AC 2010-1994: ASSESSING SENIOR STUDENT EXPERIENCES WITH A NOVEL MOBILE ROBOTICS LEARNING PLATFORM IN A COMPUTER AND ELECTRONICS ENGINEERING PROGRAM

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Assessing Senior Students' Experiences with a Novel Mobile Robotics Learning Platform in a Computer and Electronics Engineering Program

The University of Nebraska-Lincoln department of Computer and Electronics ENgineering (CEEN) has been engaged in funded educational research using robotics under the auspices of the Silicon Prairie Initiative for Robotics in Information Technology (SPIRIT) into the local community and state of Nebraska since 2006. Out of these efforts, a novel computational mobile robotics learning platform was developed by faculty and students of the department to be used as the centerpiece of outreach efforts to middle school math and science teachers in order to demonstrate STEM concepts at the K-16 levels and to provide a sense of excitement and buy-in for University students enrolled in the CEEN program. The platform, named the CEENBoT™, was first introduced to freshman CEEN students in the fall semester of 2008, while current CEEN seniors, projected to graduate in 2010, possess no direct experience with the new platform.

This paper gives the results of an assessment conducted in the fall semester of 2009 with the goal of measuring the educational impact of senior students' project-based experiences with the CEENBoT™ mobile robotics platform while enrolled in an Introduction to Robotics course. The Introduction to Robotics course, a senior level elective, included 9 students, 7 of whom were also enrolled in a preparation course for the Senior Capstone Design Project, entitled Senior Thesis Proposal. The Senior Thesis Proposal course guided students through the planning stages of the capstone design project, including topic selection and project plan creation. Assessment tools were designed to assess whether the project-based experiences with the mobile robotics platform positively impacted the senior students who were enrolled in Senior Thesis Proposal and Introduction to Robotics compared to the group of senior students enrolled only in Senior Thesis Proposal and not Introduction to Robotics. The tools included pre and post surveys and a focus group.

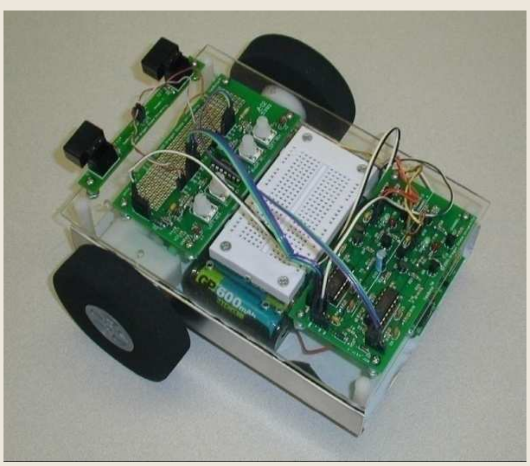
The data received from the assessment tools provided important new insights that will be applied to ongoing developments of integrating the CEENBoT™ into the Introduction to Robotics course, and to future advances toward maximizing the impact of using the CEENBoT™ for teaching and learning in a 4-year University sequence.

The Learning Platform

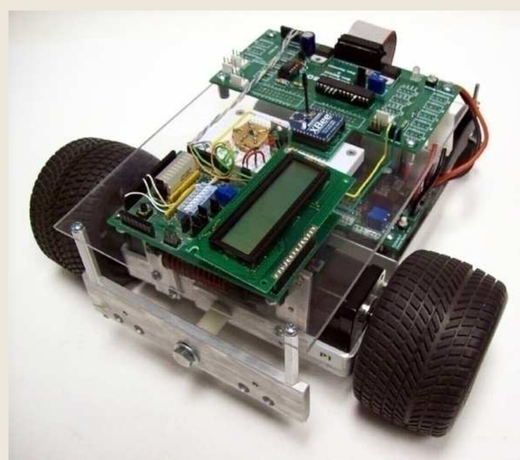
The CEENBoT™ mobile robotics platform, developed in 2008, has been used in both K-12 and college level educational environments as a motivational learning platform applicable to a wide range of STEM topics. It is a highly flexible, robust platform for project-based, hands-on learning with expandability for various microprocessors, C programming capability and a graphical programming interface (GPI) under development for K-16 users. It has a wide range of applications developed for K-12 math and science standards, and an ongoing development for a grades 5-8 curriculum via an online interactive website [2,3,4,5]. It has a modifiable design consisting of off-the-shelf electronic hobby store components, instead of proprietary components as with the LEGO MINDSTORMS® and VEX® commercially available robot kits [1]. It has been applied in the extensive SPIRIT teacher professional development project and shown to be highly successful for equipping K-12 teachers in STEM training, and to have promising initial results for increasing motivation in student STEM learning at the K-12 level [1,3,5]. The CEEN department is in the process of integrating the CEENBoT™ platform into the 4-year ECE university sequence of courses, beginning freshmen year to better engage students and to provide a hands-on continuity of experiences throughout their program. In addition, the fall 2009 Introduction to Robotics course integrated the CEENBoT™ for the first time in teaching robotics.

The CEENBoT™ was introduced in the fall semester of 2008 into the first CEEN freshman course, CEEN Fundamentals, where students build the platform in the accompanying lab. Current senior students had no experience with the platform. While the current senior students did have previous experience building a TekBot® robotics learning platform developed at Oregon State and previously used in two core CEEN freshman level courses, it had been 2 years since their exposure. The department's creation of the CEENBoT™ platform sought to improve upon certain aspects of the TekBot® to achieve a more robust, highly modifiable robotics platform at the university level[1]. Figure 1 below shows a comparison of the attributes of the CEENBoT™ and TekBot® platforms.

TekBot®



CEENBoT™



Attributes of the TekBot developed by Oregon State University: 5" by 7" footprint

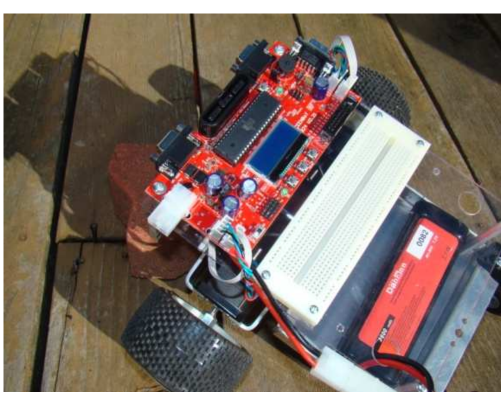
- DC motors with plastic gear train and foam wheels
- Compact design

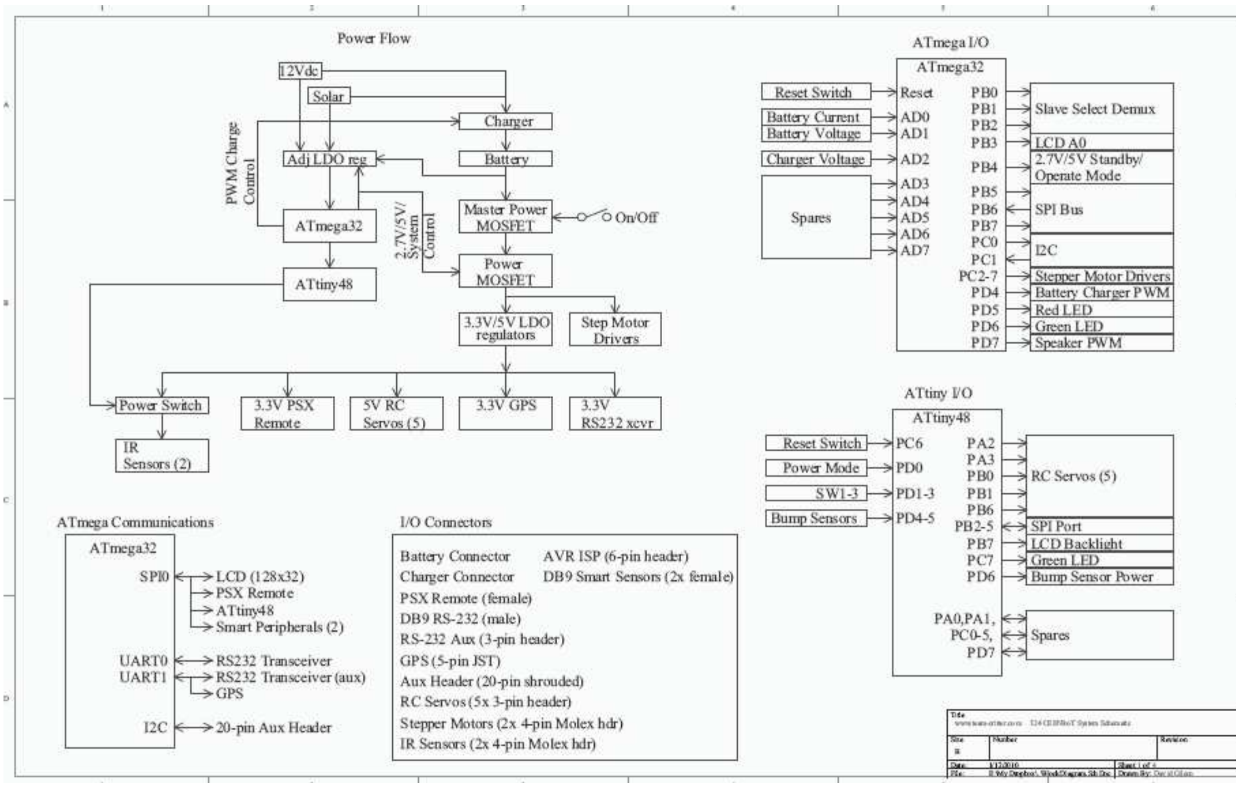
- Prototype circuit board useful to college and advanced K-12 students

Attributes of the CEENBoT developed by the University of Nebraska (CEEN): 6" by 8" footprint

- Stepper motors for precision control
- Full independent wheel suspension for traversing uneven indoor or outdoor terrain
- Larger capacity, quick-change power supply
- Interchangeable rubber drive tires
- Remotely controllable using a Sony PlayStation® wired or wireless remote controller
- Large prototype board for projects and more reliable connectors
- Serial-to-peripheral interface (SPI) to allow communication between multiple multiprocessors
- Flexible for K-16 educational applications to meet needs at multiple levels
- Graphical Programming Interface (GPI) under development for K-16 users (IBM and MAC compatibility)
- Platform will accommodate GPS, on-board video camera, robotic arm, and various sensors, wireless technologies, and microprocessor platforms
- Available in a number of configurations from unassembled kits to completed modules

In 2009, CEENBoT, INC., a small start-up from the University of Nebraska-Lincoln department of Computer and Electronics Engineering, was created to oversee the technical development, manufacturing, and distribution of the CEENBoT™ platform. With input from CEEN professors and feedback from educational field tests, CEENBoT, INC. took the original student-developed platform and developed a more cost-effective, robust, energy efficient platform, while maintaining the platform's prominent features listed above. The updated CEENBoT™ Version 2.2 included improved power management, longer battery life, and a streamlined microcontroller board. The new board contained a single primary ATmega324P microcontroller and a secondary ATtiny48 microcontroller, to replace three ATmega48 microcontrollers that contained limited programming space. This change increased user access to program the robot in C to achieve autonomous control applications. Other new features included a 128 x 32 programmable graphical LCD display, 5 servo motor control ports, I/O expandability for additional sensors, a programmable speaker, 3 programmable LEDs, and 3 programmable control switches. CEENBoT ™ Version 2.2 was completed in November 2009 and introduced to the Introduction to Robotics course as a Beta release. Photos and a schematic of Version 2.2 are shown below:





Course Content

The fall 2009 offering of Introduction to Robotics was an elective, special-topics course, designed to expose students to two distinct areas of robotics. The course consisted of two modules. The first half of the course was devoted to introducing fixed base industrial robotics, including forward and inverse kinematics. The second half of the course was devoted to introducing autonomous mobile robotics and included hands-on projects with the CEENBoT™ mobile robotics platform. This section of the course focused on the following outcomes:

Mobile Robotics Course Outcomes

(A subset of the Introduction to Robotics Course Outcomes)

1. Describe the major components of an autonomous mobile robot, determine the degrees of freedom of a mobile robot, and understand basic DC, servo, and stepper motor operation.
2. Distinguish between active and passive sensors, and demonstrate an understanding of how light sensors, sonar, lasers and cameras operate, as well as how to integrate, program and practically use a variety of sensors in a robot control sequence.
3. Program a mobile robot microprocessor-based platform in C to execute a variety of programming and autonomous robot control objectives.
4. Understand the difference between closed loop and open loop control and the various types of feedback control, including proportional, integral, and derivative, and the applications of these in the control programming of an autonomous robot.

The assessment study focused on the second half of this course, and in particular, the impact of student experiences with the CEENBoT™ mobile robotics platform.

Project-based experiences with the CEENBoT™ mobile robotics platform were organized into four individual student lab assignments. Each student received a CEENBoT™ platform, battery charger, in-circuit programmer, and a CEENBoT™ operation manual containing schematics and example C code. The lab assignments were completed as individual student assignments during the last 6 weeks of the 15 week semester course.

The labs began with an introduction to controlling the CEENBoT™'s stepper motors to achieve basic movement, and built upon this by integrating and controlling active sensors. The lab objectives required using bit-level C programming techniques and communication between microcontrollers to achieve robot control objectives using the integrated sensors. The labs culminated with an assignment that required students to apply the skills and sensors controlled in previous labs to achieve autonomous wall following with feedback control. The four labs required students to apply theoretical knowledge not covered in other classes (e.g. motors, sensor integration, active sensor control, and feedback control). Their hands-on interaction and trouble-shooting with the physical aspects of the platform exposed them to additional skills. Details of the four labs are listed below:

> Lab 1: Dead Reckoning.
>
> Objective: Gain familiarity with programming the CEENBoT™ and explore robot locomotion using odometry alone. Students examine the problems with raw odometry for pose estimation and how it impacts the ability to program the robot to move autonomously along a predefined path. Students learn how to control the stepper motors using the provided C base code. Due: Week 1
>
> Lab 2: Obstacle Avoidance with Infrared Sensors.
>
> Objective: Incorporate external sensor data to guide CEENBoT™ locomotion. Students program the CEENBoT™'s microprocessor to use sensory input provided by the onboard infrared (IR) proximity sensors mounted on the front of the CEENBoT™ to avoid detected obstacles. They gain experience using the Serial Peripheral Interface (SPI) bus to communicate between onboard microcontrollers in order to access and control IR sensor inputs and outputs. Due: Week 2
>
> Lab 3: Obstacle Avoidance with Ultrasonic Sensing.
>
> Objective: Incorporate an ultrasonic range sensor, and use its signal output into an obstacle avoidance routine for the CEENBoT™. In this lab, an ultrasonic range sensor is added and mounted on a standard servo motor on the front of the robot so that the sensor

can be moved in a 180 degree arc for sensing obstacles. Students learn to trigger the sonar sensor and calculate distances from its returned readings, and use these readings to avoid obstacles. This exercise also provides a direct comparison of ultrasonic sensing operation and tradeoffs with IR sensing. Due: Week 4

Lab 4: Wall Following with Feedback Control.

Objective: Implement a wall-following routine for the CEENBoT™ using the ultrasonic sensor, and incorporate Proportional and Derivative feedback to improve wall-following performance. Students learn to control a servo motor to face toward the wall that will be followed, to the right or left side of the robot. As an optional part of this lab they experiment with using the front IR sensors for obstacle detection during wall following, or the ultrasonic sensor controlled by the servo to maintain a desired distance from the wall along the left or right side of the robot, and to detect obstacles in front of the robot. In the latter case, the servo is moved continuously. Due: Week 6

Assessment Objectives and Tools

The assessment study implemented tools to assess if specific skills, capabilities and self-efficacies were enhanced in the students having hands-on control and programming experiences with the CEENBoT™ platform as part of the Introduction to Robotics course as compared to the subset of students enrolled in Senior Thesis proposal who are not enrolled in the robotics course. The tools implemented included a pre and post student survey, attached in the appendix, and a focus group session. The pre-survey was administered to the Introduction to Robotics course students within the first week the CEENBoT™ was introduced in the class. The post-survey was administered to the Senior Thesis Proposal class, which included all graduating seniors in the CEEN program, and 7 of the 9 students enrolled in Introduction to Robotics. The focus group consisted of a group interview of the Introduction to Robotics students conducted by Dr. Neal Grandgenett, Professor of Mathematics Education at the University of Nebraska-Omaha (UNO), and Dr. Elliot Ostler, Professor of Education at UNO. The course instructor was not present during the focus group session. It was conducted with 2 weeks remaining in the course.

Analysis of Assessment Data

The pre and post survey results revealed an increase in the students' perceived technical abilities and measures of self-efficacy in the overall group of seniors at the end of the semester (questions 11 – 14) compared to the subset of Introduction to Robotics students surveyed earlier in the semester, prior to CEENBoT™ exposure. However, additional studies are needed to differentiate the specific cause and effect of this result. The results in questions 15 and 22 show only a slight correlation for motivation for a senior project idea in robotics or control as a result of the taking the course. One student indicated that a robotics course would be better placed earlier in the sequence so they would have time to consider a robotics-based senior capstone design project. Thus, the robotics exercises perhaps occurred too late in their 4-year sequence to show a sizable impact here.

Percentage Yes or Agree/Strongly Agree		
Statement	Pre (7 students)	Post (27 students)
11. How would you rate your confidence to program an autonomous robot?	42.80%	55.50%
12. How would you rate your confidence to diagnose a problem with a programmable electronics or computer device?	57.10%	85.18%
13. How would you rate your confidence to trouble-shoot a programmable electronics or computer device?	57.10%	85.18%
14. How would you rate your confidence to resolve and repair a diagnosed problem with programmable electronics or computer device?	71.40%	85.18%
15. My enrollment in Intro to Robotics has positively influenced my definition of a senior thesis project.	42.80%	16.70%
22. Are you considering a robotics project for your senior thesis project?	57.14%	19.21%

Additional studies will be needed to determine the specific skills that are impacted in students who have experiences with the robotics platform that transfer to their successful execution of the Senior Capstone project. The instrument would need to be redesigned to study these elements including formulation of the project plan, self-directed learning, and tools to achieve the project plan, as well as technical integration and trouble-shooting skills. Outside of the survey data, the focus group provided important new insights.

Comments from the focus group observation summary prepared by Dr. Grandgenett revealed the pros of using the CEENBoT™ voiced by students. Their comments included the following:

The CEENBoT™ is . . .

> “Perhaps the only avenue for the current CEEN student to truly put what they learn into practice;

Easier to get behind a project that is so easy to show students results;

Has the ability to add on more features;

Is an interesting and realistic connection to robotics;

Has the ability to get started quickly at a low level, but can still be taken a long way by more advanced students."

Students recognized that the platform was recently modified for the course, and felt that the newness of the CEENBoT™ made it a challenge for this iteration of the course. Even with these challenges, students felt that "the CEENBoT™ was still a very useful platform for CEEN learning, and was superior in potential use to the TekBot®, and worthy of continued use and refinement for CEEN instruction."

Several students wrote comments in the feedback section of the last lab report indicating their enjoyment of the lab experience. One wrote "I had a great time with all the labs." Another wrote "designing (and) watching the improvements with each iteration and finally having everything come together made the hours of effort worth it in the end." Another student commented "after doing this lab, I kind of wish there were a few more weeks of class so that we could do more complicated labs like this one."

Student feedback from the focus group session provided many constructive insights for the further integration of the CEENBoT™. These included suggestions for instructional refinements for this course and suggestions to achieve a cohesive integration of the platform into other courses. Students suggested the need for a dedicated laboratory structure for this class, the need to expand upon and refine laboratory instruction, the need to achieve a steady-state in platform development, and the need to separate the course into two separate courses to allow for a dedicated course in mobile robotics. They also recommended that the integration of the CEENBoT™ into the 4-year CEEN sequence continue to be developed and coordinated between instructors.

Programming exercises with the CEENBoT™ required the electronics engineering majors to "catch up on some of the coding and addressing aspects" they had not had to perform in several semesters. This supports the continued integration of the platform into earlier classes in a continuum so that all students' skills are maintained with the platform from year to year.

Students felt that they were motivated to do more with robotics because of the course, and the CEENBoT™ was an appropriate platform to instill motivation in the students. They felt that as the class evolves the platform would be a good context for more advanced team-oriented work.

Finally, students praised the use of the focus group format and "appreciated that the instructor cared enough about the learning process to organize and receive this sort of candid input" and they recommended this process be used in other courses to benefit from this type of feedback which they viewed as superior to course evaluations. The course instructor was grateful for the expertise provided by the UNO College of Education professors who conducted the focus group experience, providing a rich source of student feedback.

Summary and Next Steps

This assessment study provided important data from student feedback that will be applied to further refinements of assessment tools of student learning, and ultimately to an informed and effective integration of the CEENBoT™ robotics learning platform into the Introduction to Robotics course and other courses in the 4-year ECE sequence at the University of Nebraska-Lincoln Department of Computer and Electronics Engineering.

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Robotics in CEEN Survey

A Survey of Student Views of Robotics Development Efforts
Date Developed: October, 2009 Date Administered: ____________

Purpose: This survey is designed to examine CEEN student responses to questions about robotics program innovations introduced as part of efforts to improve undergraduate motivation and professional commitment. Please respond as accurately as possible. Your responses will remain anonymous but we ask for your name in order to track your responses along with your academic record of success in CEEN (Computer and Electronics Engineering) at PKI (Peter Kiewit Institute). This feedback will help the department study and improve student experiences within the Computer and Electronics Engineering Program. Thank-you for your very important assistance and input.

Private and Voluntary Participation: All data collected in this survey will be kept in the strictest confidence. No individual names will be reported in any report and only group information will be described. Individuals have the full right to participate or not participate in the survey as desired.

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Background and Demographics

Please respond to the following items to help us summarize general background and demographics information for students responding to this survey. All information will be kept confidential. Thank you!

Name: ____

Last four digits of your student ID number __________

1. What is your major? Computer Engineering ____ Electronics Engineering ____ Other ____

2. What is your expected graduation date? ___________________________

3. University level? (circle one) **4. GPA?** ____

a. Freshman b. Sophomore c. Junior d. Senior

5. Are you currently enrolled in Thesis Proposal? ______________

6. Ethnicity? (circle one)

a. Black b. Hispanic c. Caucasian d. Native American e. Asian f. Other:______________________

7. Approximately how many students were in your high school graduating class? (circle one)

a. Less than 100 b. 100 – 199 c. 200 – 299 d. 300 – 399 e. 400 – 499 f. 500 or more

Please answer these questions on program innovations currently underway in the CEEN programs:

8. The TekBot™/CEENBoT, which will be dispersed throughout the programs, improves the motivation of the students in CEEN.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

9. Did you build a TekBot™/CEENBoT while you were in the program?

Yes No

10. I wish I would have had (or am glad I had) exposure to this robotics platform as a student in the program.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

Please answer the following questions concerning your perceived abilities with robotics *prior* to the current semester.

11. How would you rate your confidence to program an autonomous robot?

Very low	Somewhat low	Neutral	Somewhat high	Very high

12. How would you rate your confidence to diagnose a problem with a programmable electronics or computer device?

Very low	Somewhat low	Neutral	Somewhat high	Very high

13. How would you rate your confidence to trouble-shoot a programmable electronics or computer device?

Very low	Somewhat low	Neutral	Somewhat high	Very high

14. How would you rate your confidence to resolve and repair a diagnosed problem with a programmable electronics or computer device?

Very low	Somewhat low	Neutral	Somewhat high	Very high

Please answer the following questions involving your interest in robotics.

15. My enrollment in Intro to Robotics has positively influenced my definition of a senior thesis project.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

16. My interest in circuits and sensors has encouraged my enrollment in Intro to Robotics.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

17. My interest in gears, motors, and chassis has encouraged my enrollment in Intro to Robotics.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

18. My interest in autonomous and pseudo-intelligent behavior has encouraged my enrollment in Intro to Robotics.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

19. My interest in computer control systems has encouraged my enrollment in Intro to Robotics.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

20. My interest in industrial automation (mechatronics) has encouraged my enrollment in Intro to Robotics.

Strongly Agree = 1 2 3 4 5 = Strongly Disagree

21. Do you intend to do an individual study in CEEN using a robot? Yes No

22. Are you considering a robotics project for your senior thesis project? Yes No

23. Are you considering graduate studies in robotics? Yes No

24. Would an available sequence of CEEN graduate courses in robotics influence your answer to question 23?

Yes No

25. Rate your confidence in your ability to execute your senior thesis project.

Very low	Somewhat low	Neutral	Somewhat high	Very high

Please answer the following open-ended questions. Yes and No answers, while valid, do not provide as much useful information as well considered, constructive responses.

26. Do you expect your continuation in the robotics course with mobile robotics to impact the formation of a senior project plan?

27. Will continuation with mobile robotics affect your senior thesis execution next semester?

28. What, if anything, in performing mobile robotics labs and programming the CEENBoT would impact your level of preparedness for your senior project?

29. What are you *expecting* to gain in performing mobile robotics labs and programming? What would you *like* to gain via these experiences?

30. Describe your current senior project definition and plan.

31. Any other comments, thoughts?