Mentoring In The First-Year Engineering Course: Reflections and Best Practices

[1]David J. Ahlgren
Trinity College, Hartford, CT, USA, david.ahlgren@trincoll.edu[1]

Abstract

This paper describes a peer-mentoring program in the first-year engineering course *ENGR 120: Introduction to Engineering Design—Mobile Robotics*. The course provides an introduction to the engineering profession by considering such topics as design practices in industry, intellectual property, and engineering ethics. The mentors guide eight student teams through a rigorous sequence of team-based robot design projects. With multiple course foci and a heavy workload, students benefit from guidance afforded by mentors, each of whom completed ENGR 120 and is highly motivated to share their experiences and to help teams work effectively. Assessment includes student evaluations of their mentors and mentor self-evaluation. The 2011 evaluatons suggest that some mentors perform better than others and that selection, training, and monitoring are areas for further study.

1. Introduction

In 2000 the Trinity College Engineering Department offered a new course, *ENGR 120: Introduction to Engineering Design—Mobile Robotics*, aimed at first-year students. The accessibility of the Trinity College Fire-Fighting Home Robot Contest [1], the interdisciplinary nature of robot design, and the author's interests led to main course theme: design of autonomous mobile robots for competition. Normally the course enrolls 24 students each year (28 students in 2011). Eight teams are formed by a random selection process that joins students with different engineering interests (EE, ME, etc.) on each team. ENGR 120 requires three hours of lecture and a one-hour team technical workshop each week, and it has no prerequisites.

As reported in [2], ABET outcomes [3] guided development of ENGR 120. The result is that the course has enabled students to make progress toward realizing important educational milestones in their first year of studies. Table 1 lists the ABET outcomes along with course activities crafted with the outcomes in view. The course covers a broad range of "hard" and "soft" engineering topics including design, human factors, intellectual property, engineering ethics, sensors, computers, and mechanics. Assignments include design projects, problem sets, team-led seminars that discuss readings [4, 5], oral presentations, CAD exercises, and examinations. All course assignments are carried out by teams, except for examinations and problem sets, which are completed by individuals.

2. Major Course Projects

Among the course assignments are three major design projects: a two-week introductory design exercise in biomedical and assistive technology, the design of an autonomous mobile robot to compete in the Trinity College RoboWaiter Contest [6], and a capstone design exercise, the ENGR 120 Robotics Olympics. A description of each project follows.

Table 1. ABET Outcomes a – k and related course activities

Out-come	Outcome Description	Activities
a	an ability to apply knowledge of mathematics, science, and engineering	Problem sets, lab experiments including battery drain exercise to determine stored energy in robot battery and equivalent mechanical work.
b	an ability to design and conduct experiments, as well as to analyze and interpret data	Measurement of sensor characteristics and recognition of sensor limitations.
c	an ability to design a system, component, or process to meet desired needs within realistic constraints…	Design of assistive biomedical device, autonomous assistive robot for competition, and autonomous robot for the ENGR 120 robot Olympics.
d	an ability to function on multi-disciplinary teams	Team-based design projects, seminars, and presentations
e	an ability to identify, formulate, and solve engineering problems	Identification and solution to design problems associated with robot claw and gripper design, locomotion, sensor deployment and interfacing.
f	an understanding of professional and ethical responsibility	Interactive guest lectures on engineering ethics and on intellectual property.
g	an ability to communicate effectively	Team-led seminar discussions, written project reports, logbook, final design presentations.
h	the broad education necessary to understand the impact of engineering solutions in a global…societal context	Wide range of readings about human factors and philosophy of design. Guest lectures on global engineering design projects and biomedical design.
I	a recognition of the need for, and an ability to engage in life-long learning	In-class discussions of future directions in robotics and engineering.
j	a knowledge of contemporary issues	Discussion of current trends in biomedical engineering, aircraft engine design, assistive robotics, etc.
k	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Use of lab instruments, programming tools, sensors, and actuators as part of robot design projects. Exposure to SolidWorks.

<u>Biomedical Device Design Project</u>. This assignment requires teams to design a robotic biomedical device to assist persons with disabilities. During the third and fourth weeks of the semester a senior engineer from Phillips Medical Division oversees the design project. In the first class visit he presents a design methodology that requires teams to write a mission statement, value proposition, and to carefully define essential requirements and value-added requirements. Also at this time teams choose a project from a list provided. Two weeks later teams submit a formal written report and make 8-minute PowerPoint presentations. In this assignment teams must address the following: reliability, interaction of the device with human operators; problems and constraints, criteria that may be used to detect emergencies; robotic features that add value and function to the design, sensors that are needed, device setup and documentation, device flexibility. Teams are encouraged to survey the state of the art, seek device requirements from real users (parents and grandparents, for example), avoid biases and pre-conceptions, consider possible follow-on products, and develop a marketing plan. In 2011 teams chose projects from this list: Robotic Shopping Cart for The Disabled, Robotic Travel Assistant, Robotic Lifeline, Communication System for Autistic Children, Robotic Physical Therapy Assistant, and Robotic Assistant for Post-Surgical Patients. Mentors play an important role in this project, meeting with their teams to enable brainstorming, understanding the design methodology, and preparing the reports.

RoboWaiter Project. This nine-week assignment requires each ENGR 120 team to create an autonomous mobile robot to compete in the Trinity College RoboWaiter Contest. It is in this part of the course that teams also need the most guidance from their mentors. The RoboWaiter event, developed in concert with a team from the Connecticut Council on Developmental Disabilities [7] attracted 25 robots from 5 countries in 2011. In this event, robots operate in a scale model kitchen that measures 2.5 m x 2.5 m. Each robot has three chances to navigate autonomously from a starting position to a scale-model refrigerator and to execute these tasks: 1) pick up a plate of food from a shelf, 2) navigate to the table where a person with a mobility impairment is sitting, 3) place the plate on the table, and 4) return to the home position. Robots must avoid collisions with obstacles—a sink, a chair, and a second, elderly person—whose positions are not precisely known. Design of a RoboWaiter robot requires teams to apply fundamental concepts of mechatronics including motion control, programming, sensing, interfacing, and mechanics. For many students, this is the first integrated exposure to these topics, and the experience is extremely challenging. Specific problems include design of a programmable robot base, choice and deployment of sensors to aid navigation and object detection, claw and gripper design, and developing programs that integrate sensor readings and implement robot navigation. Figure 1 shows a RoboWaiter robot developed by an ENGR 120 team in spring 2011.

The weekly team workshops are designed to develop hands-on technical skills needed by teams to succeed in RoboWaiter. Workshops take place in a laboratory equipped with six PCs, test equipment, and a contest arena. In workshops students perform a sequence of exercises that lead to a complete robot design: 1) introduction to C-language programming on an embedded computer, 2) design of a simple wall-banging robot, 3) sensor interfacing (touch sensor and IR ranging sensor), 4) sensor-based wall following, 4) navigation, 5) design of manipulator and claw, and 6) system integration and test. Two teaching assistants, advanced undergraduates with strong backgrounds in robotics, lead the workshops under direction of the instructor.

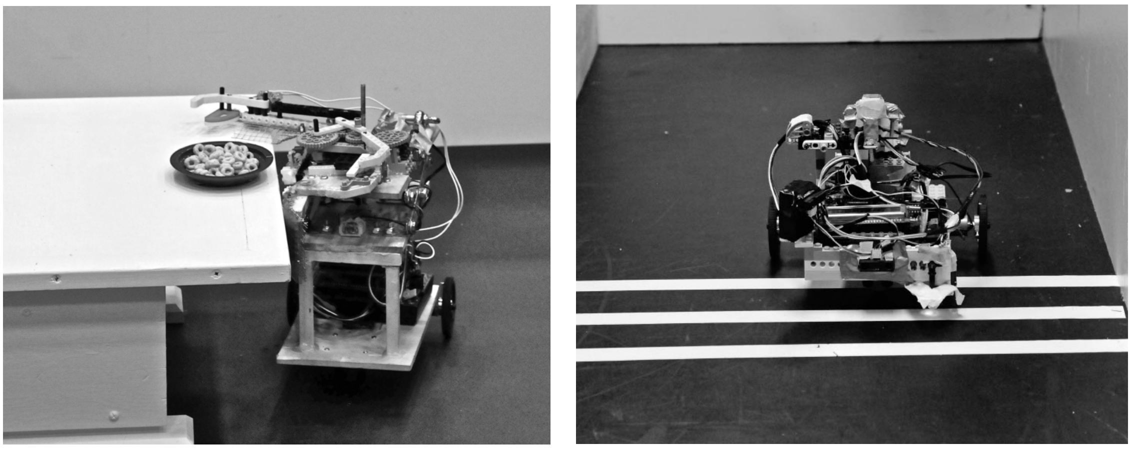

Figure 1. Robots for 2011 events, RoboWaiter (left) and ENGR 120 Olympics (right)

ENGR 120 Olympics. This three-week capstone project presents a new robot design problem that challenges teams to apply and generalize knowledge they gained from their RoboWaiter experiences. The 2011 event, “Inner City Driving”, required robots to start at a fixed location and to navigate through a maze while completing tasks as directed by sensory inputs from the environment. Specifically, robots must detect groups of stripes along the path, count the stripes in each group (1, 2, or 3) and take actions as follows: if a group consists of a single stripe, back up across the stripe before continuing on; if two stripes, show the robot’s driver’s license (by displaying a message on an LCD screen); and if three stripes, take a 360 degree turn and continue forward. In addition, the robot must stop at a traffic light (a LED flashlight) before moving on. Finally, when the robot reaches its destination—a 0.5m x 0.5 m square of white drawing paper—it must deploy a pen and draw a figure. This event required students to modify their robot base, develop and deploy light sensors and a stripe detector, and write reliable programs. Seven of the eight ENGR 120 teams successfully finished the Olympics course.

3. Mentoring Program

It was clear after the first offering of ENGR 120 in 2000, that teams needed guidance to navigate the labyrinth of course assignments. Starting in 2001, each team was assigned a mentor who would provide encouragement and support for their team's activities and guide their teams through workshops and robot competitions. The instructor chose mentors based on their performance in a past ENGR 120 section and candidates' communication, organization, and interpersonal skills. This plan was inspired by mentoring programs at the University of Tennessee [8], Lehigh University [9], and the Colorado School of Mines [10].

The responsibilities of a mentor include attending all team meetings and workshops, helping teams with project planning and management, providing advice on personnel issues, helping teams to develop and adhere to schedules, and offering limited technical assistance. Each mentor is expected to attend a weekly meeting with the instructor and the other mentors where s/he gives a 3-minute report on team progress and fills out a team evaluation sheet. Mentors are responsible for workshop discipline including clean up each week by their teams, and for monitoring and reporting problems with lab equipment or their team's robot components. Mentors developed the 2011 ENGR 120 Olympics assignment, which integrated autonomous navigation and fine art into a single, thematic, and challenging event that students enjoyed. Mentors earn 1.5 hours of independent study credit for this work and for writing a final paper, which assesses their experiences.

A student who has several years of experience in the mentoring corps is chosen each year to serve as the senior mentor. The senior mentor examines team logbooks each week and provides written comments. This student also monitors the meeting schedules of the various teams, advises other mentors, attends one workshop and two team meetings each week, and leads development of the ENGR 120 Olympics assignment. Mentors attend a training event with the instructor at the start of the term in which they participate in role-playing exercises. In 2011 the exercises focused on three areas: How to conduct the first team meeting of the semester, how to handle a workshop problem in which a team copies another team's work, and how to handle personality differences during a team meeting. Although limited in their scope, these exercises provide a training base that helps new mentors to get started in their roles.

4. Evaluation

The course and the mentoring program are evaluated using a variety of instruments. These include a departmental student evaluation form, a faculty course evaluation form, a student evaluation of mentors, and mentor self-evaluation survey. Mentors receive a grade based on participation in weekly meetings, contributions to the ENGR 120 Olympics, quality of the final paper, evaluation by their teams, and a self-evaluation. Here we focus on two spring 2011 surveys—the student evaluation of the mentoring program, and the mentor self-evaluation. Both surveys presented 15 statements, listed in the first column of Table 2, to be rated on a Likert scale ranging from 1 = strongly agree to 5 = strongly disagree. Also the student survey asked three questions related to role of the course and the mentor in increasing interest in the engineering field and the degree to which the mentor and the course improved the student's teamwork skills. The student evaluation form and the mentor self-evaluation form posed three questions: 1) How would you improve the mentoring program, 2) What were the benefits of having a team mentor, and 3) Do you think that the mentoring program should continue in this course? Table 2 summarizes the results of the student survey, which gathered information from 27 members of the eight teams.

For each team, the members' ratings were averaged for every statement. The first two columns of Table 2 list the range of ratings for each of these averages. The third column shows the average ratings by the 27 students who completed the survey. These results indicate a wide difference in mentor ratings by students. The most highly rated statement was "Course should continue to have mentors"; for this statement all responses were all in the "agree" to "strongly agree" range. Other strong responses were for the statements "ENGR 120 enhanced your interest in Engineering" and "Mentor was a good communicator". The lowest rated statements were "Mentor was essential your team's success" and "Mentor was essential to your individual success."

Columns three and four compare the average student ratings and the mentor self-evaluation ratings for the first 15 statements. For most statements mentors gave themselves higher ratings than students did. For example, both groups agreed that mentors attended workshops, were good communicators, and helped to improve team productivity. However, there was a marked difference between students and mentors about the contribution of mentors to individual success, and some difference about whether mentors met regularly with teams or whether mentors helped organize teams. Students and mentors agreed that ENGR 120 enhanced interest in Engineering.

Table 2: Team assessment (N=8, 27 students) and mentor self-assessment (N =7)

Statements Rating Scale: 1= strongly agree, 2 = agree, 3=neutral, 4=disagree, 5 = strongly disagree	Lowest Team Avg.	Best Team Avg.	Stud. Eval. Avg.	Mentor Self.Eval. Avg.
1. Team met regularly with M	2.50	1.00	1.75	1.29
2. M helped you to organize your team	3.00	1.25	2.00	1.29
3. You learned a great deal from M	3.25	1.33	2.23	1.86
4. M knew his/her stuff	2.75	1.00	1.81	1.29
5. M was in the lab during workshops	2.75	1.00	1.81	1.71
6. M was a good communicator	2.75	1.00	1.63	1.43
7. M was essential to your team's success	3.50	1.33	2.35	2.00
8. M was essential to your individual success	3.25	1.75	2.35	1.00
9. Course should continue to have M's	1.75	1.00	1.28	1.57
10. M provided important tech. info.	2.75	1.00	1.97	1.43
11. You are satisfied with tech. support received	3.00	1.00	1.88	1.29
12. M was easily accessible	2.25	1.00	1.72	1.57
13. Team meetings were important for success	2.75	1.00	1.94	1.57
14. M helped to improve team productivity	2.75	1.25	2.02	2.00
15. E120 enhanced your interest in Engineering	2.50	1.00	1.50	1.29
16. M enhanced your interest in Engineering	3.67	1.00	1.98	
17. ENGR 120 improved your teamwork skills	3.00	1.00	1.68	
18. M helped to increase your teamwork skills	3.33	1.00	1.94	

Written comments indicated that students were aware of differences in mentor performance from team to team. They wrote that mentors from some other teams did not seem to care about their teams, seeming too preoccupied and busy, and that mentors' attendance at meetings and workshops should be mandatory (which it was). Two students felt that mentors should interact more with their teams, meet more frequently, and be flexible for contacts outside of meeting times. One student offered that getting together just before the team's workshop would improve the team's workshop productivity. Two students felt that mentors needed to be informed more closely about in-class activities, and one offered that mentors should be present when their teams made project presentations. One student wrote that this a “very good program” but felt that, in order to better help teams, mentors should be screened to identify their areas of expertise.

In response to the same question—how to improve the mentoring program—several mentors expressed satisfaction with the current program, offering such comments, as “the current system is good enough,” “the program is a good concept and is already good,” and “the weekly team meetings and weekly meeting with other mentors are good for the mentor program.” However, others recommended changes:

> I believe that the mentoring program could be organized differently…Mentors should fill out (weekly) an evaluation form for the team for the first two months of the semester.
>
> Sometimes a student might feel out of place with the class or the team and periodic individual meetings with a mentor could help a student get through.
>
> I felt I needed a refresher course when it came it to the technical areas of the robot construction, i.e. connecting stripe sensors, motors, coding, etc. I felt I could answer my students’ questions 80% of the time instead of every time.

In response to the second question, “What were the benefits of having a team mentor?,” a few students wrote that mentors gave advice about design projects and were helpful when teams had technical questions. However, the main benefit was the mentor’s help with guiding, organizing, and advising the team:

> The main advantage is the access to someone who has been through the same experiences and can therefore provide better assistance with the issues. It helps guide our team at the beginning when we were overwhelmed.
>
> Guidance. The team mentor brought great experience to the rather inexperienced teams. It makes building robot process more interesting.
>
> Previous knowledge of how the competition operated. Guided us in the right direction. Was always there for support or question-asking. Easily accessible. Fun to have around!

Mentor responses agreed with the students’ views:

> There were organizational and technical benefits of having a mentor. The team has someone who has been through the robotics process before to give them technical help, but more importantly to make sure they have continual progress.
>
> The benefits of having a mentor are someone for the team to bounce ideas off and to guide them through the semester…and having someone to teach a team what it means to have an effective relationship among team members and what teamwork skills will be necessary across any discipline.

Student and mentor responses to the question, “Do you think that mentoring should continue in this course? Why?” were unanimously affirmative; for example:

> (Student) Yes, the students are exposed to a lot in ENGR 120 and some stuff can be overwhelming. It's good to have someone who's been through the process...
>
> (Student) Yes, mentors are necessary in this course to keep the team intact. Mentoring is an essential resource in this course.
>
> (Mentor) The program should definitely continue. In this introductory engineering course students rely heavily on their mentors for support in this class, and for advice in terms of

majors, concepts of teamwork, and innovative thinking. Mentors play a vital role in how a student might view engineering and possibly spark interest.

(Mentor) Mentors inspire students to be the best they can possibly be and always serve as resource not only in this class but also throughout their tenure at the college.

5. Mentor Feedback

The 2011 final paper assignment asked mentors to assess the current program and to design a better program based on three compelling themes of their choice. Mentors' papers offered many recommendations, each a possible direction in the continuing process of course improvement. The recommendations, summarized below, focused on three issues: role of mentors, choosing and evaluating mentors, and improving mentor effectiveness.

Regarding role of mentors:

> Instead of giving students the solution to every problem, I challenge them to communicate with each other and to derive a method of solving the problem…A great aspect of the class is the opportunity to work with mentors designing the ENGR 120 Olympics.
>
> It is my responsibility as a mentor to help mold the minds of students and help them to become problem solvers…It was essential for me to pay close attention to each student's personalities throughout the semester.
>
> I think that an important aspect would be participation in grades or a grade coming from the mentor on each student. No other classes incorporate a team-based class that makes different people work together. Because of this, some students blow off their responsibilities as teammates and do not try in this class.

Regarding mentor choice, evaluation, performance:

> Some mentors perform better than others. Evaluating mentor performance is necessary and not complete.
>
> Mentor training is key to achieving goals. Mentors should…write a mid-term paper.

Improving mentor effectiveness:

> Make first few weeks more communication—intensive (key to develop good comm. early in term).
>
> It is unacceptable for mentors to be late for team meetings (or not to attend them).
>
> It is important to have a system that would show a bad teammate that their actions are harming others and their own GPA.

5. Discussion

Based on the survey results and mentor papers, the author offers several observations about the effectiveness of mentors in ENGR 120. Surveys show that students value mentoring but that quality varies from team to team. Therefore it is important to improve the consistency of mentoring across the teams. Choosing the best mentors is the first step in ensuring quality. Ideally there is a large pool from which to choose; then, the instructor can evaluate candidates on the basis of their expertise, motivation, leadership skills, reliability, and academic record. For many years the pool of applicants for ENGR 120 mentoring slots has nearly matched the number of teams, so the luxury of choice has been absent. It may be helpful to assess personality traits with a standardized test (e.g. the Meyers-Briggs Type Indicator, as in [8]) or to enlist a colleague in a psychology or sociology department to consult about qualities of successful mentors.

Whatever the size of the pool, undergraduate mentors need effective training. Surveys suggest that training topics should include mentor reliability, flexibility, communication skills, and conflict recognition and resolution. Mentors must be well informed about class assignments and be able to guide students with reports and presentations. If they are to play a role in evaluating each student on their team, as suggested in the survey, must be trained in evaluation methods. One must remember that mentors are themselves students who require supervision and supportive monitoring.

From the survey, it is fair to conclude that the mentoring program is an important part of the course and that it should be continued. We can strive to meet a description expressed in the survey by one mentor: "The optimal mentoring model should include leadership, learning, and teamwork themes at all levels of the program—among students, mentors, TAs, and professors."

6. Acknowledgements

The author thanks guest lecturers Morton Pearson, David Ware, Peter Gutermann, Harry Blaise, and Christine Engel; teaching assistants John Lehrkind and Binay Poudel; and mentors Gerald Antoine (head mentor), Gary Williams, Jaynie Murrell, Anson McCook, Ugo DiBiase, Shraddha Basnyat, Mike Atsalis, Rashid Azeez, Morris Jalloh, and Ben Wheatley. Fred Borgenicht led the biomedical design project, and Igor Verner contributed to the assessment.

References

1. Trinity College Fire-Fighting Home Robot Contest, http://www.trincoll.edu/events/robot/

2. D. J. Ahlgren, "Fire-Fighting Robots and First-Year Engineering Design: Trinity College Experience," *Proc. of ASEE/IEEE Frontiers in Education Conference*, Reno, October 2001.

3. Criteria For Accrediting Engineering Programs. "Accreditation Board for Engineering and Technology (ABET), Baltimore, 2011.

4. D. A. Norman, *The Design of Everyday Things.* Basic Books, New York, 2002.

5. H. Petroski, *Invention by Design*. Harvard University Press, Cambridge, 1996.

6. D. J. Ahlgren, and I. M. Verner, "Assistive Robotics Competition RoboWaiter: A New Approach to Socially Responsible Robotics Education," *Proc. of 2010 ASEE Annual Conference,* Louisville, 2010.

7. Connecticut Council on Developmental Disabilities, http://www.ct.gov/ctcdd/site/default.asp

8. Knight, D. et al. "An Evaluation of a Design Team Facilitator Training Program for Engineering Upperclassmen." *Proc. of the 29th ASEE/IEEE Frontiers in Education Conference*, 1999.

9. N. Rivera, M. Troup, and G. Tonkay, "Perspectives of Undergraduate Apprentice Teachers Assisting with Freshman Design Projects," *Proceedings of the 28th ASEE/IEEE Frontiers in Education Conference*, San Juan, 1998.

10. M. J. Pavelich, R. D. Knecht, "Mentoring Freshmen Through Design," *Proceedings of the 28th ASEE/IEEE Frontiers in Education Conference*, San Juan, 1998.