
AC 2012-5002: A TWO-SEMESTER PROJECT-BASED ROBOTICS CURRICULUM

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A TWO-SEMESTER PROJECT-BASED ROBOTICS CURRICULUM

Introduction: Robotics is a set of ideas and technologies that transform civilizations by enabling computers to interact intimately with the physical world, especially in hostile and hazardous environments for humans. Recent technological advances and societal needs have yielded considerable developments in the field of robotics. Since the first fixed robotic manipulator, Unimate, at a General Motors plant in 1961¹, the robotics field has evolved to combine machines interacting with humans and environments in different settings such as autonomous cars^{2,3}, vacuum cleaners⁴, humanoids^{5,6,7} or surgical robots⁸ with an enormous potential for future applications such as flying robots or smart weapon systems. Based on the robotics field estimated growth rate of up to 13%⁹, comprehensive undergraduate¹⁰ as well as graduate research programs^{11, 12, 13}, remote¹⁴ or virtual¹⁵ educational labs, a number of robotics competitions^{16, 17, 19, 20} including the DARPA Urban Challenge¹⁸, and extensive summer demonstrative^{21, 22, 23} and research camps²⁴ have been developed to increase the robotics understanding and related engineering program enrollment numbers. However, Hispanic serving institutions face a bigger challenge since Hispanics are less likely to earn engineering or engineering technology degrees²⁵. Moreover, the only current USA dominant position in fundamental robotics research¹ can be strengthened via robotics programs that address the shortage of interest and pipeline issues, effectively answering the world challenge on applied and industrial robotics applications. However, a stand-alone robotics program is a formidable challenge for many institutions with limited faculty, space, and funding sources, due to the inherently interdisciplinary nature of robotics field coverage and laboratory hands-on instrumentation requirements. Thus, a concise and collaborative robotics curriculum, tracking a national design competition and offering a mentoring opportunity, can provide significant contributions for a viable solution, with many pedagogical benefits.

Interdisciplinary nature of robotics offers enormous educational opportunities for students. A robotics engineer needs to have a general scientific background and multidisciplinary technical skills in, at least, mechanical and electrical engineering, computer science, physics, and control systems for anticipated open-ended real world problems. Robotics students can benefit from effective learning under project-based and technology-supported enhanced learning environments²⁶, enabling students link the analytical methods in lectures with practical phenomena in laboratories. Building blocks of robotics are studied in a number of different courses while the actual robotics projects are typically covered in Senior Design projects for anticipated benefits. In spite of traditional emphasis on theoretical foundations, simultaneous theoretical coverage and hands-on laboratory implementations for an intense robotics curriculum can be very effective. Moreover, hybrid learning environments including cooperative and competitive learning offer extended benefits to students while students gain cooperative learning skills in their team design and, at the same time, they gain competitive learning skills during their competition. As the cooperative learning techniques improve student accomplishment, enhance satisfaction and self-esteem, and develop plausible race relations and social skills^{27, 28}, the competitive learning approaches enable students to realize that they will be rewarded based on their performance comparisons with other teams.

This paper presents a two-course robotics curriculum design, implementation, and comprehensive evaluations. The robotics curriculum was integrated with a national design

competition and educational mentoring opportunities, was sponsored by National Science Foundation (NSF-0942932), and was developed and offered by Frank H. Dotterweich College of Engineering at Texas A&M University-Kingsville (TAMUK), a minority serving institution. The traditional lecture format was successfully transformed into hands-on design experiences that were extensively supported by corresponding theoretical principles, in a hybrid learning environment for superior educational achievements. The curriculum focuses on simultaneous theoretical knowledge achievement and practical hands-on design experience for the national IEEE Region-5 robotics design competition, providing a successful robotics education model for other comparable institutions. Due to the popularity of robotics for Science, Technology, Engineering, and Mathematics (STEM) related outreach activities, the current curriculum plays a major role in robotics programs in South Texas, both to attract potentially promising students to robotics as well as STEM fields and to track a nationwide hands-on design competition.

Two-Course Robotics Curriculum: Inherently interdisciplinary robotics field involves fundamental theoretical and practical knowledge in, at least, mathematics, electrical and mechanical engineering, and computer science, both in classroom and laboratory environments.

The two-course, Robotics-I and Robotics-II, curriculum was developed by three Electrical Engineering and Computer Science (EECS) and one Mechanical and Industrial (MEIE) Engineering faculty members. Both Robotics courses involved project-based hands-on design as well as implementation by student teams, and included a 3-hour lecture and, at least, a 2-hour laboratory session per week during the long semesters. The lectures focused on theoretical and practical robotics knowledge while the laboratory sessions focused on hands-on exercises on lecture materials and project-related activities, i.e., effectively complemented the lecture materials while providing additional time for robot designs. The laboratory also provided a number of assembly tools and equipments for robot development as well as construction activities and two lab assistants with knowledge on robotics for immediate assistance. Furthermore, the four project faculty members were always available for student questions, discussions, and laboratory demonstrations. All team design aspects were considered to be laboratory projects prior to assembling the robot platform such as the theoretical coverage of the Pulse-Width-Modulation (PWM) concept for servo-motor systems in the classroom required a team laboratory activity about the same concept by using the commercial components, i.e., the laboratory activity both enforced the component practical operation principles and ensured timely robot project design for the regional competition. The robotics curriculum included mandatory weekly team presentations to four project faculty members, ensuring timely progress on robot design and laboratory activities, prompt feedback and assistance to teams, and individual student contribution in each team.

The two-course, laboratory-based and project-driven robotics program was first implemented during the 2010-2011 academic year. The curriculum exposed robotics to senior-level undergraduate students by tracking the IEEE Region-5 annual design competition and enhanced student educational learning experiences by offering creative thinking, teamwork, time management, communication as well as system design challenges, by establishing a robotics club and by implementing a high school mentorship program. Both courses were electives and were developed with lecture presentations that greatly supported the laboratory projects, i.e., the class students took their respective discipline-specific senior-level required courses, in addition to the

robotics courses. A number of students took both robotics courses to fulfill their capstone design requirements and transferred the course credits for their graduation degree plan engineering design requirements to comply with the ABET accreditation condition. The robotics curriculum was initially offered as developmental courses but was also proposed to the university curriculum committee for permanent course opportunities under the robotics name in the future semesters.

The robotics curriculum students were asked to establish a campus-wide robotics club. The students organized the related paperwork and logistical efforts, resulting in an official “Robotics” club at TAMUK during the Fall-2010 semester. The robotics club was led by the course students and was open to all interested students. The club members held a number of planning meetings during the semesters, participated in several college-wide events such as engineering open-houses, designed a robotics club T-shirt, and coordinated the “Outreach Day” logistical events. Moreover, the club members established a website to present all robotics related materials for a broader exposure to all interested parties in timely manner.

Robotics-I: The first course of the robotics curriculum was a prerequisite for the second course and was offered during the Fall-2010 semester by two faculty members from EECS and one faculty member from MEIE departments for a total of 22 undergraduate students, most of whom were Hispanics from EECS and MEIE departments. Diverse teams of 3-5 students were formed by utilizing academic discipline, gender, ethnicity, grade-point average, different social background and personal skills data. The mandatory course prerequisite was to be at senior-standing with proper background, i.e., the course was open to students who studied subjects such as calculus, basic programming languages, basic electric circuits, and computer-aided design concepts to successfully follow the robotics course topics. The course students were asked to take Robotics-II for a successful continuation of the robot development and team unity. The student teams were expected to understand the basic building blocks of a robot, to design a robot with minimum number of off-the-shelf components, and to initiate the robot assembly and associated programming phases. The course learning objectives are:

- i) Students will be able to describe stationary and mobile robot kinematics in mathematical frameworks
- ii) Students will identify and use different types of locomotion
- iii) Students will become familiar with the theoretical and practical aspects of various sensors and actuators
- iv) Students will develop a timeline to design a robot for the regional competition
- v) Students will perform peer-mentoring activities at college and high school levels.

The course introduced the fundamental robotics concepts, given in Table 1, involved a number of software tools such as Matlab, C, and Microsoft Office programs for robot operation, documentation, and reporting purposes. The course content was geared towards the IEEE Region-5 robotics competition specifications that required a fully autonomous, self-contained mobile robot design for energy transfer from different power sources to a consumption site with the goal of shortest operation completion time. Since the IEEE Region-5 contest was about an open-ended robot design for predefined practical problems with a large number of potential robotic platforms, microcontrollers, sensors, control algorithms and robotic operations, the competition provided an excellent and challenging design venue for the course students. Thus,

theoretical concepts such as inverse kinematics were covered in the classroom while the corresponding perspectives for the robot development were extensively discussed both during the classroom and laboratory activities. The students were expected to understand the theoretical concepts to use during the design activities. The course content was supported by two suggested textbooks:

- R. Siegwart, I. Nourbakhsh, Introduction to Autonomous Mobile Robots, MIT Press, 2006.
- L. Sciavicco, B. Siciliano, Modeling and Control of Robot Manipulators, Springer, 2002.

Table 1. Robotics-I course content

Course Module	Contents
Locomotion (1 Week)	Legged Mobile Robots, Wheeled Mobile Robots, Complex Wheels, Tracked Vehicles, Aquatic Vehicles, Flying Vehicles, Space Robots
Robot Kinematics (3 Weeks)	Coordinate Frames, Rotations, Homogeneous Coordinates, Link Coordinates, The Direct Kinematics Problem, The Inverse Kinematics solution
Mobile Robot Kinematics (3 Weeks)	Kinematic Models and Constraints, Mobile Robot Maneuverability, Mobile Robot Workspace
Actuators (3 Weeks)	DC Motors, Gearing and Efficiency, RC Servo Motors, Stepping motors, Motor Control and Microprocessor implementations
Sensing-I (3 Weeks)	Non-visual Sensors and Algorithms, Contact Sensors, Bumpers, Internal Sensors, Infrared Sensors, Sonar, Radar, Laser Range Finders

The course grading policy focused on robot design activities as well as documentations and satisfactory participation in robotics related events. The four-faculty team evaluated all components and the averages determined the final grade of each student. The course grade distribution is:

- Weekly assignments for the project 500 pts.
- Midterm progress report on the project 200 pts.
- Semester-end progress report on the project 200 pts.
- Satisfactory peer mentoring activities at college and high school levels 100 pts.

The course also provided educational support for three ABET outcomes, given as

- (a) apply knowledge of mathematics, science, and engineering
- (c) design a system, component, or process to meet desired needs
- (g) communicate effectively

The lectures also included the competition overview, expected project descriptions as well as anticipated tasks, and required teams to design and construct different parts of the replica of the

IEEE Region-5 competition platform during the first part of the semester. In addition to the theoretical coverage of the course subjects and hands-on design preparations, the teams were further asked to a) develop and submit a project design, timeline and a required component list for the robot assembly based on the 2011 IEEE Region-5 competition guidelines, deadlines and objectives; b) participate in the mentorship program; and, c) to establish an official robotics club. All robot design components were obtained by the project management based on the team proposals. The students enhanced their robotics educational experiences significantly by providing mentorship to a number of middle-high schools teams during the local BEST middle-high school robotics competition.

High School Mentoring and BEST Robotics Competition Participation: The course students utilized the valuable mentoring opportunity prior to the 2011 Coastal Bend BEST robotics design competition that took place at TAMUK campus on October 19, 2011. The students were assigned to all participating 22 middle and high school teams, ranging from Laredo, TX, to Sinton, TX, and Edinburg, TX, i.e., each school received one student mentor from the robotics class, based on student availability as well as willingness and actual distances to assigned schools. The mentors coordinated the mentoring schedule with the middle-high school coaches for maximum team exposures. All mentors were asked to schedule up to 6 meetings with the school teams for reasonable amount of meeting durations, resulting in varying number of meeting times with approximately 1-3 hour meeting durations partially due to middle-high school team preferences. The mentors prepared for the meetings and provided valuable insights about relevant design perspectives and immediate feedback about the school team progress while refreshing their own robotics understanding and concepts. The robotics students were provided reimbursements for their mentoring-related expenses such as commuting costs and stipends proportional to their total mentoring times. The mentor performance was evaluated by middle-high school team coaches in terms of amount of time during the meetings and ranking about the mentors in terms of 'Helpfulness', 'Knowledge/Preparedness', 'Ethics', 'Professionalism' and 'Communication Skills' on a 1-10 scale, with 1 being the worst and 10 being the best mentor performance. The coaches used the ranking scale and entered their comments and justifications for the corresponding evaluations to substitute a common rubric. The mentoring activity was evaluated by middle-high school student surveys and their coach phone interviews. The mentors also went through mandatory background verifications since the mentoring sessions involved minors. Furthermore, the mentors also volunteered during the Coastal Bend BEST robotics competition to further involve with robotics and social environments.

Robotics-II: The second course in the robotics curriculum was offered during the Spring-2011 semester and was covered by three faculty members from the EECS department for a total of 21 undergraduate students from the Robotics-I course. One student withdrew from the course due to an out-of-state internship opportunity. The course students maintained the same teams with the continuation of their robot designs from Robotics-I. The student teams were expected to follow their project schedules, yielding successful robot designs during the field tests. The course learning objectives are:

- Students will utilize coordinate frames, rotations, transformations, link coordinates, direct kinematics and inverse kinematics,
- Students will integrate signals, systems and filtering concepts,

- Students will learn source localization,
- Students will understand the basics of wireless communication,
- Students will use state equations of a robot, classical and intelligent control algorithms,
- Students will manipulate range, proximity, force and torque sensing concepts, and touch sensors,
- Students will perform satisfactory peer mentoring activities at college and high school levels.

The course built upon the previous robotics concepts to introduce advanced topics, given in Table 2, for practical purposes with a focus on the IEEE Region-5 competition and utilized the same software tools including the assembly language for the robot implementation and documentation purposes. Simultaneous lecture and laboratory activities ensured solid theoretical understanding and concurrent implementations during the robot design. The first course suggested textbooks, grading policy and ABET outcomes remained the same for the second robotics course. The four faculty team rigorously evaluated all robot designs as well as implementations, with a focus on robot field testing performances and associated improvements.

Table 2. Robotics-II course content

Course Module	Contents
Sensing-II (3 Weeks)	Satellite-Based Positioning, Data Fusion, Biological Sensing, Visual Sensors, Image Features, Multiple Cameras, Active Vision
Communications (3 Weeks)	Signals and Systems, Kalman Filtering, Robotics Software and Interface Networks
Localization (2 Weeks)	Simple Landmark Measurement, Nongeometric Methods, Correlation-Based Localization, Global Localization, Geometric Maps, Topological Maps
Planning and Navigation (3 Weeks)	Representing Space, Representing the Robot, Path Planning, Obstacle Avoidance, Navigation Architectures
Practical Mobile Robot Tasks (1 Week)	Robotic Assembly and Manufacturing, Intelligent Vehicles, Space Robotics, Bomb and Mine Disposal, Underwater Robotics

Course subject theoretical coverage was complemented by focusing on hands-on design as well as improvements, by reviewing the regional competition application process and guidelines, and by following the expected project descriptions as well as anticipated tasks for the successful project completion and associated documentation. The students were also asked to participate in all robotics activities, the Outreach Day events, and the Senior Design conference on the campus. The five Robotics-II class teams presented their robot designs during the campus-wide ‘Senior Design Conference’, organized by Frank H. Dotterweich College of Engineering at TAMUK, with a large number of participants from different disciplines, ranging from marketing officials

to freshman students. The Outreach Day and IEEE Region-5 competition further extended the impact of the two-course robotics curriculum and greatly elevated the student achievements.

Outreach Day: The outreach day was designed both to demonstrate the robot designs to university as well as local community members with an expectation of higher robotics interest and understanding, and to rank the designs in terms of pre-defined IEEE Region-5 competition guidelines. The outreach day was advertised for both potential on- and off-campus participants and was held on May 3, 2011, at the main lobby of the Frank H. Dotterweich College of Engineering at TAMUK. The event started with a technical presentation by a guest speaker from Southwest Research Institute (SWRI), San Antonio, TX, followed by the robotics competitions with the identical platform and competition procedures, and concurrent robotics T-shirt sale for the attendants. Mr. Roger R. Lopez, the manager of the Autonomous Systems and Controls division of SWRI, emphasized robotics fundamentals, perspectives and professional opportunities to the audience of approximately fifty people. The robots were tested three times on the real platform with the competition guidelines to determine the best robotic design team that qualifies for the IEEE Region-5 competition. Based on the competition scores, the best robot design team included three Electrical and one Mechanical Engineering students while the second best robot design team included three Electrical and two Mechanical Engineering students. The T-shirt sale aimed to attract attendees to robotics and to motivate T-shirt purchases for relevant parties such as children for a long lasting impact, with the final goal of attracting them to robotics and STEM fields. In addition, a local TV station was contacted to cover the event and the coverage including best design student interviews was broadcast to whole South Texas area during the main news program, greatly amplifying the effect of the project on the area population with Hispanic majority. Event participants, except the robotics class students, completed a survey to evaluate the effectiveness of the outreach day activities.

IEEE Region-5 Competition: IEEE Region-5 covers the southwestern USA with the states of Texas, Colorado, Kansas, Missouri, Louisiana, Arkansas and Oklahoma, and parts of New Mexico, Wyoming, South Dakota, Nebraska and Illinois, and coordinates a number of chapters in different locations with different interests such as control systems, robotics or signal processing. The IEEE Region-5 Annual Technical, Professional, and Student Conference gathers large number of participants from academia and industry in different venues such as technical presentations or student design contests. The robotics competition, one of several competitions, assigns an open-ended design problem with very specific guidelines each year in around September-October period and participating schools/teams attempt to achieve the best design criteria prior to the competition in Mid-April of the following year.

The 2011 IEEE Region-5 robotics design competition focused on energy transfer by fully autonomous and self-contained mobile robots to raise a flag, shown in Fig. 1-c, at the destination. The 8'x8' platform, shown in Fig. 1-a, included two fixed energy sources and one source with a-priori unknown location in the lower right quadrant and, at least, 6" away from the wall or the edge of the platform. All three sources were characterized in terms of Thevenin equivalent circuits, with a constant Thevenin voltage of 5 volts and varying Thevenin resistor values, indicating different power generation levels. For example, the location of the energy source with the Thevenin resistance of 120 ohms was fixed and closest to the flag station, but it was also the slowest to provide energy for a mobile energy carrier device such as a power

capacitor. As the robot was free to use any or all of the energy sources from a pre-determined starting point, the competition was about harvesting the most energy with the connectors shown in Fig. 1-b and raising the flag in the shortest amount of time after three rounds of field performances. It was observed that a number of teams optimized the robot design based on the starting location and orientation of their robots.

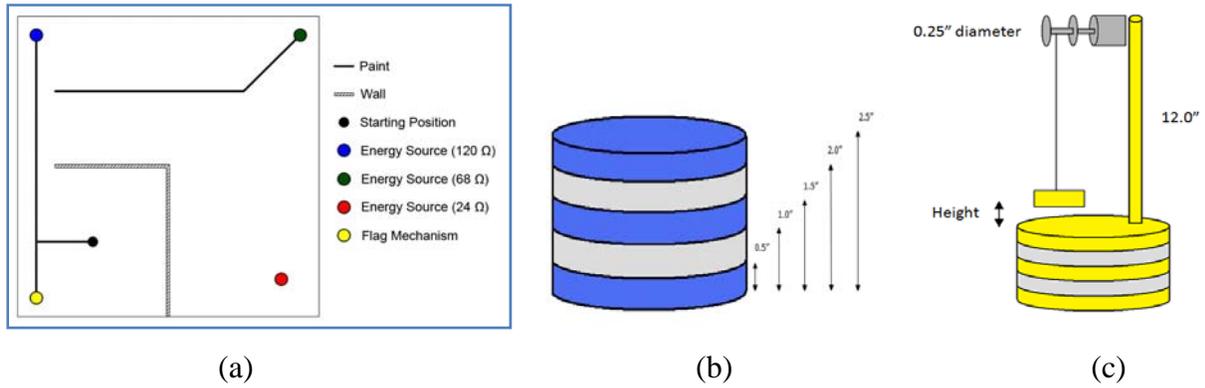


Figure 1. The 2011 IEEE Region-5 robotics competition a) Platform, b) Connections for the robots, energy sources, and the flag station, and c) Flag station

The IEEE Region-5 robotics competition took place on April 19, 2011, in New Orleans, LA, and two best robot designs, shown in Fig. 2, from the robotics curriculum participated. The best robot design team with four students was fully sponsored to attend the competition while the second best team was partially covered for their participation expenses, including registration, travel, lodging, meals, and incidentals. The TAMUK robotics curriculum success during the competition was remarkable such that the best TAMUK robot design performed the required competition tasks in thirty seconds while the overall competition second place robot finished the equivalent tasks in one minute and eight seconds.

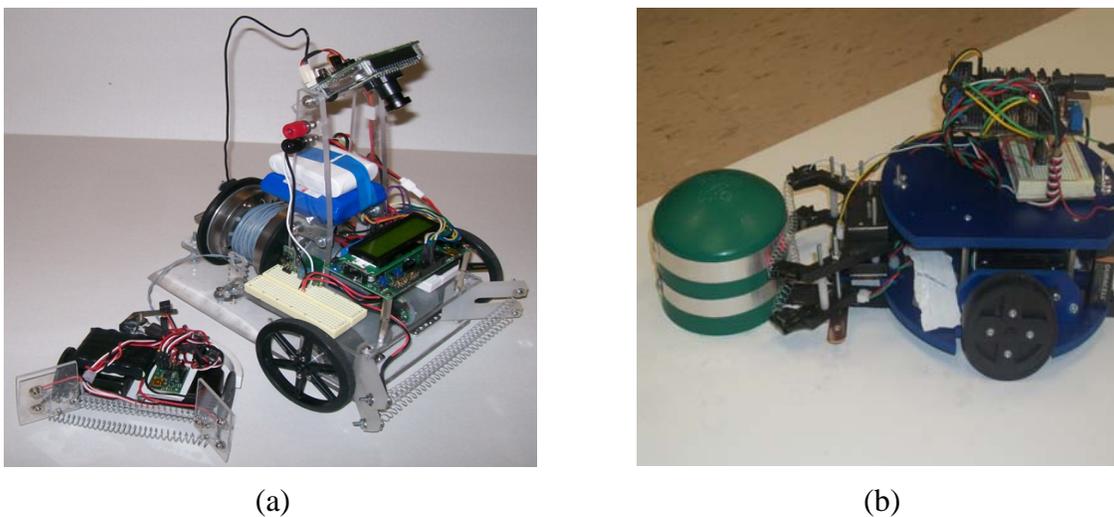


Figure 2. The TAMUK a) Best, and b) Second best robots in the Region-5 competition

Evaluation: The effectiveness of the two-course robotics curriculum has been illustrated by using two class surveys, the high school mentoring survey, and the outreach day survey.

The Robotics-I students followed the class as well as laboratory materials, mentored area middle-high school students, and established a formal robotics club. The Robotics-I survey was completed by 21 course students, twenty of whom were males and thirteen of whom were from Electrical Engineering while the rest from Mechanical Engineering disciplines. With respect to the student demographics, nine students marked ‘Hispanic’, seven students indicated ‘White’, one student selected ‘Hispanic and White’, one student chose ‘Asian’, one student gave ‘Pacific Islander’, one student declared ‘Multi-Ethnic’ while one student did not respond. Based on the survey results, the course was very effective to attract students to robotics field. Majority of the course students (14) described their robotics awareness as ‘Know only a few things about robotics’ before taking the class. The course increased the student interests in robotics and associated careers, as shown in Fig. 3, where there were only 3 students stating ‘Very interested in robotics’ before the course while 10 students stated the same outcome after the course. Moreover, nine students became interested in a robotics career after the course while there was only one student with the same ranking before the course.

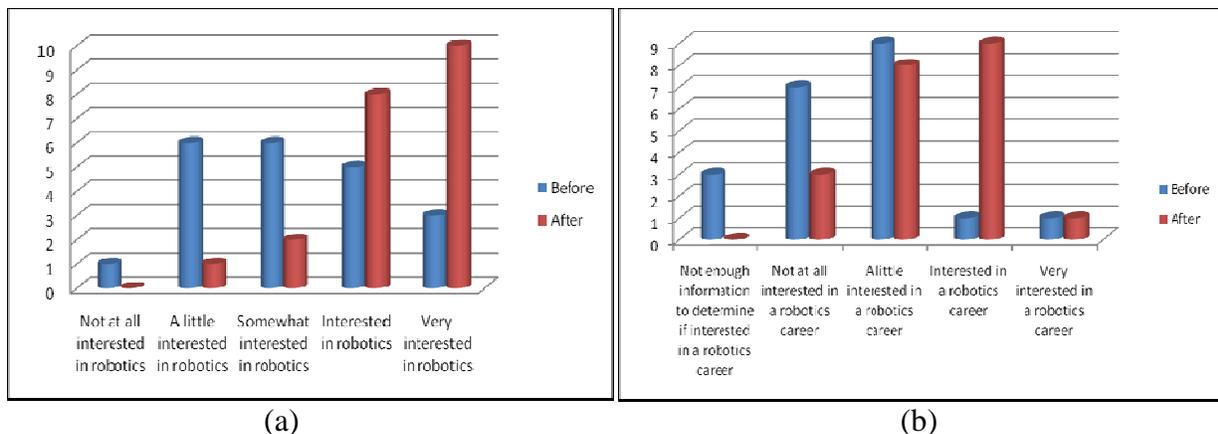
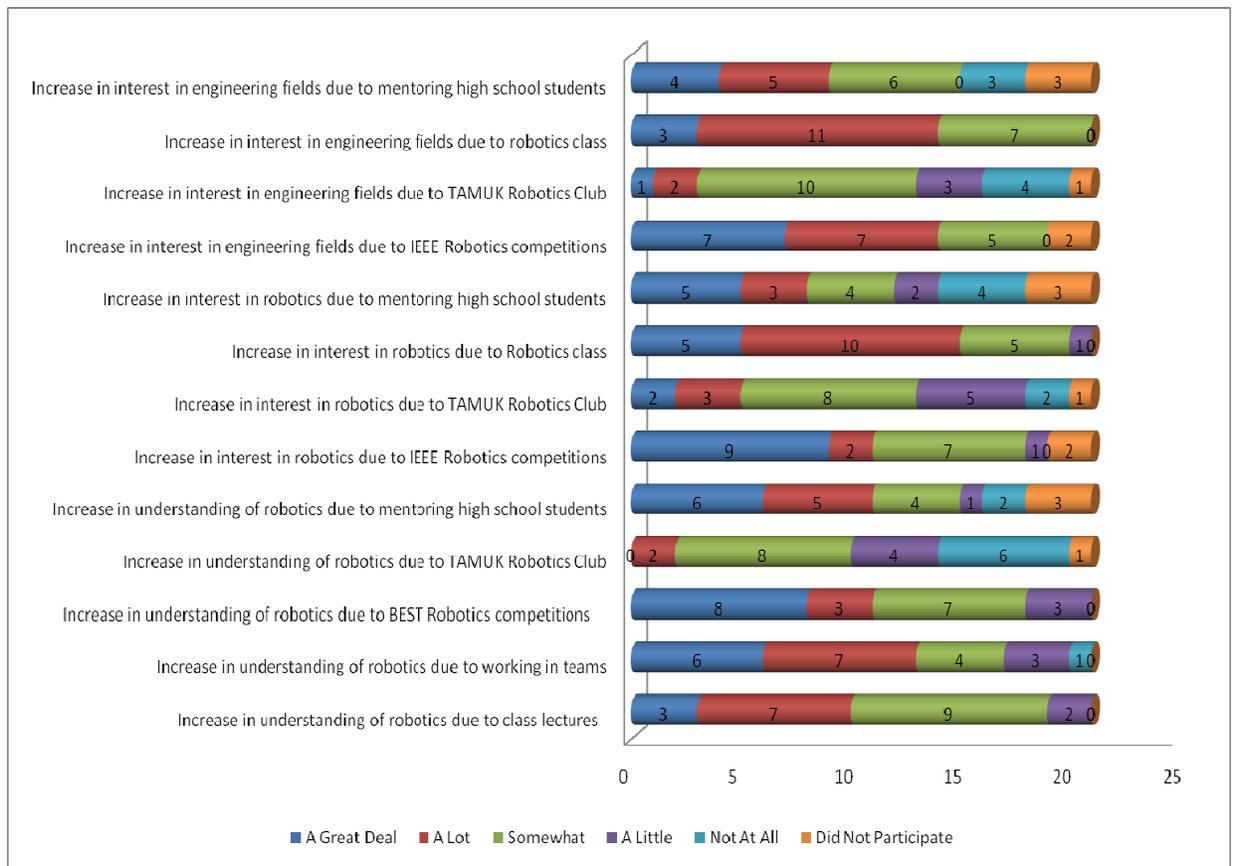


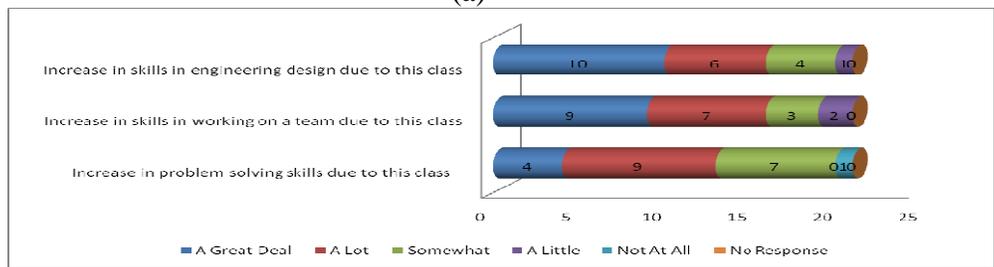
Figure 3. The Robotics-I course student interests in a) Robotics, and b) A career in Robotics before and after this class

The students also rated the Robotics-I activities that increased their robotics understanding and interests, engineering interests as well as their improved skills, as shown in Fig. 4-a-b, where teamwork and engineering design skills, and BEST robotics competition along with middle-high school mentoring greatly benefitted the students. For example, the middle-high school mentoring activity is seen to add to the student understanding of robotics due to a total of 11 out of 21 student ratings of “A great deal” or “A lot”.

The impacts of the Robotics-I course concepts, detailed in Table 1, on the student understanding were also rated, as shown in Fig. 5. The course subjects were effective to convey the robotics concepts to the students due to a majority of ‘A Lot’ or higher ratings for the student comprehension levels.



(a)



(b)

Figure 4. The Robotics-I student a) Robotics understanding and engineering interest increases, and b) Skills improvements

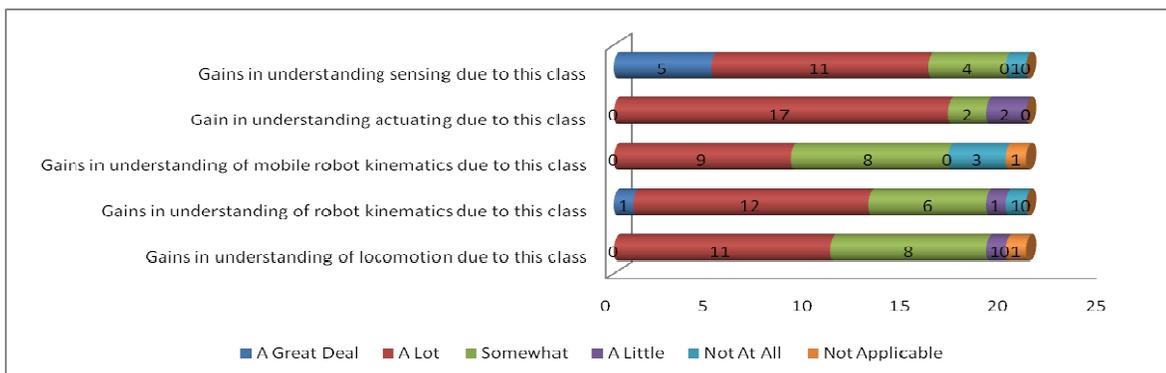


Figure 5. The Robotics-I student gains from the course subjects

The student agreements with the curriculum enhancements were also evaluated, as shown in Fig. 6, indicating the positive effects of the middle-high school mentoring, competition participation, and interdisciplinary approach in engineering design.

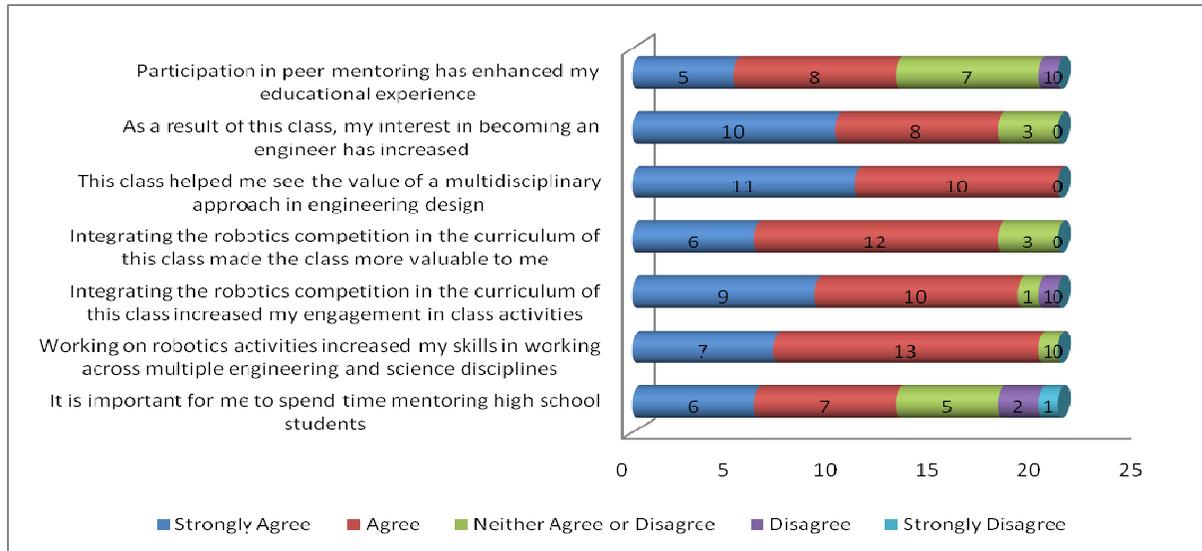


Figure 6. The Robotics-I student agreements on educational enhancements

Open-ended questions and student statements in the survey also yielded valuable results for the Robotics-I course. Main results reveal that the students prefer hands-on laboratory activities with respect to lectures, that a designated meeting times can improve the middle-high school mentoring activity, and that the robotics club can be more active in terms of club activities or regular meetings. The impact of the course was stated as ‘Have grown to really understand what an actual engineering project entails’, ‘The activities involved in this class have greatly increased my interest in Engineering as a career’, ‘Mentoring high school students helped a great deal because it challenged us to not only learn about Robotics but teach it as well’ and ‘My interest has grown and so has my understanding in Robotics’.

The Robotics-II students followed the class as well as laboratory materials, organized and participated during the Outreach day, and two teams participated in the IEEE Region-5 competition. The Robotics-II survey was completed by the same Robotics-I students who further verified the effectiveness of the course to attract students to robotics field. The course enormously increased the student interests in robotics and associated careers, as shown in Fig. 7, e.g., there were only 4 students stating ‘Interested in robotics’ before the course while 11 students developed interests in robotics after the course. Moreover, the robotics career interests increased considerably as 1 and 9 students developed interests before and after the course, respectively.

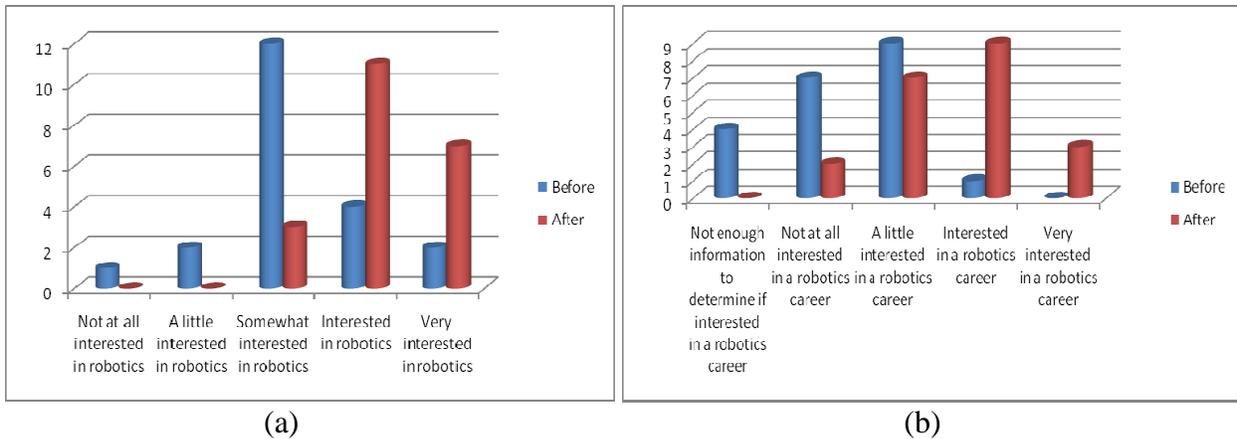
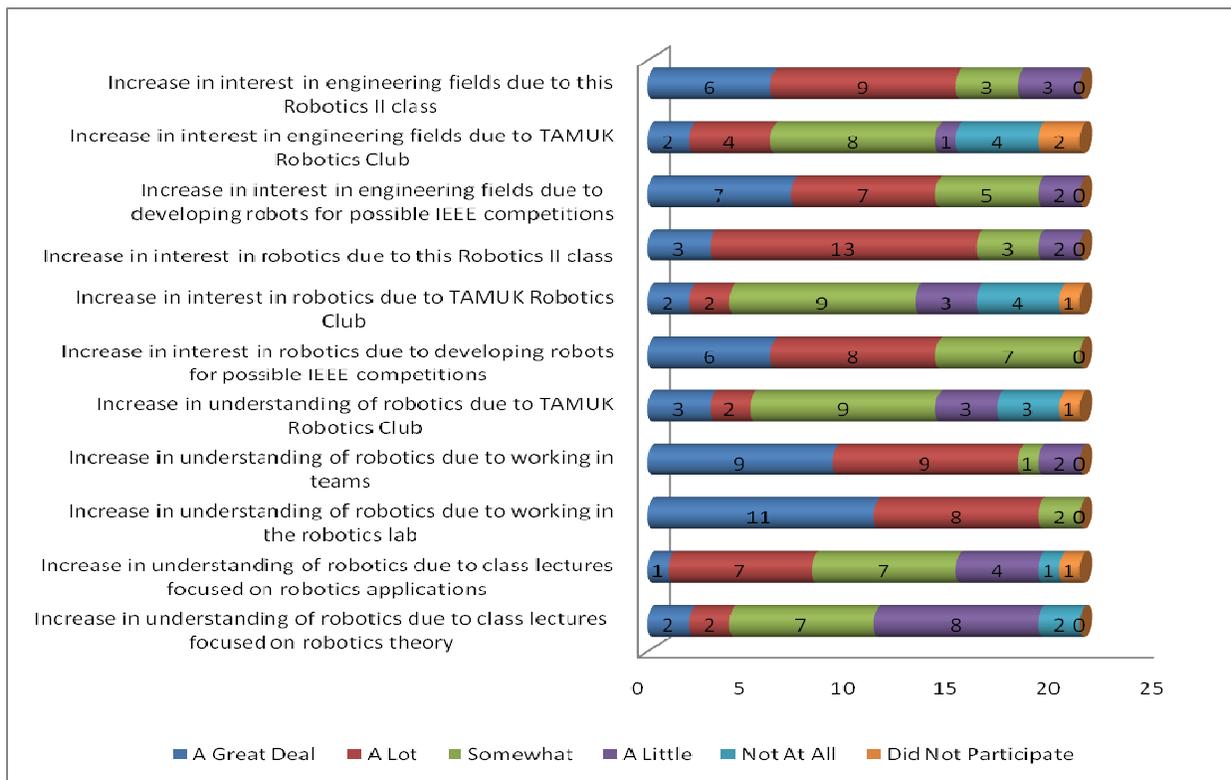
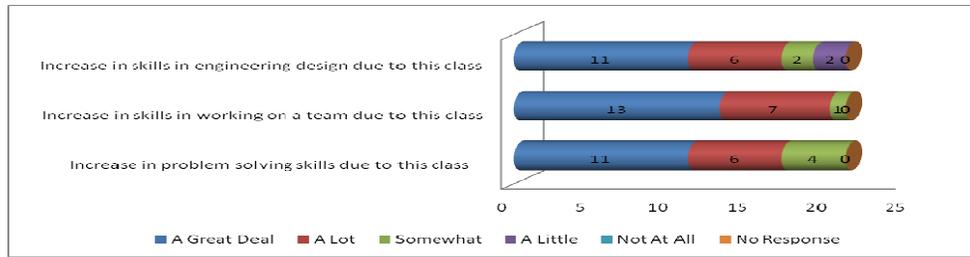


Figure 7. The Robotics-II course student interests in a) Robotics, and b) A career in Robotics before and after this class

The Robotics-II course activities increased the student robotics understanding and interests, engineering interests as well as their improved skills based on the ratings given in Fig. 8-a-b, e.g., working in the robotics laboratory and teams yielded higher student understanding of robotics. The student robotics interests also increased due to the course itself and the IEEE Region-5 competition. Furthermore, the students improved their problem solving, teamwork and engineering design skills considerably.



(a)



(b)

Figure 8. The Robotics-II student a) Robotics understanding and engineering interest increases, and b) Skills improvements

The impacts of the Robotics-II course concepts, detailed in Table 2, on the student understanding were also rated, as shown in Fig. 9. Robotic planning and navigation, sensing and practical mobile robot tasks were the most effective subjects for student conceptual gains. The students also focused heavily into their robot design during the semester, possibly overlooking theoretically complex subjects.

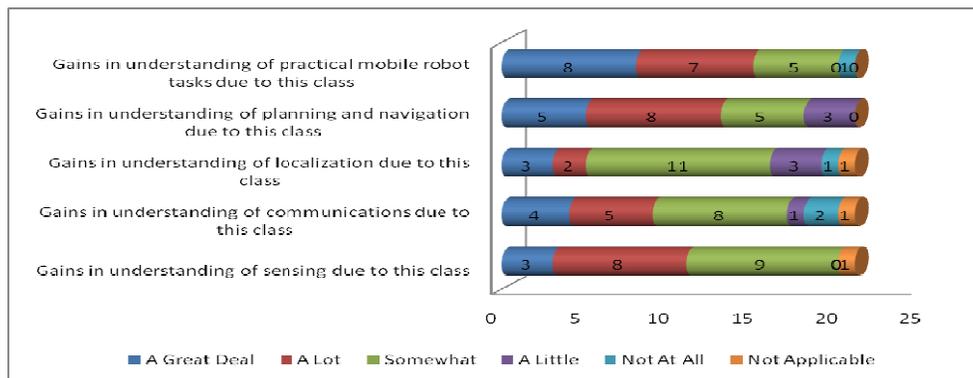


Figure 9. The Robotics-II student gains from the course subjects

The student agreements with the curriculum enhancements were also evaluated, as shown in Fig. 10, indicating the positive effects of the interdisciplinary activities, the IEEE competition, laboratory availability and essential equipments. The results also suggest a significant potential for improvement by closely instructing the laboratory assistants. It should be noted that the class student expectations and proper laboratory assistant roles were discussed during the classes to avoid possible confusions.

The Robotics-II survey open-ended questions and student statements implied a number of results. The announcement of fully sponsored best team participation in the IEEE Region-5 competition was very motivational on students who extensively spent hours in the laboratory for superior robotic operations after successfully designing and building their robots. The students preferred more hands-on engagement against theoretical coverage during the robot design, especially prior to the Outreach day competitions, and extended laboratory availability. The student interests about the hands-on robot activity enormously increased due to the expectation of best robotic operation during the competitions. It should be noted that the laboratory was mainly open during the daytime with an easy key access from the departmental secretaries but the laboratory assistant presence was limited to several sessions. Moreover, the student class

schedules presented a continuing challenge to work in the laboratory for extended number of hours. The Robotics club was expected to have more activities with broader student involvement. The students also suggested that the mentoring activity and high school robotic demonstrations included a great potential for improved outreach efforts of the curriculum. The long-lasting impact of the course was obvious from the student testimonials, including ‘This class has been one of the largest developments to my career as a student. By working with my team I was able to progress and through competitions and professional presentations. I’ve even been offered future employment and am considering continuing on into grad school’, ‘I had no clue how to use a microcontroller to interface with a robot prior to this class. Now, I could comfortably build a robot alone’, ‘Made me strive to achieve excellence’, ‘A great sense of accomplishment once the robot was done’ and ‘The building of the robot was a great and fun experience’.

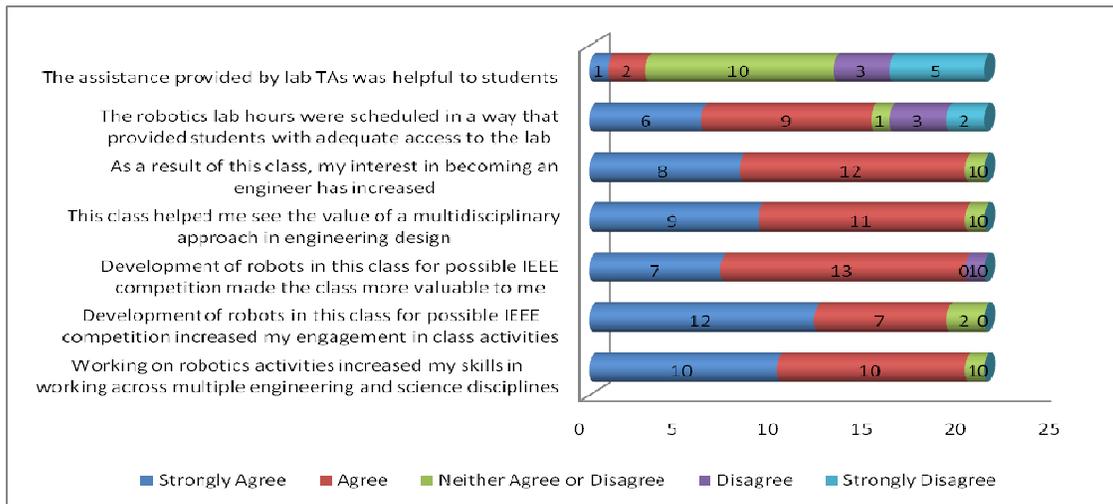


Figure 10. The Robotics-II student agreements on educational enhancements

The middle-high school mentoring activity resulted in remarkable effects on both the robotics curriculum student mentors and middle-high school students. The robotics students were able to refresh their own understanding while performing an advisor role for the middle-high school students who were given engineering design principles to achieve superior designs for their own BEST robotics competition. The robotics students were able to reach out approximately 230 middle-high school students from a number of local schools, with most teams having 10-16 students. The mentoring program efficiency was evaluated by high school coach phone interviews. Based on the results, the mentoring program was very well received and was suggested to continue with possible institutionalization of the program. It was also suggested that the robotics student mentors were trained properly and encouraged to attend the BEST robotics competition, and that the high school coach expectations about the mentors were clarified. The robotics class mentors and middle-high school team meeting schedules presented formidable challenges for the program, partially due to heavily loaded mentors and students with extensive extra-curricular activities at middle-high schools leaving very restrictive time slots for the mentoring meetings. The travel reimbursements and stipends for the discussion times proved to be very effective positive factor to motivate robotics students for more mentoring sessions. The mentor efficiency was also rated by the high school coaches and the associated evaluations were used during the course grade assignments.

The Outreach Day event proved to be effective to attract local people to robotics in an informal setting with the very enjoyable robotic competition activity, along with influential robotics presentation by the experienced professional engineer. The Outreach day was coordinated by the Robotics club members with close supervision by the project faculty members. The event gathered huge number of people, 48 of whom were able to complete the corresponding survey. There were 32 TAMUK students who attended the event while the remaining individuals were from high schools including five middle school students, a high school robotics team coach, student relatives, and other TAMUK officials. It should be noted that the robotics curriculum students did not fill out any Outreach Day survey to fully recognize the impact of the event for on- and off-campus individuals, as outlined in Fig. 11-a-b-c that imply positive effects on event participants with respect to robotics awareness and interest. For example, the Outreach Day proved to be effective since there was 22% increase in the number of students who became interested in taking a robotics class at the host institution after the event.

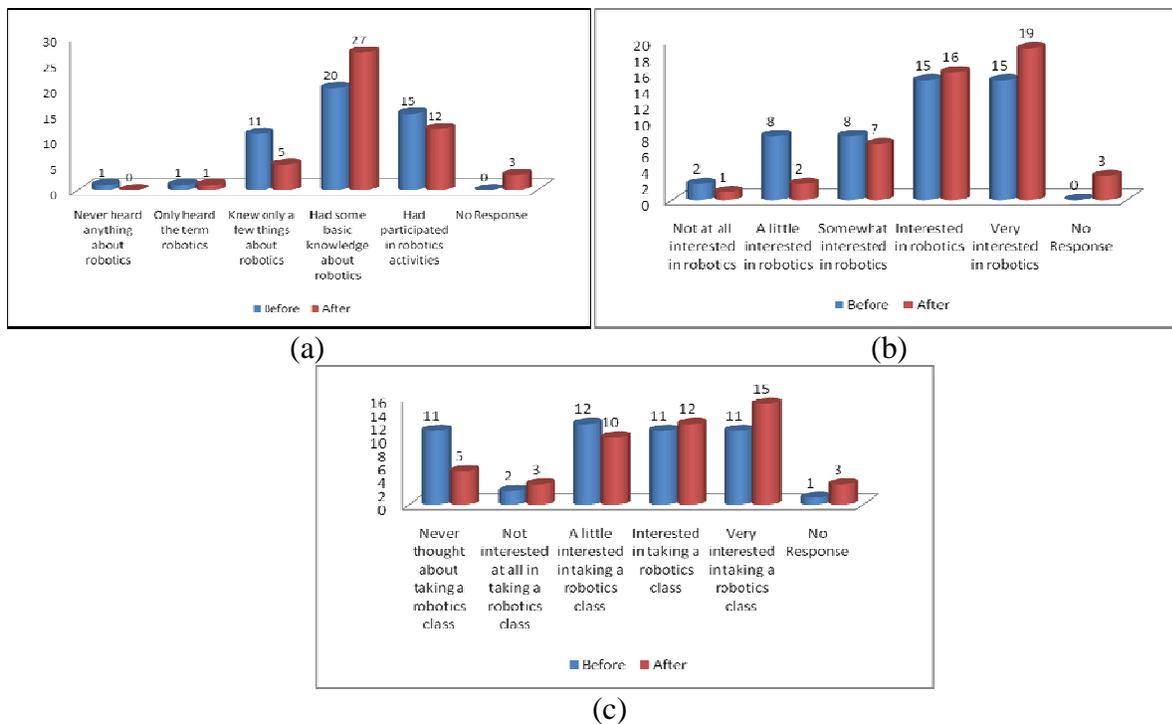


Figure 11. The Outreach Day respondent interest changes in a) Awareness of robotics, b) Interest in robotics, and c) Interest in taking a robotics class at TAMUK before and after this robotics outreach event

Conclusions: The two-course robotics curriculum was successfully developed and implemented at TAMUK. The curriculum included two robotics courses as well as a hands-on laboratory, a high school mentoring activity, an Outreach day, and participation in the IEEE Region-5 robotics design competition. The curriculum evaluation by four surveys illustrated that the project-based robotics curriculum with proper support for hands-on laboratory activities was very effective to stimulate student interests towards robotics. Moreover, the curriculum enhancements proved to increase student educational achievements. It has been observed that a robotics curriculum in creative, competition-driven environments with extensive support can highly improve student accomplishments.

The robotics curriculum is currently being improved by addressing the survey outcomes. Also, the potential procedures for the course student post-graduation follow-up are investigated and planned to be implemented to quantify the long-lasting impact of the robotics curriculum.

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