Humans vs. Robots Workout Challenge

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Abstract

This work addresses an exciting humanoid robots experiment developed by engineering students to raise awareness and knowledge of engineering within a university campus. Three robotic kits, Robotis Premium, from Robotis, Inc. are purchased and three 18 degrees-of-freedom humanoid robots are assembled and programmed to perform various human-like physical workout exercises. In order of difficulty, the exercises include some of the following: squats, sit-ups, fingertip push-ups, and headstands (straight legs and splits). To create a "Humans vs. Robots Workout Challenge" the engineering student team chose the exercises and the number of repetitions for each exercise. Then, they programmed the humanoid robots accordingly. To encourage other students to participate, a number of small thunder-wolf mascot statues are 3D printed as prizes for human winners. Then, the challenge was presented to three groups of students (two engineering student groups and one non-engineering student group). A short questionnaire was developed and administered to the participants of the challenge. For non-engineering students, the results of the questionnaire show that these students were excited to participate in the challenge but they don't have a good grasp of what engineers do.

Introduction

Engineering students often have difficulty explaining their chosen profession to non-engineering students. Their motivation to finish an engineering degree and to fit within their social environment can be enhanced by doing something interesting yet useful for the community. With this in mind, mechatronics engineering students approached the Humans vs. Robots Workout Challenge lab. The main justification for the lab was to use various pedagogical learning instruments such as project-based learning, peer learning, and increased student engagement, all in the function of learning basic robotic concepts and robot programming, as well as developing communication skills. Student engagement was directed towards increasing awareness of engineering in the campus community.

Many educational institutions, both formal and informal, have implemented some type of robotic kits to support science, technology, engineering, and math (STEM) education. The great popularity of these kits (like LEGO NXT/EV3) stems from their affordability and flexibility. However, many students feel overexposed to these products since they used them in high schools or even middle schools. Also, NXT Mindstorms kits are often incapable of performing more complex robotic tasks and they don't look like humans. Thus, in our institution, students' exposure to humanoid robots is investigated as a means to increase student retention through extrinsic motivation. In addition, since the university does not offer a general education course on technology/engineering to increase students' awareness of our current technological society, this role is left to possible technological demonstrations by the Department of Engineering. Departmental labs like the Robotics Lab and the 3D-printing Lab are often used to demonstrate technological advances at a number of community events that take place on campus. However, these are mostly passive, non-engaging demonstrations.

The workout challenge is a physical activity with a robot as a leader. Humanoid robots are often viewed as mechanical people and are assigned human characteristics like intelligence, emotions, behavioral patterns, etc. With the help of the entertainment media humanoid robots are accepted in our society. This acceptance is rooted in humanoid robots' physical similarities with humans, the similarity of their motions with human motions, and the similarity of their actions (programmed behaviors) with those of humans. When a robot performs a human-like action (like bowing or chest pounding) humans quickly accept such a robot as a fellow intelligent being. Through humanoid robot demonstrations, the awareness and appreciation of STEM disciplines can be raised among the campus community.

This work includes sections on previous work, curricular context, short description of the robotic hardware with associated integrated development environment (IDE), the workout program, and the Humans vs. Robots Workout Challenge. Also, the results of a questionnaire are described and analyzed.

Previous Work

According to one of the well documented and widely accepted learning theories, Kolb[1] in his experiential learning cycle theory claims that people learn best if they follow a cycle consisting of four steps (axes): experiencing (concrete experience), watching (reflective observation), thinking/modeling (abstract conceptualization), and applying/doing (active experimentation). This learning theory has been implemented in various engineering education programs such as civil[2-4], mechanical[4], chemical[2,3,5], industrial[6], aeronautical[4], and manufacturing[2,3,7] engineering.

While there was only a single student team that built and programmed the humanoid robots many other engineering and non-engineering students benefited from the workout challenge as observers or participants. This project provides both, active experimentation for robot builders/programmers and reflective observation (for all other students that were not involved in assembling and programming of the humanoid robots).

Reported robotics activities in engineering education have been successful[8–12], but they mostly involve inexpensive small wheeled robots. The cost of humanoid robots and their complexity are often prohibitive factors for their in-class implementation. The NAO humanoid robot system from Aldebaran Robotics used in Zalewski and Gonzalez [13] now costs about $10,000, while the Robotis Bioloids robots used in undergraduate projects reported by Thai, Kuo, and Yen[14] currently cost about $1,200.

The advanced humanoid robots described in this work are assembled from Robotis Premium Bioloid kits featuring CM-530 controllers that were introduced in 2014[15]. The accompanying RoboPlus Robotis software was upgraded in 2015[16].

Curricular Context

The Humans vs. Robots Workout Challenge project described in this work is implemented in a three-credit one-semester Independent Study course with two MS-level engineering students. Both students are enrolled in our Master of Science in Engineering with emphasis on

Mechatronics (MSE-Mechatronics) program. In the program, students take a number of advanced mechatronics courses like Artificial Intelligence, Virtual Reality, Intelligent Robotics, Advanced Controls, etc. They explore other advanced mechatronics topics in the Independent Study course, often as a preparation for MS thesis research. Since the department offers a Bachelor's of Science in Engineering with specialization in Mechatronics (BSE-Mechatronics) degree, many engineering students gained valuable knowledge by observing the performance of the humanoid robots during the workout challenges.

Hardware

Originally, Robotis Premium Bioloid robotic kit was manufactured by Robotis, Co., Inc. in 2007. After a number of upgrades to the motors and the controller, the kit currently consists of 18 Dynamixel AX-12A servo motors, a CM-530 robotic controller, a number of sensors, an infrared (IR) remote controller, a number of mechanical parts (frames, cables, wheels, nuts, bolts, etc.) used in the assembly, and an optional wireless communications module. A more complete description of the hardware is provided elsewhere[16,17]. The three humanoid robots built by engineering students are shown in Figure 1.

Figure 1. Three Robotis Premium Humanoid Robots Built by Engineering Students

Software - Robotis IDE

An integrated development Environment (IDE) RoboPlus software is included with each robotic kit. It is also available for download from the company's website. The software installation of version 2.0 creates four desktop icons (Robo+ Launcher, Robo+ Motion, Robo+ Task, and Robo+ Manager) allowing users to run multiple instances of these programs. Robo+ Launcher is a graphical user interface (GUI) for the other three programs. Software details and idiosyncrasies of this IDE are explained in the Robotis Premium Software Programming Guide[15], and in our concurrent work[17]. In general, the procedure of creating and downloading a program for a humanoid robot consists of the following steps.

1. Assemble one of the three humanoid robot configurations (type A, type B, or type C)

2. Turn on the robot and check that the robot type is correct by pushing the START pushbutton on CM-530. In response, the robot plays a musical sequence: Do for type A, Do-Re for type B, and Do-Re-Mi for type C
3. Connect the robot to the computer using a USB cable
4. Make sure the robot is in the PROGRAM mode by checking that the blue LED indicator on CM-530 above the word PROGRAM is ON. If it is not, use the MODE pushbutton to select the PROGRAM mode
5. If required, download the correct firmware to the CM-530 controller (type A is already downloaded)
6. If there is a need to create new motions that are not in the motion library, run Robo+ Motion program and create new motions
7. Save the motion file as a .mtnx file and download it to the robot
8. Run Robo+ Task to create behavioral algorithms as required by the tasks the robot is to perform
9. Save the task file as a .tskx file and download it to the robot

Figure 2 shows the Robo+ Motion 2.0 GUI. As an example, the movement shown is a pushup. The bottom left corner of Figure 2 indicates that the robot is not connected to the computer while the three boxes above the picture of the robot show that this complicated motion consists of three steps. The complete .mtnx file is not included since it is not readable and the GUI consists of a number of pictorials with robot sequences. While the whole .tskx program file has 946 lines, Figure 3 shows a snippet of the Task code in the Robo+ Task GUI. The snippet shows the start of the main sequence of tasks performed by the robot.

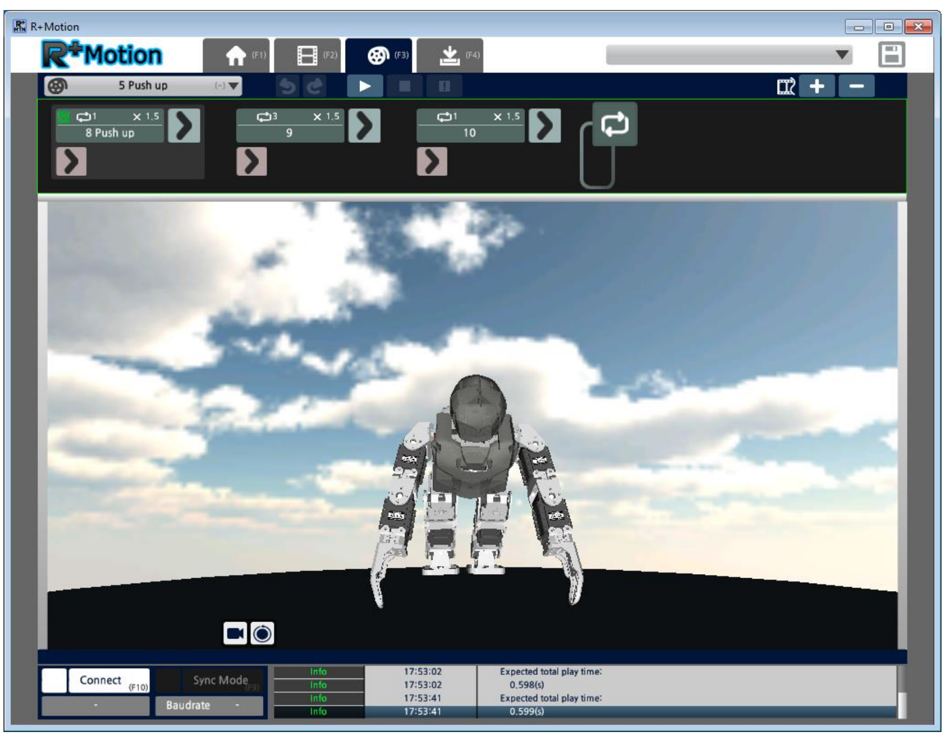

Figure 2. Screenshot of Robo+ Motion 2.0 GUI – Pushup

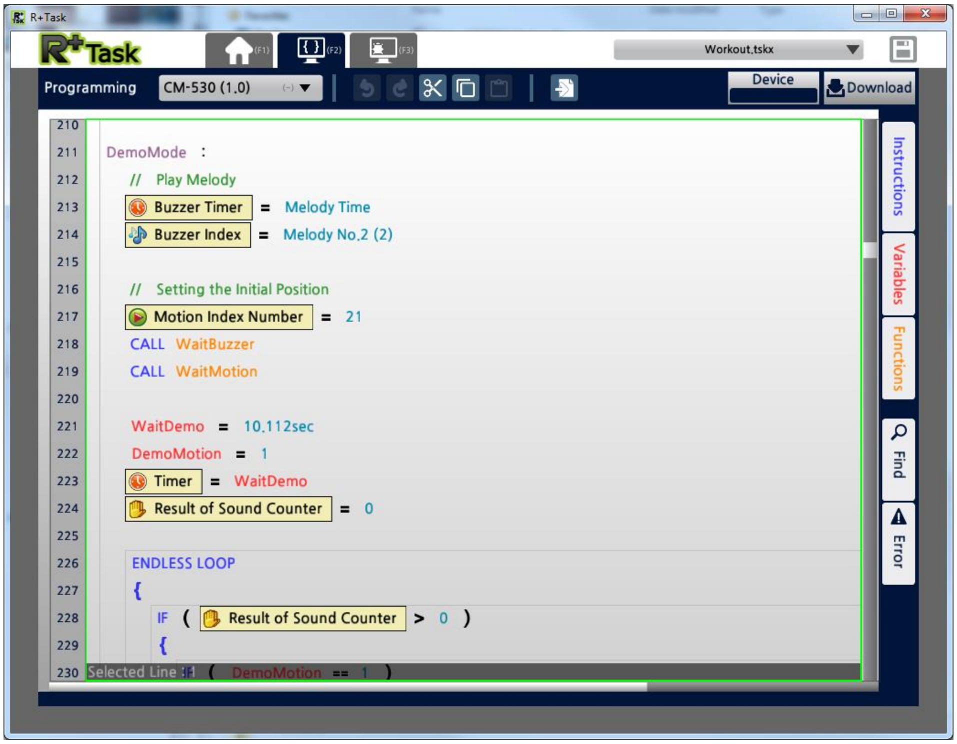

Figure 3. Screenshot of Robo+ Task 2.0 GUI

To run the program

a. change MODE to “play” by pressing the red MODE pushbutton until the red LED indicator above the word PLAY turns ON
b. Press the START pushbutton
c. Press the D pushbutton

Humans vs. Robots Workout Challenge

Two MSE-Mechatronics students built three humanoid robots. They programmed a set of workout exercises for Humans vs. Robots Workout Challenge. The challenge comprised one starting bow, one chest pounding, twenty squats, twenty fingertip pushups, a headstand with feet together, while in the headstand - three leg motions to splits and back, return to standing position, and the final appreciation gesture for the public (arms wide open and a small bow). Each set of motions is separated and starts with a clap of hands. During building and programming of the humanoid robots, the two student-builders/programmers dramatically increased their practical knowledge of humanoid robots, their capabilities, their range of motions, and their limitations.

The workout challenge was presented to ten third-year BSE-Mechatronics students during the lab portion of the Controls II course. Two students tried the challenge. Figure 4 shows students performing fingertip pushups after the robot. However, as depicted in Figure 5, the students could not perform the headstands so they just watched the robot doing them and enjoyed the robot performance.

Another Humans vs. Robots Workout Challenge took place during a faculty supported event, the Semi-Annual Engineering Students Welcome Back Pizza Party. The event included faculty introductions and various professional student club activities and promotions. This year, a number of engineering students observed the robot workout demonstration. Twelve students filled the surveys. Finally, an additional group of students from a different discipline took the Humans vs. robots Workout Challenge. The Department of Exercise Science, Health Promotion, and Recreation offers EXHP 106L Martial Arts and Self Defense course. Seventeen students taking EXHP 106L were exposed to the workout challenge of a humanoid robot. All students observed the robot and about ten of them tried the workout challenge. They all received small thunder-wolf 3D printed figures as prizes. Five students were able to match the robots in performing workout exercises. All 17 students filled out the questionnaire.

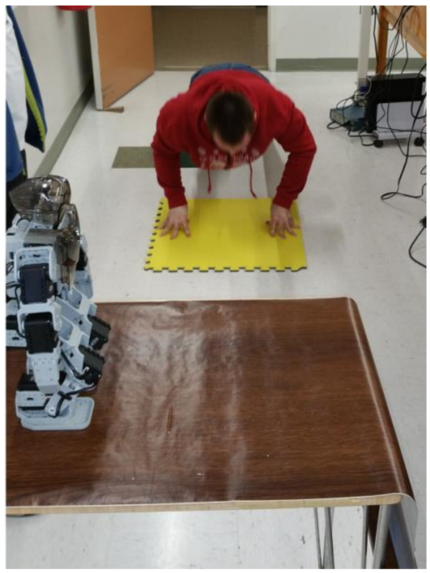

Figure 4. Engineering Student Doing Fingertip Pushups during the Humans vs. Robots Workout Challenge

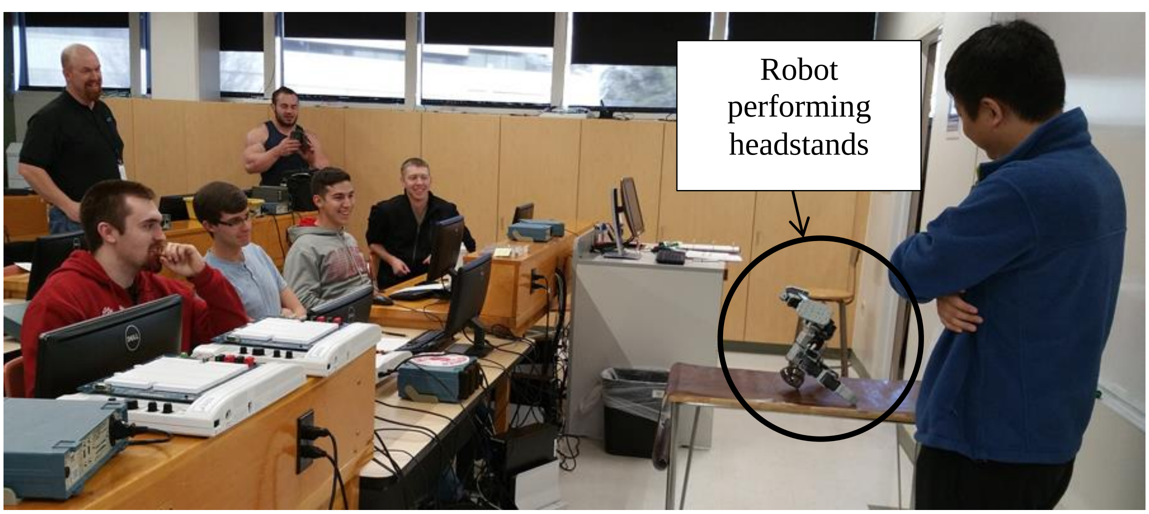

Figure 5. Humanoid Robot Performing Headstands in Lab

Assessment and Evaluation of Student Responses

A survey shown in Figure 6 was developed to assess students' knowledge and appreciation of engineering. The instrument was administered to three groups of students: twelve students participating in the Semi-Annual Welcome Back Pizza Party, ten third-year BSE-Mechatronics students taking Controls II course, and 17 students from various departments taking EXHP 106L Martial Arts and Self-Defense course offered by the Department of Exercise Science, Health Promotion, and Recreation. One can assume that the students from EXHP 106L represent general student population.

The questionnaire consists of three questions rated on the Likert scale from 1 to 5, where 1 means "not at all," and 5 means "very." Also, there are three additional open-ended questions. Surveys were administered immediately after the workout challenges.

Humans vs. Robots Workout Challenge Survey

On the scale 1 – 5 (where 1 means "not at all" and 5 means "very") please rate the following three questions.

1. How exciting was the robotic challenge? 1 2 3 4 5
2. How well do you understand what engineers do? 1 2 3 4 5
3. How interesting is engineering to you? 1 2 3 4 5
4. What could you do with a humanoid robot?
5. What kind of an app dealing with humanoid robots would you like to see?
6. How exactly would you like to communicate with humanoid robots?

Figure 6. Humans vs. Robots Workout Challenge Survey

Figures 7 – 9 show the distribution of student responses for the first three questions. Since the three groups did not have the same number of students, the responses were normalized.

Results shown in Figure 7 suggest that most of the students liked the Humans vs. Robots Workout Challenge. Results in Figure 8 were expected to show a difference between the two engineering groups and the group from general student population. It seems that majority of the university students don't know what engineers do. Again, as expected, Figure 9 shows that the students already in an engineering program like engineering profession, and that the general student population results are just slightly skewed in the positive direction. Even though these results may not be quite correct due to a relatively small sample size, they indicate that there is a room for improvement in understanding engineering in our technology-driven society.

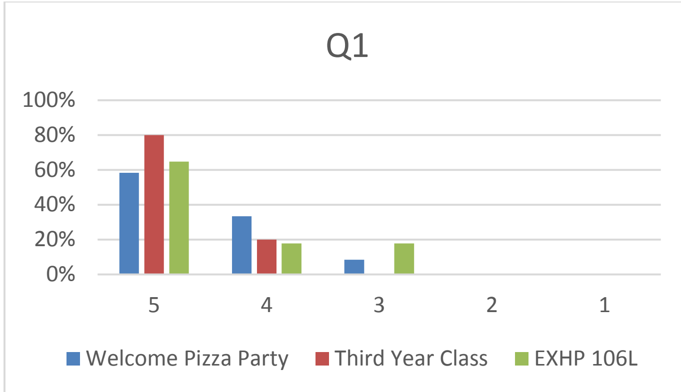

Figure 7. Responses to Question 1: How exciting was the robotic challenge?

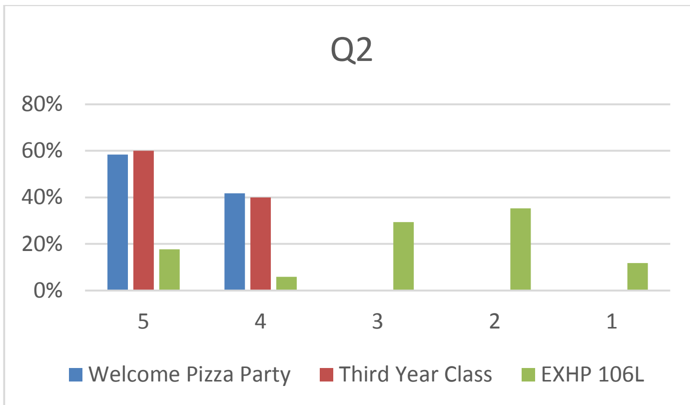

Figure 8. Responses to Question 2: How well do you understand what engineers do?

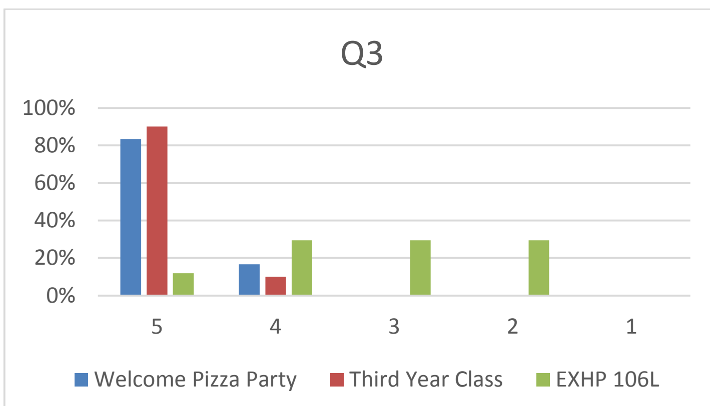

Figure 9. Responses to Question 3: How interesting is engineering to you?

The open-ended questions 4 – 6 were also used in another study dealing with humanoid robots[17]. They were designed to make students think in terms of new humanoid robot applications.

In Question 4, "What could you do with humanoid robots?" it was expected of engineering students to at least mention cooperative robotics – but that didn't occur. Students responses show that they want humanoid robots to do everyday activities, household chores, fight among themselves, work instead of humans, work in hazardous environments, work as security, help with workouts, be pets, impress people with new ideas, “ chase small animals and children,” and “hack the planet.”

Question 5, “What kind of an app dealing with humanoid robots would you like to see?” elicited responses such as “beat Usain Bolt in a foot race,” robot-view cameras, “fruit ninjas app with robots,” “tell us when someone is lying,” Internet of Things (IoT) functionality, “one that gives orders,” accept and understand voice commands, etc.

Responses to Question 6, “How exactly would you like to communicate with humanoid robots?” included vocal commands, natural language understanding of all languages, texting, and visual cues.

An additional set of informal interviews was conducted with the third-year BSE-Mechatronics students enrolled in the Controls II (Discrete Controls) course. These students are already proficient with LabVIEW, Matlab, SIMULINK, and some popular microcontrollers. The interview questions were designed to assess if students gained any new conceptual or system-level knowledge of humanoid robots or robots in general. The questions were:

1. What (if anything) impressed you about humanoid robots?
2. Since all 18 actuators are servo-motors, how hard would it be to program a humanoid robot to walk – from a control’s point of view?
3. Could you use Matlab or LabVIEW to do this?
4. What controlling hardware would you need (number and type of I/Os, motor drivers, etc.)?
5. Without any hardware, could you simulate one of the robot’s behaviors (like chest pounding) using SIMULINK?
6. How difficult would it be to program an industrial robot in comparison to a humanoid robot?”

Judging from the interviews, the students were mostly impressed by robot’s ability to do head-stands, thus surpassing many humans. Then, when trying to answer the second question, the students would quickly realize the sheer complexity of the humanoid robotics tasks. Most of them claimed that it would take some time to program a humanoid robot, but since all the actuators are independent from each other (in control’s sense) it would be possible. They predicted a large amount of testing. The students would use either Matlab of LabVIEW but they were not sure how to model the servo-motors which already have built-in feedback loops. Question 4 was rather specific. It made students think in terms of adequate number of I/Os and their types. All students already used servo-motors with microcontrollers, so this was not much of a stretch for them. However, with the proliferation of inexpensive microcontrollers with large number of I/Os, the students didn’t think in terms of multiplexers/demultiplexers. For Question 5, the students were not sure if they could use SIMULINK for the given robotic task. Finally, they all agreed that programming an industrial robot would be much easier than programming a humanoid robot.

Conclusions

In this paper, a novel robotic experience, Humans vs. Robots Workout Challenge using humanoid robots is described. A group of engineering students assembled three humanoid robots, chose physical workout exercises, created the workout challenge, programmed the robots to perform the exercises, and challenged students to compete against the robots. Robot builders and other students (engineering and non-engineering) gained valuable knowledge of humanoid robotics. While the robot builders learned humanoids hardware and programming, other students learned what can be accomplished with humanoid robots. While watching actual humanoid robots perform workout exercises, the observing/participating students' attitudes towards such robots became more positive. Survey results show that all students liked the workout challenge. Also, the survey results for the non-engineering segment of student population show that these students don't think they know much about engineering profession, and are only mildly interested in engineering. The results of interviews with third-year mechatronics students indicate that they are almost ready to build and program their own robots - but not necessarily humanoid robots.

Bibliography

1. Kolb, D. A., *Experiential Learning: Experience as the Source of Learning and Development*, Prentice Hall, Englewood Cliffs, N.J., 1984.
2. Harb, J. N., Durrant, S. O., and Terry, R. E., "Use of the Kolb Learning Cycle and the 4MAT System in Engineering in Education," *Journal of Engineering Education*, Vol. 82, April 1993, pp. 70-77.
3. Harb, J. N., Terry, R. E., Hurt, P. K., and Williamson, K. J., *Teaching Through the Cycle: Application of Learning Style Theory to Engineering Education at Brigham Young University*, 2nd Edition, Brigham Young University Press, 1995.
4. Ortiz, L. E. and Bachofen, E. M., "An Experience in Teaching Structures in Aeronautical, Mechanical and Civil Engineering, Applying the Experimental Methodology," *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, Session 2526.
5. Abdulwahed, M. and Nagy, Z. K., Applying Kolb's Experiential Learning Cycle for Laboratory Education, *Journal of Engineering Education*, July 2009, pp. 283-294.
6. Wyrick, D. A. and Hilsen, L., "Using Kolb's Cycle to Round out Learning," *Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition*, Montreal, Canada, June 17-19, 2002. Session 2739.
7. Harding, T. S., Lai, H.-Y., Tuttle, B. L., and White, C. V., "Integrating Manufacturing, Design and Teamwork into a Materials and Processes Selection Course," *Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition*, Montreal, Canada, June 17-19, 2002. Session 1526.
8. Pomalaza-Raez, C., Groff, B. H., "An Educational Brief - Retention 101: Where Robots Go … Students Follow," *Journal of Engineering Education*, pp. 85 - 90. January 2003.
9. Self, B. P., Wood, J. J., and Hansen, D., "Teaching undergraduate kinetics using LEGO Mindstorms race car competition," *Proceedings of the 2004 ASEE Annual Conference and Exposition*, Session 3668, 2004.
10. Jaksic, N. and Spencer, D., "Multidisciplinary Robotics Experiment: LEGO Mindstorms NXT Bluetooth Convoy," *International Journal of Modern Engineering*, Vol. 10, No. 1, pp. 5 – 10, Fall/Winter 2009.
11. Spencer, D. E. and Jaksic, N. I., "A Multidisciplinary Robotics Learning Environment: What Mindstorms and DARPA Urban Challenge have in Common," *Computers in Education Journal, Special issue on Novel Approaches to Robotics Education*, Vol. 1/3, pp. 32-40, July – September, 2010.
12. Jaksic, N., "DaNI-K: A Vision-based Robot Control Experiment with a DaNI Robot and Kinect Sensor," *Proceedings of the 2013 ASEE Annual Conference and Exhibition*, Atlanta, GA, June 23-26, 2013.
13. Zalewski, J. and Gonzales F. G., "Creating Research Opportunities with Robotics across the Undergraduate STEM Curricula," *Proceedings of the 2014 ASEE Annual Conference and Exhibition*, Indianapolis, IN, June 15-18, 2014. Paper ID #10496.
14. Thai, C.N., Kuo, Y., and Yen, P., "Experiences in Cross-Teaching within a Distance Education Environment," *ASEE International Forum*, Atlanta GA, June 22, 2013. Paper ID #8247.
15. *Robotis Premium Software Programming Guide: User's Guide*, Revision 2, Robotis Co., Ltd., Republic of Korea, 2015.
16. *Robotis Premium Quick Start*, Revision 1, Robotis Co., Ltd., Republic of Korea, 2014.
17. Jaksic, N., "Dancing Humanoid Robots Lab Demonstration for the First Year Engineering Students," *Proceedings of the 2017* ASEE *Annual Conference and Exhibition*, Columbus, OH, June 25 - 28, 2017.