# LEGO 101: A Multidisciplinary Freshman Team Experience

**Dick K. Blandford, Deborah J. Hwang, Anthony Richardson**
**University of Evansville**

Abstract

Some have indicated that it is not possible to do an multidisciplinary team project with freshman in engineering and computer science that meets the specifications set out by ABET for multidisciplinary teams. This paper presents a course whose goal is to do just that. We define a multidisciplinary team as one in which each team member brings to the team unique skills and interests that are essential to solving a problem. ENGR/CS 101 has a section for electrical engineers, a section for computer engineers, and a section for computer science majors. During the first four weeks of the class each section is taught concepts which are fundamental to their major and which are essential to solving a problem involving an autonomous LEGO vehicle. For example, the electrical engineers are taught about sensors, amplifiers, and electronics. The computer science majors are taught the rudiments of programming in C, and the computer engineers are taught micro-controller fundamentals. During the last ten weeks of the semester-long class, teams are formed that have at least one person from each major. Each team member is assigned a unique responsibility on the team. The objective is to construct an autonomous LEGO vehicle to compete in a classic predator/prey problem. Some instruction in team dynamics is provided by lectures, and teams use faculty as consultants. This paper summarizes the course details, the objectives, outcomes, and assessment.

## I. Introduction

The Electrical Engineering and Computer Science (EECS) Department at the University of Evansville offers three bachelor's programs: electrical engineering (EE), computer engineering (CoE) and computer science (CS). Separate introductory courses in engineering and computer science have been in place for some time. These courses provide a contact relationship between new majors and departmental faculty and introduce major concepts. Operating systems and programming concepts have been introduced for the CS majors and some introduction to design concepts has been done with the engineering majors.

As part of an on-going effort to meet ABET Criteria 2000, the introductory course (ENGR/CS 101) has been undergoing revision to provide a multidisciplinary team experience for our freshmen students[1]. The freshman year offers a unique opportunity to introduce multidisciplinary team concepts in that the mechanics and logistics of mixing two or more disciplines on a wholesale class level are easier. Students are involved in basic science and math courses and are not taking multiple courses in their major area which are less flexible in tolerating objectives that cross the discipline. The obvious difficulty is that freshmen have not

studied enough of a particular discipline to qualify as experts and become effective team members.

In order to make ENGR/CS 101 truly multidisciplinary, the first four weeks are spent in major-specific sections where students are taught fundamental concepts of their major that have application to the final project. For the final ten weeks, students are assigned to teams consisting of at least one person from each major to create an autonomous LEGO vehicle. Each student is responsible for a particular area of the team project ranging from team coordination to vehicle construction to documentation.

## II. Objectives

The combined ENGR/CS 101 retains the objectives of the separated predecessor courses taught the previous year and adds two new objectives in accordance with ABET 2000 guidelines. These new objectives are:

Graduates will be able to formulate problems and identify creative solutions.
Graduates will be prepared to be effective team members.

## III. Major-specific Tasks

*CS Students:*
During the first four weeks of the semester, the students meet in major-specific sections for instruction in fundamentals of their major. The CS students are introduced to the UNIX operating system for reasons independent of the LEGO project. However, they also are introduced to basic C programming using the GNU gcc compiler. The focus of this instruction is on fundamental program structure including selection, repetition, and functions. This allows the CS students to participate in the LEGO project as programming "experts," while allowing the CS program to fulfill its needs regarding the UNIX operating system and its programming environment. CS students are not introduced to hardware and have only a basic familiarity with real time concepts such as interrupts.

*EE Students:*
The focus for the EE students during the first four weeks is on sensor electronics and sensor construction. The LEGO vehicle project requires that the vehicle be able to sense light and obstacles in the vehicle path. EE students get a four week short course that covers Ohm's law, switches, voltage and current measurement, operational amplifiers, analog to digital conversion, and construction techniques. Students meet three times a week in a lab setting construct small projects and learn to use the instrumentation that is fundamental to electrical engineering.

*CoE Students:*
Each team in the LEGO vehicle project gets their own LEGO construction set along with a computer module (built in house). The computer module uses a Philips 89C51RD2 micro controller and is programmed in C using the Keil C compiler. CoE students learn the fundamentals of C programming as it applies to micro controllers. There is less emphasis on program structure than what is given in the CS section, but there is significant emphasis on the hardware/software interaction. CoE students learn to write a C program, download it to the

micro controller, and verify that the program goes as planned. Thus they get some introduction to the oscilloscope and electronic components such as LED's, switches, and analog to digital converters. The CoE students meet in a computer lab environment and complete several small projects centered around the micro controller.

IV. LEGO Project

*Teams:*
The final ten weeks of the semester has students assigned to teams of 4 with at least one person of each major. Each student is required to be the team leader in a particular area of responsibility. The areas of responsibility are: Coordination and Documentation, Software, LEGO Construction, and Hardware Electronics. The responsibilities of each area leader are as follows:

Coordination and Documentation- Responsible for arranging all meeting times and places. The Coordinator will also be the "keeper" of the parts and will be responsible for seeing to it that parts are available when they are needed and for working with the instructors on problems related to parts and equipment. The Coordinator will be the team spokesperson and is responsible for producing the written documentation that is to be handed in.

Software - Responsible for organization of the software and for its proper operation. This includes documenting and adding comments to all of the source code.

LEGO Construction - Responsible for the physical construction of the project. The constructor will ultimately be responsible for what the project looks like.

Hardware Electronics – Responsible for the sensors, the computer, the connectors, and any added electrical features such as the light.

Teams are allowed to decide among themselves which student is responsible for each area.

*Teaching Teamwork:*
To many students a team is simply a group of people thrown together and assigned a common task. To teach teamwork concepts each team is assigned a faculty member who meets with them informally and outside of class. The faculty member serves as a consultant on technical matters but more importantly provides direction and assistance in matters of teamwork.

The faculty member assigned to each team has the following responsibilities:

1. Provide assistance in getting the resources necessary to do the task assigned. Resources include such things as additional electronics for sensors, access to labs, instruments, and work space in off hours, and repair of broken parts.
2. Provide clarification and guidance as to team responsibilities.
3. Act as a fair arbiter in personality disputes and settle only those disputes that cannot be settled by the team itself.
4. Encourage active participation by all team members.

*Project Notebook:*
The project notebook is a log of all of the team activities related to the project. Each entry in the notebook lists the time and date of all team activity, the team members present, and provides a summary of important results. This might include rough sketches of various designs in software or hardware, and it may include printouts of software. The notebook is intended to be a complete log of the time spent by each project member working on the project alone or as part of the team.

*Preliminary Assignments:*
To familiarize the student teams with aspects of the LEGO project, each team is given an identical pre-assembled vehicle and several preliminary assignments. These assignments include writing programs to operate motors and use sensors to follow a flashlight beam. At the end of these exercises, the vehicles are disassembled. Some LEGO construction instruction is given and the student teams build their vehicle for the final project. Some of the preliminary assignments are repeated for the teams' final vehicle.

*The LEGO Vehicle Problem:*
The assignment is a classic predator/prey problem in which a predator car chases a prey car around a playing field. Each car has an incandescent light on top and the predator can detect the prey or, the prey can detect the predator using a light sensor. The contest is run in head-to-head heats that last 5 minutes each. The rules of the contest are as follows:

1. The cars must be built out of the LEGO sets furnished, and no additional parts are allowed. A computer for each car is also furnished. Sensors, lights, and actuators may be added as needed to fulfill design requirements.

2. Each car must be small enough to fit into a box which is 8"wide x 8"deep x 12"high.

3. All cars must have an incandescent light (furnished separately) mounted at the topmost part of the car and clearly visible from all angles. The light must be located between 6" and 10" from the floor.

4. Each car must be programmed to be either the predator or the prey. Contestants will not know whether their car is predator or prey until just before their heat starts. Switches must be used to tell the software whether it is the predator or the prey. Each contestant will therefore, place her car on the playing field, push the appropriate switch, and let the car compete. The timing for the contest begins when the judges give the signal and the appropriate switch is pushed.

5. Each heat will be counted as 100 points to be divided between the predator and the prey. If the predator bumps the prey within the first 30 seconds, the predator gets 100 points. If the predator bumps the prey between 30 seconds and 5 minutes into the contest the predator gets between 100 and 0 points linearly scaled with the time. The prey gets 100 minus the predator's points.

6. The predator car must start in a predefined predator box that is marked off on the track. The predator car may be oriented in any direction by the contestant. After the predator car is located and oriented, the prey car may be placed anywhere on the track.

7. The track will be approximately 8 foot across. Sidewalls will prevent a vehicle from falling off of the track and may be detected by bump sensors. The track will be painted flat black. One or more obstacles will be placed inside the track but these will be no more than 6" tall. The obstacles will also be painted flat black.

*Project Evaluation:*
The LEGO project vehicle is evaluated on documentation, creativity of the design, design effectiveness, and on the total number of points scored during the contest. All team members get the same score for the project.

Creativity and design effectiveness points are subjectively awarded by the judges after all of the teams participated in the contest. This provides a mechanism to award a team which worked particularly hard on a project or whose design had novel features but whose vehicle did not perform as well as expected in the contest.

The evaluation of the documentation is done on an ongoing basis by grading the notebooks. Thus teams get feedback throughout the semester on the notebook.

V. Outcomes and Assessment

Assessment of the LEGO project was done in three ways: 1. A focus group was conducted using 6 randomly selected students. 2. A survey form was done for all freshmen. Students were surveyed at the beginning and the end of the semester. 3. Written opinions were solicited from faculty members who taught follow on classes that involved teamwork and/or fundamental concepts related to the major.

*Focus Group:*
The focus group sought to determine student opinion about the class. Students in the focus group were asked to discuss their background prior to coming to the class, what it was they thought they learned from the class with regard to their major, and what they learned about (if anything) about teamwork. Results were recorded and summarized.

*Student Survey:*
The student survey was given on the first day and on the last day of class with the same questions. The survey provided us with A) a measure of student attitudes towards their major, B) each students personal assessment of their ability of work in multidisciplinary teams, and C) the students attitudes toward the class.

*Formal Faculty Opinions:*
Formal written faculty opinions were solicited from faculty teaching the C++ class which followed the LEGO project in the Spring term and in the circuits class which students take in the Sophomore year. The CS students take the C++ class, the EE students take the circuits class, and

the CoE students take both classes. The C++ class was used to determine if the students were any better prepared for a first course in their major. This class traditionally suffers from the diversity in the programming background of the freshmen. The circuits class includes several small multidisciplinary projects so those instructors were asked for opinions as to the readiness of their students to participate in multidisciplinary projects.

The results of all three assessment methods is used to modify the syllabus for the next year's version of LEGO 101.

## VI. Summary

Overall, we have found the LEGO project to be an excellent vehicle for introducing a multidisciplinary team experience for freshmen. The four-week major specific introduction is sufficient to allow students to participate in a project that is greater than the sum of their individual experiences. Details of the course, such as preliminary assignments, C library code, computer module specifications, and pictures of student vehicles, can be found on the project web page at `http://csserver.evansville.edu/~lego101`.

Acknowledgements
This work was supported in part by the EXCEL Program at the University of Evansville.



Bibliography

1. D. Hwang and D. Blandford, "A Multi-disciplinary Team Project for Electrical Engineering, Computer Engineering, and Computer Science Majors", Proceedings of ASEE 2000 Annual Conference, St. Louis, MO. June 18-21, 2000

DICK K. BLANDFORD
Dr. Dick K. Blandford is the Chair of the Electrical Engineering and Computer Science Department at the University of Evansville.

DEBORAH J. HWANG
Dr. Deborah J. Hwang is Director & Associate Professor of Computer Science at the University of Evansville. She received a B.S. in Computer Science from Iowa State University in 1985, and an S.M. and a Ph.D. in Computer Science from the Massachusetts Institute of Technology in 1988 and 1994, respectively.

ANTHONY RICHARDSON
Dr. Anthony Richardson is an Assistant Professor of Electrical Engineering at the University of Evansville. He received a PhD. in Electrical Engineering from Duke University in 1992.