Experiences in Cross-Teaching within a Distance Education Environment

Dr. Chi N. Thai, University of Georgia

C. N. Thai is an Associate Professor for the College of Engineering at UGA. He teaches courses in Robotics, Machine Vision and Systems Simulation. His main research areas are in Robotics and Spectral Imaging applications for plant health and quality characterization of agricultural products, and also in Human Robot Interactions within Theatrical Environments.

Prof. Yan-Fu Kuo
Dr. Ping-Lang Yen, National Taiwan University

Dr. Ping-Lang Yen was born in 1966. He Received B.S. degree from Dept. of Power Mechanical Engineering, National Tsing-Hua University, M.S. degree from Dept. of Mechanical Engineering, National Taiwan University, and PhD. degree from Dept. of Mechanical Engineering, Imperial College, London in 1998, 1990 and 1996 respectively. He joined Acer Peripheral Incorporation from 1997 to 1999. Currently, he is an associate professor of Department of Bio-Industrial Mechatronics Engineering, National Taiwan University. His research interests are medical robotics, computer-assisted orthopaedic surgery and computer-assisted breast cancer diagnosis.

Experiences in Cross-Teaching within a Distance Education Environment

C. N. Thai[1], Y. Kuo[2] & P. Yen[2]
[1] University of Georgia, College of Engineering, Athens GA 30602-4435
E-mail: *thai@engr.uga.edu* - Web site: *http://www.engr.uga.edu/~mvteachr*
[2] National Taiwan University, Bio-Industrial Mechatronics Engineering Department, Taipei, Taiwan.
E-mail: *ykuo@ntu.edu.tw* - Web site: *http://bime.ntu.edu.tw*

Abstract

A project-based course in Robotics was created to serve as an elective for engineering students at the University of Georgia (UGA) and National Taiwan University (NTU). It was implemented during the Spring and Fall 2012 semesters with a total of 27 students from both universities. It was designed around 4-5 projects with lectures and laboratory demonstrations performed by the instructors (from both sides) to provide necessary background materials for students to carry on successfully with their chosen projects. The major difficulties were the differences in the start date and duration of the respective courses at each university and prevented our attempt to synchronize student progress and interaction. The "technical" issues turned out to be easily solved by each side using similar hardware and software. The instructional materials were shared via classroom capture and webcasting technologies: recordings of live lectures from either university were re-purposed to accommodate the flow and topical differences in the materials taught and frequency of class weekly attendance - twice a week for NTU students and once a week for NTU students. We also had found the necessity to change the instructor-student interaction method as NTU students were less comfortable in interacting directly with the UGA instructor. Student surveys at both universities showed strong enthusiasm for the Project-Based Learning approach. Differences in student motivation and project quality were found between the 2 universities, perhaps as an unplanned consequence of the differences in how each university provided the students access to the robotic hardware and software components.

I) Introduction

At the ASEE Inaugural International Forum in 2012, many authors called for international collaboration in curriculum and laboratory innovations, and also in faculty development[1] citing the need for balancing demands and capacities between the developed and developing countries, and showing that information and instructional technologies had risen to levels that enabled these collaboration opportunities. Even on a local and daily level, there is no doubt that we all live within social networks, even within the microcosm of instructors and students, and the age-old question had always been about which practice, between competition and collaboration, works the best (whatever “best” means) for any individual or group? In his book “Collaborate!”, Sanker[2] discussed and showed that collaboration is “doable and critical to success”. Baker-Doyle[3] described how teachers (especially new ones) can develop their Intentional Professional Networks for support. Research by Stump et al.[4] indicated that collaborative learning strategies helped students increase their self-efficacy in learning course materials. In the area of robotics education, Ren et al.[5] surveyed over twelve syllabi from different universities and suggested a problem/project based approach to foster creativity and insight about robotics in students. Other researchers also concurred in this approach such as Cappelleri[6] , Correll and Rus[7] , and Bishop et al.[8] . Since Spring 2010, the first author[9] had been teaching a project-based robotics course for senior engineering students at the University of Georgia (UGA) based on "Smart Teaching" principles from the book "How Learning Works" by Ambrose et al.[10]. In the Summer 2010, he had the opportunity to visit the Bio-Industrial Mechatronics Engineering Department of National Taiwan University (NTU) whereas a mutual interest in teaching robotics to undergraduates emerged from discussions as a means of collaboration at the instructor and student levels. Considering the current trend of Open Courseware such as Coursera and EdX and various on-line universities such as Udacity, we took some planning steps in Fall 2011 to prepare for an offering of the UGA robotics course in Spring 2012 to both UGA and NTU students in a mixed asynchronous/synchronous environment.

The objective of this manuscript is to describe our approach in designing the course materials and the delivery methods and also to report on the impacts on instructors (in terms of cooperative teaching practices) and students (in terms of materials understanding and application to term projects) for two semesters - Spring and Fall 2012.

II) Materials and Methods

A) Structural Challenges & Approaches Taken

1. The first structural challenge of course was about "timing":
    a. The 13-hour difference in time zones between UGA and NTU.
    b. The weekly scheduling of classes was also different: twice a week for 75 minutes each time at UGA and once a week for 3 hours at NTU.
    c. NTU started 6 weeks after UGA started classes, and UGA had a 15-week semester instruction while NTU had 18 weeks of instruction (and of course with different holidays and semester breaks taken by each campus). For Spring 2012, UGA started on January 9 and ended on April 30, while NTU started on February 20 and ended on June 22.
    d. For Spring 2012 semester, we spent considerable time in designing each campus activities so that by April 2, 2012 student instructions from both sides would be synchronized, because we would like to have interactions between UGA and NTU students for at least 4 weeks. However in practice, this plan imposed lots of strains on the NTU students, thus by week 3 for the NTU students (early March 2012), we knew that we had to treat this course as two independent implementations of the same instructional materials.
2. The second challenge was to find appropriate instructional technologies to perform classroom capture (on the UGA side) and to deliver effectively those class recordings to NTU students asynchronously and on demand. For several years, UGA had been using Camtasia Studio to capture and process classroom recordings and published them via the UGA Course Management System called Blackboard Vista/Wimba for web access by UGA students to review the course materials as needed (see Fig. 1 for a typical video frame). Thus the obvious solution was to enroll the NTU instructors and students into the UGA Vista/Wimba system. In early tests, we found that this approach was technically feasible but the NTU network speed was not fast enough to handle MP4 video streaming satisfactorily in real time (essentially from half way around the Earth). Although NTU

had its own CMS (CEIBA), it could not stream videos on demand during the Spring and Fall 2012 semesters. Thus NTU instructors had to download the classroom recordings (MP4 files) in advance in order to play them on local computers for the NTU class meetings, because the capabilities for stopping and rewinding the classroom recordings turned out to be very important for NTU students as there were still some language barriers as they are not native English speakers.

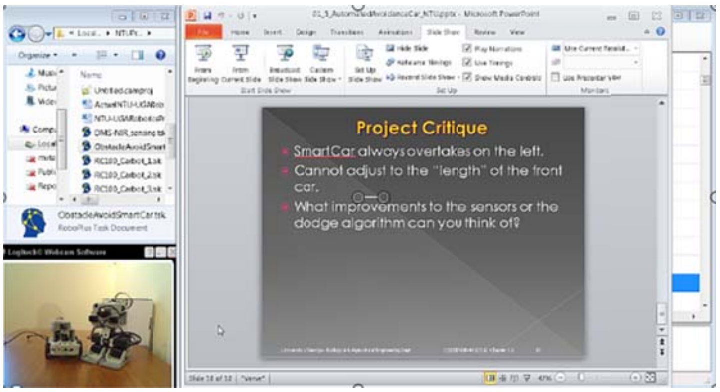

Figure 1. Typical Video Frame in a Classroom Recording.

3. The robotics hardware and software needs were easily solved by using the same Robotis Bioloid systems on both campuses[9].

B) Differentiated Course Materials Design

A project-based approach was taken for both campuses and the same core materials were offered to UGA and NTU students. However, the actual projects undertaken by students on each campus were different to accommodate for the differences in length of the course (15 vs. 18 weeks) and also for the different technical trainings already received by UGA vs. NTU students. UGA students were mostly seniors and already had taken courses on Electrical Circuits and Sensors and Transducers, but they only had formal software training in MatLab and not in C/C++. On the other hand, NTU students were at the sophomore level and had formal training in C/C++ programming, but may not have yet taken courses in Electrical Circuits or Sensors and Transducers. Furthermore, a "contract teaching" approach was used for UGA students to allow them to choose their own challenge levels in the last 2 projects out of a total of 4 projects. For NTU, students were grouped into two's or four's and all took on the same projects throughout the semester. These were some of the "cultural" differences we had to take into account.
For Spring 2012, the UGA students were trained using the following schedule of topics and project grading scheme:

1. Description of the main functional blocks for typical robotic systems and of the Robotis Bioloid systems in particular (hardware & software tools).
2. Using a carbot platform, review embedded controller programming concepts: basic logic structures, internal timer, sensor interface and motor control.
3. Project 1 using car-bot platform and RoboPlus' Manager & Task tools:
    a. Task programming and motor control (endless turn mode). Sensor interfacing (sound & NIR – active/passive) - Reactive Control & Behavior Control.

    b. Wireless (Zig100 device) remote control of car-bot with automatic obstacle avoidance (*15% of course grade*).
4. Project 2 using 2 types of simple bipedal bots (GERWALK or BiPed) and RoboPlus' Manager, Task & Motion tools:
    a. Servo control (position control mode) and Motion Programming.
    b. Bipedal bots negotiating stairs steps while keeping dynamic balance (*15% of course grade*).
5. Project 3 using multiple robots in Master-Slave(s) control mode:
    a. *Option 1* - using 3 car-bots and PC acting as base station develop a Wireless Sensor Network using C/C++ programming on the PC side or LabView and TASK programming on the robots side or,
    b. *Option 2* – using a Quadruped robot with dual controllers:
        i. RS-232 communications programming.
        ii. ZigBee communications programming via Zig2Serial device (1 to 1 and broadcast modes, packet shaping).
        iii. Master & Slave robots (open and closed loop systems).
    c. PC wireless (Zig2Serial device) communications to multiple robots to create a Mobile Wireless Sensor Network (25% of course grade as C/C++ is needed on the PC side) or a Master-Slave Quadruped robot (20% of course grade).
6. Project 4 using Humanoid robots equipped with balance sensors or color video cameras:
    a. *Option 1* - using a Humanoid robot equipped with Foot Pressure Sensors/Heel-Toe Spring Mechanisms or,
    b. *Option 2* – using a Bipedal robot equipped with color video cameras.
    c. Use Humanoid robot platform with 3-D IMU sensor and/or Foot Pressure Sensors to provide 1-leg balance on a platform with varying tilt angles (20% of course grade) or a Bipedal robot with Vision capable of tracking and kicking a ball (25% of course grade).

For Spring 2012, the NTU students were trained using a similar schedule of topics as UGA students for the first 2 projects but Projects 3 & 4 were different (see Figure 2):

1. Project 3 using a carbot and a color video camera to locate and approach a colored ball.
2. Project 4 using a team of 1 carbot and 1 humanoid robot to locate a colored ball and bring it into a goal area. Groups of 4 students each were implemented as this was a very challenging project.
3. Furthermore, the NTU students had 2 additional weeks of training on Embedded C as applied to the CM-510 controller which is based on an Atmel AVR microcontroller using the Eclipse IDE. Students also learned to interface to sensors such as NIR and color video camera, and servo motors using Embedded C.
4. The "contract teaching" approach was not used with NTU students.

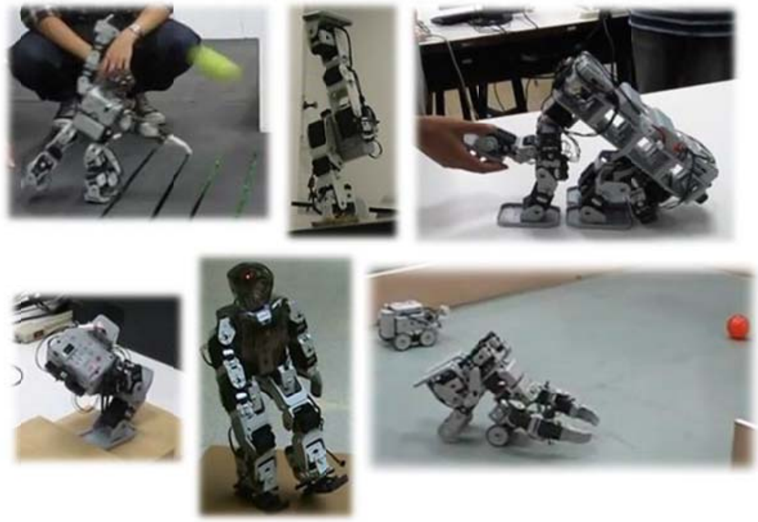

Figure 2. Montage of Selected Student Projects during Spring and Fall 2012.

For more details and video clips of these projects for both UGA and NTU students, please visit this web site *http://www.engr.uga.edu/~mvteachr/RobotVids/*.

In Fall 2012, this course was offered for a 2nd time to NTU students only (as this course is offered twice a year at NTU while it is a Spring-only course at UGA) using slightly revised core materials based on Spring-2012 feedbacks from UGA and NTU students. New materials were added for the following topics:

- Message shaping techniques used for multi-users and multi-robots ZigBee communications.
- More detailed hardware information on position encoders (potentiometer and magnetics based) used in controlling Dynamixel servo motors in their Position Control mode.
- In a personal visit to NTU in December 2012, author Thai also presented materials on hardware not accessible to NTU students such as 3-D Inertial Measuring Units, Foot Pressure Sensors, and the new Robotis CM-900 controller which is Arduino-based and can be interfaced with the Raspberry Pi system.

The total number of assignments also increased to 4 homework assignments and 5 projects:

- Project 1 using SmartCar robots and RoboPlus tools to do wireless (ZigBee) remote control of SmartCar with automatic obstacle avoidance.
- Project 2 using GERWALK robots and RoboPlus tools to do GERWALK negotiating stairs while keeping dynamic balance.
- Project 3 using twin-GERWALK robots and RoboPlus tools to do master and slave robot coordination through wireless (ZigBee) communications.
- Project 4 using Humanoid robots equipped with a Gyro and RoboPlus tools to do ball throwing.
- Project 5 using any robots equipped with a color video camera and RoboPlus tools or embedded C to search for balls and to bring the balls to designated area.

III) Project Assessments & Discussions

A) Course Impacts on Instructors Practice

The greatest benefit for instructors was the use of classroom capture technologies and web-enabled delivery methods, as it allowed each side to learn and earn instructional experiences very quickly (in terms of weeks and not months) and also to contribute to the common knowledge base from our own different strengths and interests.
Although our plans for "synchronous" interactions among students on both campuses failed due to the "timing" issue described previously, we could observe a synergistic improvement in the student projects from semester to semester as students from both campuses were exposed to what the previous student groups were "capable of" as a sort of "friendly competition".
When analyzing the student "bipedal" projects, the first author had found anecdotal evidences that "roboteering" skills may be of a 2-dimensional nature. Figure 3 is a depiction of our "model" showing that "roboteers" would require 2 independent sets of skills that we labeled "Mechanical Empathy" and "Logical-Mathematical" (we borrowed the term/concept "Empathy" from a book titled "Sparks of Genius" written by Robert and Michele Root-Bernstein[11]).

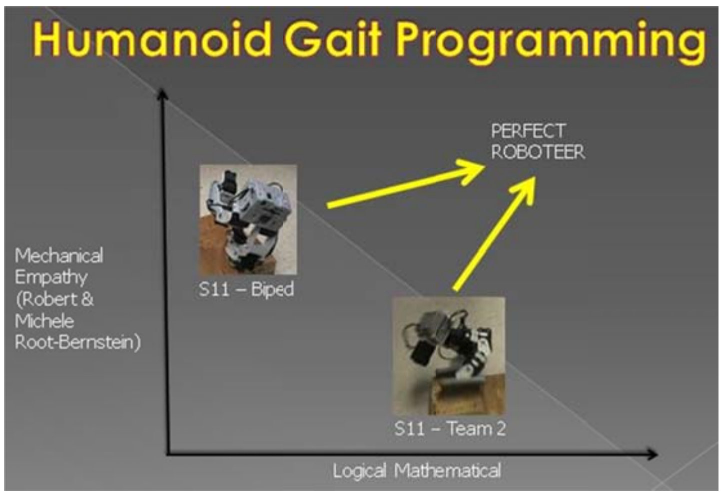

Figure 3. "Roboteering" Model with 2 Independent Skill Sets.

Essentially, we had observed that "logical-mathematical" skills (required for computer programming of robots), and "body-centered" skills (required for programming flowing gait solutions for robots) were 2 independent skill sets and that one set of skills did not necessarily imply the existence of the other for typical engineering students: by this we meant that we had encountered students who were weaker on the logical-mathematical side but created very organic gait solutions (see videos of the stairs walker project on previous web link), while the reverse was also true, strong in logical-mathematical but weak on mechanical insight & gait synthesis. Our current challenge is to design assessment tools that can help us understand better these interactions and subsequently help us design better instructional materials for our students.
Last but not least, we would like to report on a "somewhat expected" cultural difference in the way that NTU students preferred to interact with the UGA instructor. For Spring 2012, the UGA instructor was prepared to host an on-line weekly videoconferencing session (9-10 PM local US time) via Blackboard/Wimba with the NTU students so that they can ask

anything about the course. However we could tell that the students were very reluctant to ask questions during the first session, thus the NTU instructors suggested that we switched to the approach of posting publicly the "self-recorded" student questions onto YouTube, and the UGA instructor would upload his responses via the UGA-CMS as just another Camtasia classroom recording. It was very interesting to note that the students were very much relaxed and let their personalities shine through these "public" YouTube videos while they were much more reserved during the "synchronous" session with the UGA instructor. So the YouTube approach worked, but the Q&A sessions had become "asynchronous" and "on-demand". In Fall 2012, the NTU course was scheduled such that it started at 2 AM local US time, thus we had no choice but to use the YouTube approach for that semester, and most definitely for all future collaborations.

B) Students Learning Assessment based on End-of-Semester Surveys

In Spring 2012, UGA had 3 students taking this robotics course while NTU had 12 students participating. The UGA students responded to a regular "end-of-semester" paper survey, while the NTU students wanted to post video clips to report on their view of the effectiveness of this course, and also to "thank" the UGA instructor (another "cultural" difference to note). The YouTube link for their videos is at
http://www.youtube.com/watch?v=WDIZYDlK_es&list=PL2A08768DB1F6A3E8.
All 3 UGA students reported that all 3 course learning objectives were exceeded (the categories were "Not Met", "Met" and "Exceed"):

1. CLO 1 – Analyze a robotic problem description and conceptualize a solution based on computer systems engineering principles.
2. CLO 2 – Have a good understanding of the functions of embedded robotic controllers and their wired/wireless communication programming.
3. CLO 3 – Interface and control sound/light/vision/acceleration sensors and servo motors to embedded controllers.

Additionally, the UGA survey had 5 general questions and student responses were as follows:

1. What have you liked about the course this semester?
    a. I really liked learning about how to program the bots, and how the motors on the bots functioned. I also liked learning about wireless communication.
    b. The projects and working with different types of robots.
    c. Robots.
2. What aspects of the course have been valuable for your learning this semester?
    a. The projects were very useful, especially the twin gerwalk project. Also, being able to test the code for ourselves as you taught was very useful.
    b. Walking through code and examples in class.
    c. Additional coding experience.
3. What have you done that had helped you learn effectively in this course?
    a. Playing around with the bots & programming was helpful.
    b. Re-watch the videos posted and ask questions when confused.
    c. Trial and error.
4. What had the teacher done that had helped you learn?
    a. Provides example code & asking us to add more complex features was helpful.

b. Posting video lectures and example codes on eLC.
c. Example files were given.

5. What suggestions do you have for improvement?
   a. I think sometimes we could have gone through the code a bit quicker. Other than that it was great.
   b. Spending more time on the twin gerwalk project.
   c. More hands-on lectures.

To measure the effectiveness of instructional materials used in-class and outside-of-class, the UGA survey also asked students to respond to the following 7 questions using a 6-point Likert scale where "StD" meant "Strongly Disagree", "D" meant "Disagree", "SlD" meant slightly disagree, "SlA" meant "Slightly Agree", "A" meant "Agree" and "StA" meant "Strongly Agree":

1. In-class course materials delivery methods were effective.
2. I understood the materials presented during in-class lectures.
3. In-class materials presented via the second display were effective.
4. Recorded classroom lectures were useful.
5. Pre-recorded narrated tutorials were useful.
6. I felt comfortable going through multi-media presentations on eLeaningCommons.
7. I understood the materials presented in recorded lectures and narrated tutorials.
   Student responses are shown below in Table I.

TABLE I. In-class & Outside-of-class materials effectiveness survey results (UGA students).

Question #	"StD"	"D"	"SlD"	"SlA"	"A"	"StA"
1				1	1	1
2					1	2
3					2	1
4				2	1	
5					2	1
6						3
7					1	2

For the Spring 2012 NTU students, this was the first time that they went through a project-based course at their university, thus in the video clips they were very enthusiastic in their support of this approach. After this course, some of these NTU students participated for the first time in a local robotic competition involving wheeled robots and machine vision for navigation through an "office" environment and they came in 2nd place, and they reported that the topics they learned in this class contributed to their achieved performance.
In mid December 2012, the Fall 2012 NTU students were given a slightly modified paper survey but similar to the one given to the UGA students whereas 10 out of 12 students responded. The same 3 Course Learning Objectives were asked of them and the results are shown in Table II.

TABLE II. Course Learning Objectives Achievement as Perceived by NTU students.

CLO #	Not met	Met	Exceed
1	1	8	1
2	2	7	1
3	1	8	1

The NTU survey had also 5 general questions and NTU student responses were as follows:

1. What have you liked about the course this semester?
    a. There's a lot of hands-on project, so we practice a lot in class.
    b. Work of sensor.
    c. We have more chance to play robot.
    d. We can play the robots freely.
    e. The teamwork, the group based teaching, the closeness between instructor and student.
    f. Thinking what kind of robots I will do in projects.
    g. Know many sensors, robots.
    h. Control robot with RC-100.
    i. Programming is fun.
    j. Playing robots is fun.
2. What aspects of the course have been valuable for your learning this semester?
    a. I think it help me a lot to debug in program design.
    b. How to use controller and sensors to control a robot to do what we want it to do.
    c. All we have learned is debug the problem, and we finally found those is robotic problems.
    d. Play the robots ourself.
    e. Because of being able to ask questions freely, it helps with understanding the material immediately.
    f. Application of wireless communication.
    g. Use RC-100 to control.
    h. Wireless communication.
    i. How to solve the problem patiently.
    j. Very useful, but also spend a lot of time.
3. What have you done that had helped you learn effectively in this course?
    a. Discuss the project with classmates.
    b. Watching the lecture video on eLC.
    c. Reading context and doing project have helped me learning it.
    d. Examples.
    e. I checked up online tutorials and datasheets to augment my understanding of the material.
    f. Do with the course video.
    g. C language.
    h. No.
    i. Watch the example code first.
    j. Watch the course videos more than one time.
4. What had the teacher done that had helped you learn? (separately for NTU & UGA instructors)
    a. Explain the method how some gadget work (NTU). Demonstrate on class which makes us more understand the idea of project (UGA).
    b. The TXN & RXN of ZigBee (NTU). The motor's wheel & joint modes (UGA).
    c. To answer our questions and we get knowledges from the answers (NTU & UGA).
    d. Explain deeply and clearly (NTU). Explain the code very clearly (UGA).

    e. Answering my questions in class and helping with projects afterwards (NTU). Q&A sessions were effective, although it's a slow process (UGA).
    f. Help us in class (NTU). Explain the principle of operation in detail (UGA).
    g. Explain with patience (NTU). Give me some advice for studying abroad (UGA).
    h. Explain more clearly in class (NTU). Answer the question (UGA).
    i. As we confused the content in video, he can explained it again (NTU). PPT is awesome and colorful (UGA).
    j. Good interpretation in course (NTU). Very professional on teaching course and answering questions (UGA).
5. What suggestions do you have for improvement?
    a. The sound of video to be more clear.
    b. Not given.
    c. Do not use this Robotis again, it is very not easy to use.
    d. Reduce the echo in the video!
    e. Perhaps we could try using a system without so many hardware problems that are hard to troubleshoot.
    f. A robot with a person, and don't use "Robotis".
    g. Not given.
    h. Not given.
    i. Don't use RoboPlus anymore. Try Arduino.
    j. Maybe change the hardware, because Robotis Bioloid often get trouble.

The previous comments showed that we would need improvements in the following areas:

1. Audio quality in the classroom recordings. UGA was using microphone arrays dropping down from the classroom ceiling for the majority of these videos, but we had recently upgraded to a personal BlueTooth headset that had much improved audio performances.
2. The Fall 2012 NTU session had much more robotics hardware problems than the Spring 2012 NTU session. We are still investigating whether this is a consequence of wear and tear, or was this more of an electrical power quality issue or was it a humidity factor? Because the UGA side had been using the same hardware since 2007 and it did not encounter similar problems. Actually, during his December 2012 visit to NTU, the UGA instructor had witnessed these hardware problems on the equipment that he brought over for demonstration purposes (equipment that had worked fine back at UGA and in the hotel the day before). A possible environmental factor was that the NTU classroom was not air-conditioned and the weather was cold and very humid (conditions that did not exist at UGA and in the hotel). We shall see if this problem gets better or worse in the Spring 2013 session coming up in mid-February 2013.
3. The "asynchronous" situation for feedbacks between the UGA instructor and NTU students needs to be improved, i.e. the turn-around time for video Q&A sessions needs to be shortened to within 2-3 days.

To measure the effectiveness of instructional materials and delivery methods used in-class (i.e. NTU instructor) and outside-of-class (i.e. UGA instructor), the original UGA survey was modified slightly as shown below:

1. In-class course materials delivery methods were effective (NTU instructor).
2. I understood the materials presented during in-class lectures (NTU instructor).

3. Recorded classroom lectures were effective (UGA instructor).
4. Pre-recorded narrated tutorials and Q&A sessions were useful (UGA instructor).
5. I felt comfortable going through multi-media presentations on eLeaningCommons.
6. I understood the materials presented in recorded lectures and narrated tutorials.

The above 6 questions also used a 6-point Likert scale where "StD" meant "Strongly Disagree", "D" meant "Disagree", "SlD" meant slightly disagree, "SlA" meant "Slightly Agree", "A" meant "Agree" and "StA" meant "Strongly Agree". NTU student responses for the Fall 2012 session are shown below in Table III.

TABLE III. In-class & Outside-of-class materials effectiveness Fall 2012 survey results (NTU students).

Question #	**"StD"**	**"D"**	**"SlD"**	**"SlA"**	**"A"**	**"StA"**
1 (EAU)			1		6	3
2 (EAU)				2	4	4
3 (USU)		1	3	5		
4 (USU)			1	3	4	2
5		1	1	3	3	1
6				2	7	1

These results re-emphasized that the audio quality of the videos needed to be improved for NTU students as it downgraded somewhat the efficacy of Screencast Technology (Green et al.[12]) such as the "Camtasia Studio" software being used. These problems did not exist for the UGA students as they were in the same room as the UGA instructor.

C) Students Learning Assessment based on Assignments and Projects Grades

For more direct assessments, we are using the student grades from homework assignments and project performances. For Spring 2012 UGA students, the percentage grades for assignments and projects are listed in Table IV.

TABLE IV. Percentage grades for UGA students in Spring 2012

Student #	**All Assignments**	**All Projects**
1	82	100
2	110	100
3	76	89

For Spring 2012 NTU students, the percentage grades for assignments and projects are listed in Table V.

TABLE V. Percentage grades for NTU students in Spring 2012

Student #	**All Assignments**	**All Projects**
1	100	84
2	100	84
3	99	88
4	99	88
5	99	91
6	99	91
7	97	96
8	97	96
9	100	88
10	97	94
11	97	94

For Fall 2012 NTU students, the percentage grades for assignments and projects are listed in Table VI.

TABLE VI. Percentage grades for NTU students in Fall 2012

Student #	**All Assignments**	**All Projects**
1	100	93
2	100	89
3	85	85
4	100	86
5	90	89
6	100	86
7	85	86
8	100	89
9	100	92
10	90	90
11	100	92
12	100	94

These more direct assessments of student mastery of the materials taught and videos of these projects at our web site *http://www.engr.uga.edu/~mvteachr/RobotVids/* showed that our instructional goals for this course had been mostly met.

D) Comparison of Student Projects Between the Two Campuses

As shown in previous sections, our curricula were designed so that only the first 2 projects (Carbot and single GERWALK negotiating stairs) were standard for both campuses. Starting with Project 3, we adjusted the projects based on the actual hardware/software resources available on each campus and the actual motivation levels and technical skills of the student cohorts at that time.

For UGA, this course had been taught since Spring 2010 and through internal grants over many years, the UGA hardware resources were much more considerable than the ones from NTU as they only started in Spring 2012. As a consequence of this, the UGA students were provided with pre-built robots so that they only needed to concentrate on adapting the robots software-wise for their assignments. On the other hand, the NTU campus had only 6 Bioloid Premium kits that were each assigned to a group with 2 students who were also allowed to take the robot kit home. The NTU students were also in charge of building their own robots as needed for various assignments, and as each group had only 1 kit, they had to go through several cycles of construction and deconstruction of robot hardware throughout the semester. Of course, these were very valuable hands-on experiences for the NTU students, which translated to the marked design innovation features present in their projects on the Twin GERWALK and Humanoid robots shown in Fig.2 and the following YouTube videos:

- *http://www.youtube.com/playlist?list=PLVHBjRDK0kAKsl7oWeTysfunk9aFL1pd-*
- *http://www.youtube.com/playlist?list=PLVHBjRDK0kAJiCdL2efNLcMenHmRDXfsq*

As expected for the UGA campus, the student innovation came from the software angle in the Mobile Wireless Sensors Network (MWSN) project for Spring 2012. As part of the materials provided to UGA students for the subject area of ZigBee communications between PC and robots were sample C++ codes using simple DOS console interface, i.e. simple-text line commands. However the 2 students working on this project were not satisfied with this interface and took upon themselves to learn on their own about the Forms tool available in Visual C++ Express and created the GUI as shown in Figure 4.

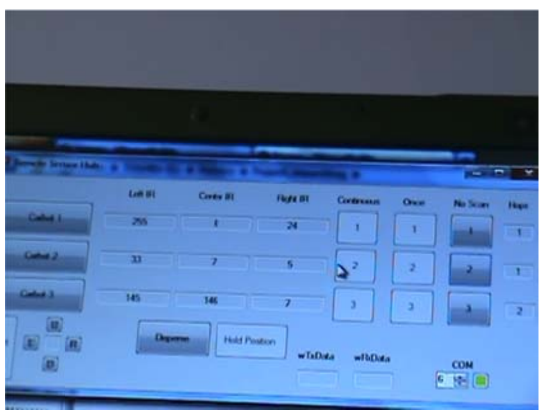

Figure 4. GUI created by USU students for the MWSN project.
(*http://www.engr.uga.edu/~mvteachr/RobotVids/MWSN_S12.wmv*)

IV) Conclusions

Through indirect and direct assessments, we believe that we had achieved our goals of creating practices in cooperative teaching that benefited both instructor groups, and that they are flexible enough to be adjusted as needed in the future.
Feedbacks from UGA and NTU students and their performances in course projects showed that there were some unintended consequences, some were beneficial, and some were not:

1. Starting in Spring 2013 session, the audio issue in classroom recordings will be resolved for the NTU students.
2. The NTU CEIBA facility can now stream video clips on demand so that will improve the NTU students' access to the classroom recordings as needed.
3. The Q&A sessions for the NTU students will have a 2-3 days turn-around time to help NTU students with their progress.
4. More Embedded C topics would be provided to UGA students, and more open-design projects will be requested of UGA students.
5. Although we did not plan explicitly the NTU version of this course to be a "flipped classroom", it had most of its main features such as: review of course recordings before live classes which were used to answer "deeper" questions from students, student hands-on activities outside the physical classroom. And in view of the positive feedbacks from the NTU students so far, the UGA plan is to offer this course as a "flipped classroom" starting Fall 2013.

Bibliography

1. ASEE, 2012. http://www.asee.org/conferences-and-events/conferences/inaugural-international-forum/presentations
2. D. Sanker, Collaborate!. San Francisco, CA: Jossey-Bass, 2012.
3. K.J. Baker-Doyle, The Networked Teacher. Teacher College Press, 2011.
4. G.S. Stump, J.C. Hilpert, J. Husman, W. Chung, and W. Kim, "Collaborative Learning in Engineering Students", Journal of Engineering Education, vol. 100, no. 3, pages 475-497, 2011.
5. P. Ren, D. Hong, J. Terpenny, and R. Goff, "Bridging theory and practice in a dual level robotics course for mechanical and electrical engineers", Computers in Education Journal, vol. I, no. 4, pages 70-81, 2010.
6. D.J. Cappelleri, "A novel lab and project-based learning introductory robotics course", Computers in Education Journal, vol. I, no. 3, pages 81-91, 2010.
7. N. Correll and D. Rus, "Peer-to-peer learning in robotics education: lessons from a challenge project class", Computers in Education Journal, vol. I, no. 3, pages 60-66, 2010.
8. B. Bishop, J. Esposito, and J. Piepmeier, "Moving without wheels: educational experiments in robot design and locomotion", Computers in Education Journal, vol. I, no. 3, pages 41-49, 2010.
9. C. N. Thai and J.M. Mativo. 2012. Development of a Senior Level Robotics Course for Engineering Students. Computers in Education Journal, vol. 3, no. 1, pp.6-20.
10. S.A. Ambrose, M.W. Bridges, M. DiPietro, M.C. Lovett, and M.K. Norman, How Learning Works. San Francisco, CA: Jossey-Bass, 2010.
11. R. and M. Root-Bernstein, Sparks of Genius. Boston, MA: Mariner, 1999.
12. K.R. Green, T. Pinder-Grover, J.M. Millunchick, "Impact of screencast technology: perceptions and performance", Journal of Engineering Education, vol. 101, no. 4, pages 717-737, 2012.