

# Building blocks of collaborative learning

Engineering graduates can generally be assumed to be technically competent, but their 'soft' skills may not be as advanced. Ciarán McGoldrick and Meriel Huggard of Trinity College Dublin describe how a Lego MindStorms course is used as part of TCD's ICT degree programme to help develop collaborative and management competencies alongside technical ability.

In recent years, engineering accreditation bodies such as the US Accreditation Board for Engineering and Technology (ABET)[1], the UK Institution of Electrical Engineers (IEE)[2] and the Institution of Engineers of Ireland (IEI)[3] have actively encouraged academic institutions to view the development of teamwork, leadership and decision-making skills as fundamental to the educational formation of engineers and computer scientists. Indeed, ABET identifies the "ability to function on multi-disciplinary" teams and the "ability to design a system, component or process to meet desired needs" as essential outcomes of any engineering degree program. Moreover, it states that engineers should recognise the "need for, and have an ability to engage in life-long learning"[4]. These skills are of benefit to the practicing engineer on both an individual and professional level. This philosophy was a key element in the design of the recently developed undergraduate degree programme in Information and Communications Technology (ICT), offered by the Department of Computer Science in Trinity College, Dublin.

One of the courses taken by students on the ICT degree programme centres on computer technology and aims to provide students with a strong foundation in topics such as logic design, microprocessor and microcontroller architectures and their uses, machine intelligence and simple robotics. The course includes a 12-week module that creates a collaborative laboratory environment with Lego MindStorm [5].

This module involves small teams of students working on the design and development of a robot using Lego MindStorms. The students are evaluated on both the quality of the robots they produce and on their performance as a team. This module seeks to reinforce learning in an enjoyable way, whilst encouraging students to become independent, critical thinkers. Moreover, it provides students with the opportunity to learn how to develop and function as a coherent, effective group - cooperating with others to attain mutually beneficial goals.

## Lego MindStorms

Lego MindStorms blocks differ from traditional Lego, in that they include an RCX and associated peripherals. The RCX is a microcontroller, based on a Hitachi H8 chipset; the 8 bit central processing unit (CPU) runs at 16MHz and the RCX 'brick' also includes 32 Kbytes of random access memory (RAM) and 16 Kbytes of read only memory (ROM) for the built-in operating system (BIOS). Input and output are achieved through three sensor inputs, three actuator outputs and a proprietary infrared (IR)



interface. The IR interface allows the RCX to be programmed and controlled wirelessly. The RCX also incorporates a small liquid crystal display.

Like a personal computer, the RCX has control and hardware interface software stored in its ROM. The user downloads firmware and compiled program code to the RCX RAM. The user's program code can be written in virtually any programming language - such as C, Java, Lisp, Forth or Assembler. The RAM is erased when power is permanently removed.

The RCX places a number of practical constraints on students. The most significant of these are the limited number of inputs and outputs and the limited memory available for the user's compiled code. Students must factor these 'real-world' limitations into all aspects of their solutions to the challenge. This forces each group to prioritise certain tasks and behaviours to ensure successful completion of the assignment.

The MindStorms kits come with different configurations of peripherals and sensors. Peripherals can include traditional RCX accessories such as servomotors or pneumatics. Sensors can be passive, such as touch sensors, or active, such as rotation sensors. Application-specific sensors are also available such as greyscale cameras, magnetic compass sensors and ultrasonic proximity sensors.

## Learning context

Students are set a number of technical tasks to complete within a given timeframe. Each group is provided with a Lego MindStorms RoboLab kit and a collection of motors, light, touch and angle/rotation sensors. The assignment, in the last academic year, required the students to create a single robot capable of completing two tasks.

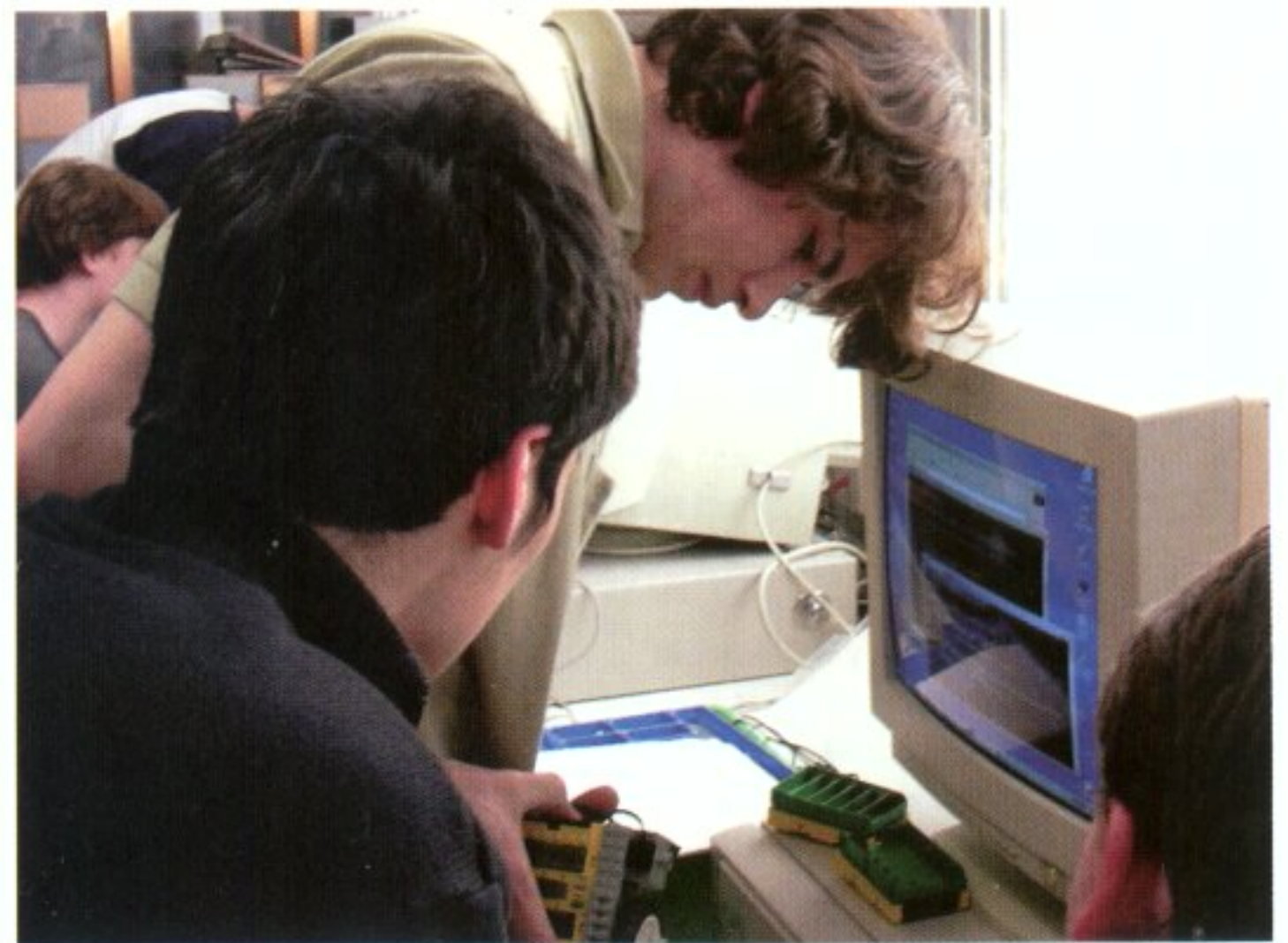
The first, and more significant, challenge was to create a robot capable of taking part in a Lego Sumo Basho. The competition takes place on a black elevated platform. A 2.5cm white circular band is painted at a 36cm radius to form the dohyo (ring). The competing robots must satisfy certain basic dimensional criteria, such as fitting in a 10cm square.

The second task requires the robot to travel in a perfectly straight line for an arbitrary distance. A narrow white line is provided, and the robot should stop at the point where the line terminates. The robot cannot use a light sensor to explicitly follow the line and, accordingly, adjust its position. It can only use a light sensor to determine when to stop.





The students were required to create a robot capable of taking part in a Lego Sumo Bash.



Students not only improve their problem-solving skills but also naturally engage in group collaboration.

The prescribed tasks encompass a variety of challenges. Each student group must analyse the task in hand, decompose it into subtasks and assign responsibility for these to specific group members. Time and project management, as well as critical path issues, impinge on this process. For example, it is not possible to test code for the robot if the robot is not already assembled. Similarly, it is not possible to produce code for the robot, if the group has not formulated a strategy for the Basho.

The group's programming team must contend with the restrictions imposed by both the Lego kits and by the programming environment. For instance, the RCX has only three inputs and three outputs, so no more than three sensors can be connected as inputs, and no more than three motors or actuators can be connected as outputs. One of these inputs must be a light sensor to detect the dohyo boundary and the line in task two. Thus, only two inputs are available for other sensors.

The group's programming and build teams must liaise closely to determine the optimum robot configuration. Use of one or more angle/rotation sensors will be advantageous for task two but will constrain effective collision detection, which is essential for task one. Thus, a robot that is specifically purposed for one task will be non optimal for the other. In task two, students must consider both the limitations of the Lego elements e.g. component tolerances, in addition to the physical environment in which the task is to be performed. Different motors, actuated for identical periods of time, do not, necessarily, produce the same number of revolutions. Similarly, dual 'belt' drive systems may experience asymmetrical slippage. It is, thus, incumbent on the group to factor these component properties into their activities.

### Evaluation

The assessment methods used are carefully chosen to reflect the course objectives and allow for the provision of positive feedback and encouragement to students during the module. The diverse nature of the course objectives mean that students must be assessed on both their technical knowledge and group collaboration skills. To assess these successfully, a mixture of formal and informal assessment techniques are employed.

In the closing stages of the module, time is set aside for technical demonstrations. Each robot must compete in at least three sumo bouts, although most compete in many more. Marks are awarded to each group for their robot, and its performance, based on technical proficiency, style of competition and combativeness. These marks are weighted by category and the

marks for victory are sufficiently low so as to encourage a friendly spirit of competition between groups. The robots must also complete the straight-line challenge, where marks are awarded for accuracy, speed, and stopping at the required location.

The novel laboratory environment described above, where students not only improve their problem-solving skills but also naturally engage in group collaboration, has proved highly successful. The module assessment structure and objectives have been aligned so that students not only focus on acquiring the necessary technical knowledge, but also receive active encouragement to reflect on, and develop, their team building and management skills ■



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### References

- [1] Accreditation Board for Engineering and Technology (ABET). <http://www.abet.org>
- [2] Institution of Electrical Engineers (IEE). <http://www.iee.org>
- [3] Institution of Engineers of Ireland (IEI). <http://www.iei.ie>
- [4] Engineering Accreditation Commission, "Criteria for Accrediting Engineering Programs", Accreditation Board for Engineering and Technology, Inc., November 2002. <http://www.abet.org>
- [5] Lego MindStorms <http://mindstorms.lego.com>

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