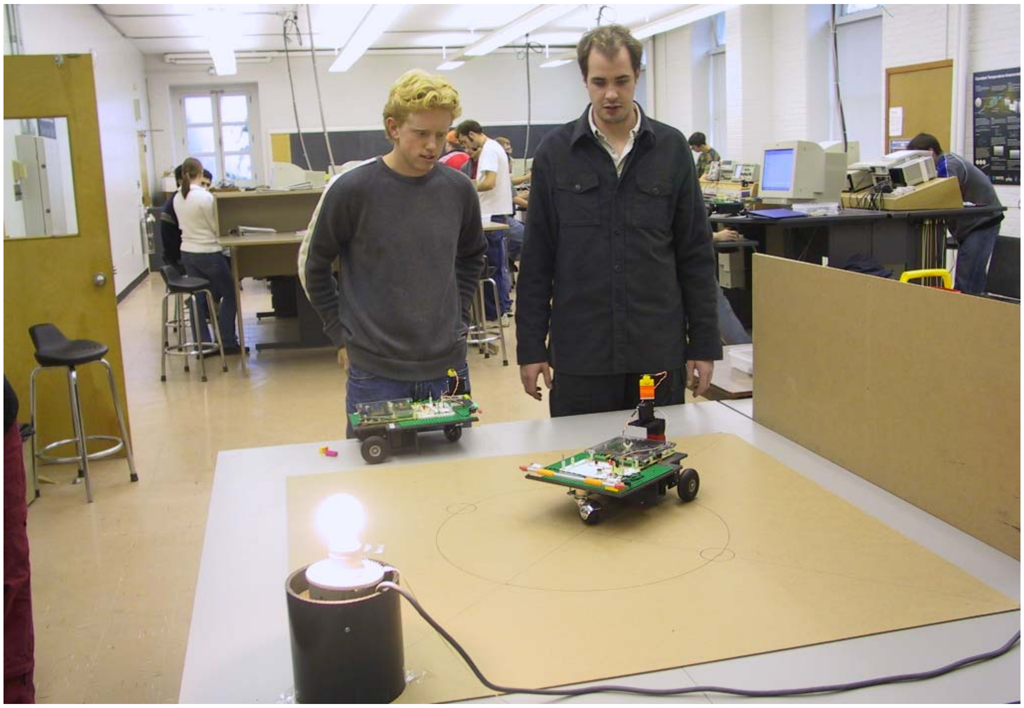

FIGURE 4
ROBOT BASED NAVIGATION BY LIGHT LABORATORY (LAB #4)

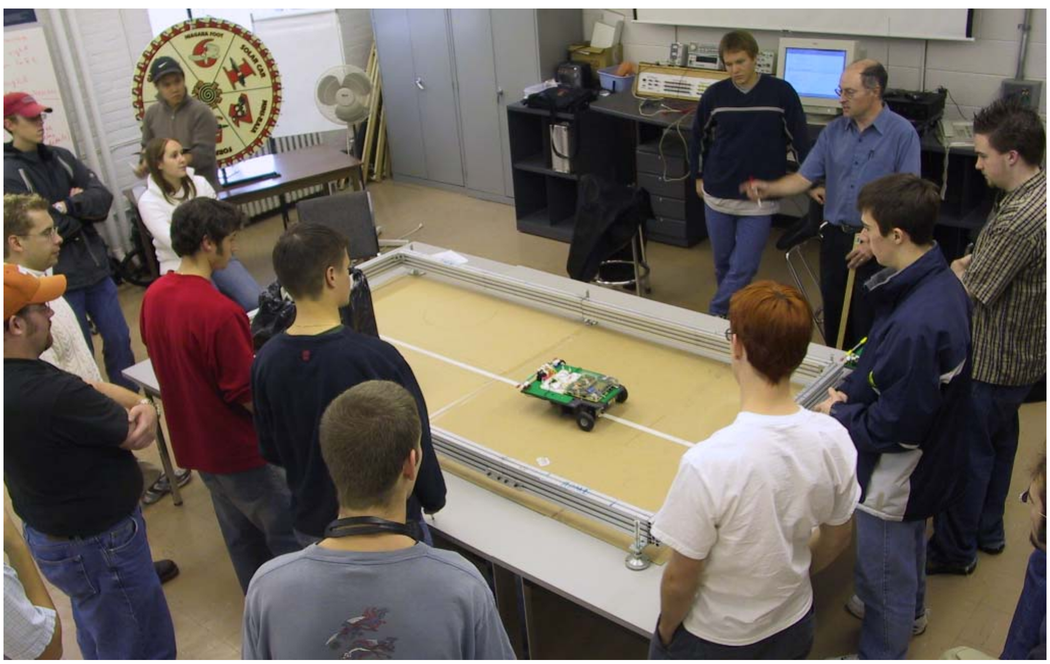

FIGURE 5
CLASS DISCUSSION FOR THE NAVIGATION BY RANGING LABORATORY (LAB #6)

Left End – Recipe	Somewhere in the Middle	Right End – Open ended
Following a recipe can be boring. Senior year students in particular are looking for more than a "fill in the blanks lab". For the first task, starting at the left end of the challenge line helps students to become familiar with the hardware, and software.	The task offers enough new material and enough student input into the hardware and/or software that **interest pulls** the students into the problem solving process. Students are asking questions, making mistakes and fixing them. The optimal challenge level is indicated when many of the groups are successful or mostly so, and there is clapping and cheering when the task is completed. As students gain experience the tasks move from the left to the right along the challenge line.	Some groups will be frustrated to the point of giving up before solving the task. Some students may perceive the task as unfair. Too much time may be spent on this task in this course. Some students are looking for this type of challenge but their other courses may suffer if the curriculum is not designed to take the workload into account.

TABLE 1
STUDENT INTEREST LEVEL ALONG THE CHALLENGE LINE

ORGANIZATIONAL DETAILS

The active learning component attracts a group of students that is enthusiastic about the hands-on nature of the course. However, this enthusiasm can become a problem when the hours spent testing and troubleshooting begin to use up time required for other courses. Furthermore, students had 24 hour access to the laboratory so they could work on their projects at any time. Steps that can be taken toward achieving a sensible balance between independent study and limiting the hours spent on the course are as follows:

1. A tight coupling between lecture and laboratory activity.
2. Arranging a preliminary task that is to be completed in the tutorial in order to avoid time wasted in cases where basic errors are being made at the outset.
3. Solid support during the tutorial and the laboratories by people who know the problems and how to solve them.
4. Back up robots and sensor sets.
5. Attendance at laboratories and tutorials is mandatory.
6. Prototyping boards and robots that are prebuilt for the first day with the basic components laid out in the same manner on every robot; troubleshooting is easier and things work quickly in the first laboratory.
7. Start with prepared sample code for the first task.
8. Have the class gather around the test area and demonstrate successful example runs at the ***beginning*** of the laboratory (except in the final design task) as a method of being clear about the target, generating relevant questions right away, and giving the students confidence that the task can be done (see Figure 5).
9. Provide component data sheets as hardcopy in the laboratory and on course website.
10. Provide a clear handout with the task and the marking scheme clearly identified.
11. Package the material as one week, or later as two week, sessions that include a tutorial and a demonstration prior to the actual laboratory.
12. Walk around from group to group during laboratories to keep in touch with progress and do not let a group spend excessive time on a simple troubleshooting problem.
13. Have a large whiteboard on hand and post common problems and answers to common questions as they arise during the course of the laboratory.

Ideally these steps lead to a balance where students are free to work hard at solving problems on their own, yet will not go overboard such that hours in the laboratory detract from the rest of their course work. The importance of Point 8 (prelab demos) cannot be overstated. This is key not only for the actual demonstration, but it also serves as a planning tool. Only by actually doing the task with the tools at hand can an instructor prepare the appropriate instructions and be aware of most (or at least some) of the problems the students will face.

COURSE RESOURCES

Group size certainly has a dramatic effect on the learning process. In our experience, two students per group per robot is ideal. The work sharing and program discussion occurs a lot with just two students in a group. As more students are added there is a tendency for one person to do all of the programming while the other does all of the assembly and often the third or fourth student is left out as an observer.

Group make up is also an important consideration where there is the option for other disciplines to take part in the course. While some thought has been given to having a course that mixes electrical and mechanical students, there is a sense that this would take away from the goal of the course. In this course the mechanical students gain an understanding of some of the issues facing people working with electronics by doing the work themselves. Indeed, students from this course would be well positioned to take part in a more advanced robot building course that involved multidisciplinary teams.

For a class size of 20 to 30 students (10 to 15 groups), the course was run with 3 instructors (2 faculty and 1 graduate student). This follows the guideline of 1 instructor for every 6 students in a laboratory setting. While the number of instructors can be reduced as students become more experienced, the regular addition of new equipment keeps the need for resources up. A mechanical technologist and an electronic technologist provided technical backup for off-line repairs and out of term maintenance.

Suitable workspace is another key element in making a mechatronics course successful. In our case we were fortunate to have a room of eleven workstations each equipped with a computer, power supply, oscilloscope and multimeter (see Figure 2). The room had been designed as a prototype for Queen's new Integrated Learning Centre (ILC) and it served the needs of the students very well. There was storage space for equipment, open floor space for demonstrations and a data computer projector for showing graphics and computer code.

Accessibility to workspace is also an issue. Students were given keys as they could have 24 hour access to the laboratory. But more importantly, they were the only users of the space. Thus, the students (and the instructors) had the luxury of a dedicated workspace, in much the same way that competition design teams have dedicated workspace. At a time when every university is short of space due to expanding enrolment, the is viewed as highly inefficient use of space. However, allowing students to come in at any time to work on their project, and the fact that laboratories do not have to be torn down at the end of every laboratory period, does led to very effective learning.

SUMMARY

After several years of experience, it is believed that a mechatronics course has been established that moves in stages from the highly constrained extreme to the open ended extreme of the Challenge Line Problem and yet provides both a broad and stimulating learning experience for the students. It does so through a combination of lectures, tutorials and laboratories that culminates in a design project that requires a team of students to assemble and program a team of robots. Sufficient detail has been given to assist others in the duplication of the efforts and experience of the authors.

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