AC 2012-2956: INFUSING THE CURRICULUM WITH CUTTING-EDGE TECHNOLOGIES THROUGH PARTNERSHIPS WITH INDUSTRY

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Infusing the Curriculum with Cutting-Edge Technologies through Partnerships with Industry

Abstract

To ensure that curricula and course content reflect both academic and industry standards the School of Engineering and Computing Sciences (SoECS) at NYIT believes that course content must include elements of contextual teaching and learning (CTL) which emphasizes the relationship of course content to real-life situations[1,2]. It is expected that CTL which incorporates

1. hands-on activities
2. work-based learning experiences
   and
3. project-based learning

will engage today's students more thoroughly than the traditional lecture/textbook/dialogue models of education do. This is in line with the overall mission of NYIT which is to provide its students with a career-oriented education and a commitment to practical application-oriented research that will benefit both local and global communities.

As such, the SoECS embarked on pilot projects which seek to infuse our engineering, technology and computer science programs with cutting-edge technologies through partnerships with industry.

This paper will discuss in detail, one particular partnership with Quanser, to develop pedagogy that incorporated contextual teaching and learning that led to effective "Collaborative Undergraduate Lab" materials. These materials have now been incorporated into the curricula and are expected to provide our undergraduate engineering students with the professional skills demanded of a "Global Engineer".

Both Quanser's and NYIT's commitments to the pilot project will be described and an assessment of their effectiveness, as well as, an assessment of the curriculum developed and the pedagogy will be given so that the project can be duplicated at our other campuses and for other institutions as well.

As both our engineering and technology programs are ABET accredited, course and program outcomes will be consistent with ABET outcomes a to k and will be assessed using Faculty Course Assessment Reports (FCARs).

Introduction

The engineering and technology programs are prominent among the undergraduate disciplines that benefit most from experiential learning. Despite a comprehensive classroom and laboratory curriculum, program outcomes are best achieved when course content includes elements of contextual teaching and learning (CTL) as even the most complex academic engineering exercises fail to capture the project and work –based learning experiences that are found in industry.

To address both the outcomes of the program and the expectations of industry, the SoECS embarked on a pilot project with Quanser which led to collaborative and project-based learning in senior and master level capstone projects. This industry partnership provided our students with career-oriented education as well as a commitment to practical application-oriented research for the benefit of both local and global communities.

The senior capstone projects are taken by students in the fall and spring semesters of their fourth year. At this point in the curriculum, students have completed nearly all of their required technical coursework. They are expected to complete a design project under the guidance of a faculty advisor that draws significantly on the knowledge and skills acquired in previous lecture and laboratory course work. The work requires a written and oral proposal, followed by periodic progress reports and culminates in a completed product and presentation. The students are expected to look beyond the design analysis and deliver a project design that reflects and incorporates engineering standards, realistic constraints and technologies found in industry.

From the SoECS' perspective these senior projects provide, through assessment, an invaluable quantitative measure of the program's ABET outcomes that is not easily drawn solely from graded course material.

This paper will discuss in detail the SoECS' partnership with Quanser and the commitments that both we and they made to ensure successful pedagogical outcomes as well as an assessment of their effectiveness. Our experience/agreement with Quanser will serve as a model for our developing partnership with Balfour Technologies.

Quanser

Quanser is a Canadian company that provides hi-performance control solutions for complex industrial problems. It is also a world leader in education and research-based systems for real-time control design and implementation, providing control challenges for all levels of university education and research As a partner institution we are using Quanser's Turnkey Labs (QTLs) which provide the cutting edge hardware and software for the development of mechatronics and controls experiments and "challenges". The QTLs provide the SoECS with the CTL tools to teach successful and exciting control laboratories in both the engineering and technology programs as well as our senior design projects.

By working in such an innovative manner – for example developing a controller for a simulation and digitally sending it to another site for implementation –

students are also gaining valuable experience related to the important professional skills of:

- project management (task and schedule planning and integration),
- teamwork and a willingness to respect the opinions of others,
- communication (written, oral, graphic, listening, and digital and Internet collaboration tools),
- working as a "Global Engineer" (interacting at first with teams of students, via the web, at dfferent locations i.e. our two campuses in Manhattan and Old Westbury, and later across the world at our campus in Nanjing, China)

Consideration has also been given to deliberately embedding erroneous data in the model and/or changing the specifications of the motor and/or encoder mid-experiment so students understand the need for flexibility and the ability to adapt to rapid, continuous or major changes. These materials are now being incorporated into the curricula and are providing our undergraduate engineering and technology students with the professional skills demanded of today's "Global Engineer"

Quanser Commitments

- Quanser has provided NYIT with the specific pre-requisite skills needed by students participating in the pilot study.
- Quanser has lent NYIT Quanser Turnkey Laboratories (QTLs) including hardware, software and curriculum for the duration of the pilot study.
- Quanser's engineers have worked with NYIT instructors to integrate the QTLs with NYIT's existing equipment and licenses to ensure a superior mechatronics teaching environment.
- Additionally, Quanser's engineers are training NYIT faculty to implement the QTLs in the Senior Design Project (EENG491.) as well as other control courses deemed to be appropriate.
- Also, Quanser engineers have worked with NYIT faculty to design the pilot study's specific mechatronics and controls experiments and challenges and to incorporate experience in the professional skills required of a Global Engineer.

SoECS Commitments

- The SoECS' lab managers have worked with Quanser's engineers to integrate the QTLs with SoECS' existing equipment and licenses to ensure a superior controls teaching environment.
- The SoECS' faculty has integrated the QTLs into appropriate controls courses and the Senior Design Project (EENG 491.)
- Also, the SoECS' faculty has worked with Quanser's engineers to design the pilot study's specific control experiments and challenges and to

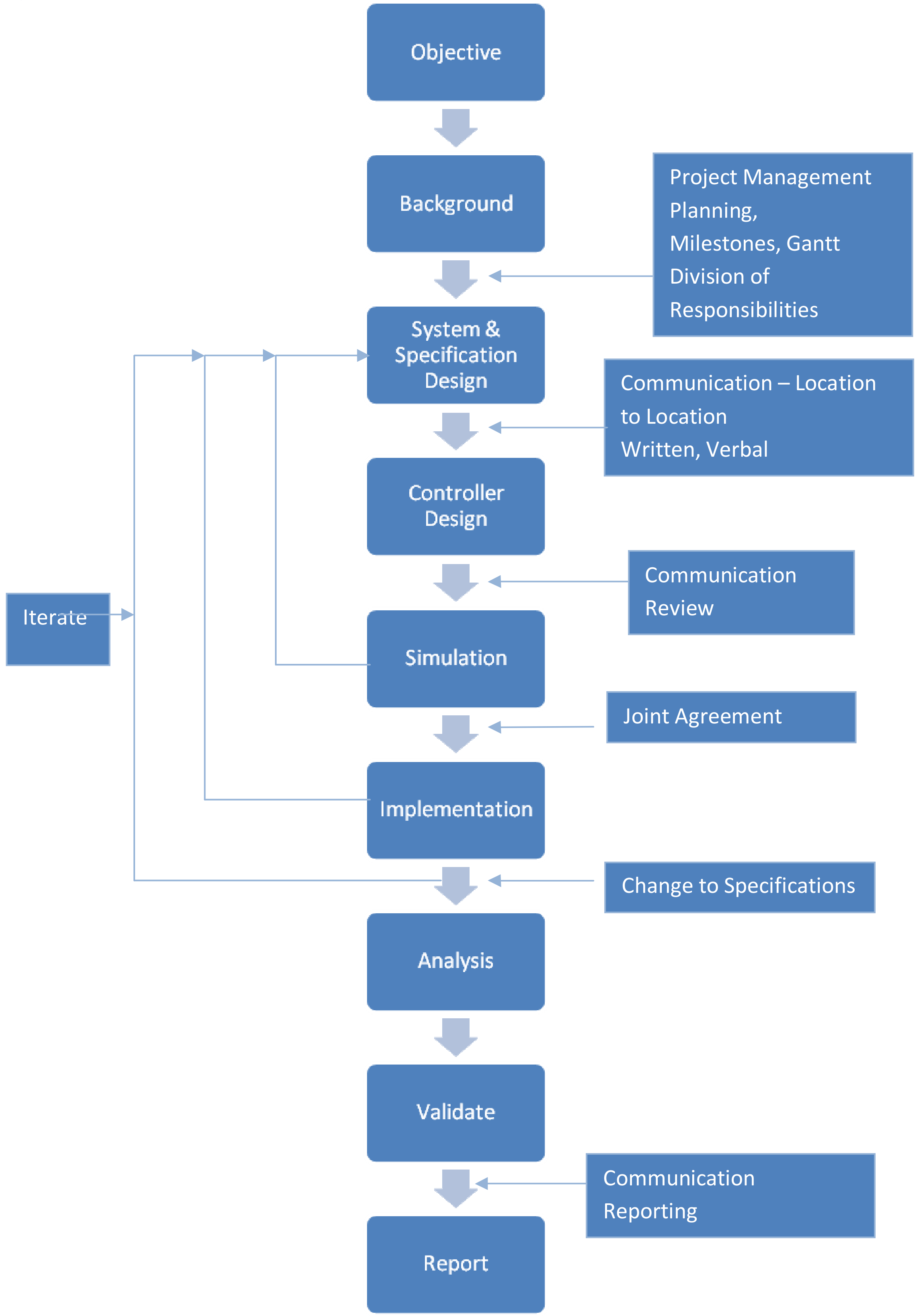
incorporate that experience in the professional skills required of a Global Engineer.

- The SoECS is providing Quanser with periodic pilot study student progress reports and will provide a final pilot study report addressing the questions posed below and including recommended pedagogy for establishing truly effective Collaborative Undergraduate Labs.

The flow chart that follows (see Figure 1) is meant to provide a structure so that Quanser, working in tandem with faculty can:

- best understand firsthand what difficulties students encounter
- determine at which point guidance is required
- determine strengths and weaknesses of the skill set students bring to the capstone courses.

Figure 1


Objective
Background
Project Management
Planning,
Milestones, Gantt
Division of
Responsibilities
System & Specification Design
Communication – Location to Location
Written, Verbal
Controller Design
Communication
Review
Iterate
Simulation
Joint Agreement
Implementation
Change to Specifications
Analysis
Validate
Communication
Reporting
Report

Preliminary Faculty/Student Assessments

Dr. Cecilia Dong [3]

Quanser provided NYIT with an education platform (Quanser Ball and Beam system) that combines mechanical and electrical control hardware with the interfacing software (QUARC) that allows users to use Matlab Simulink modules to control the hardware.

The first phase of the collaboration between NYIT and Quanser was a pilot program that introduced two small groups of NYIT students who registered for EENG 491 "Senior Design Project" with the Quanser equipment. The course, which is part of a two-semester design sequence, was offered in the fall semester. This one-year design project allows students to acquire the knowledge and experience in every aspect of an engineering design project such as project planning, project management, proposal writing, project reporting, as well as collaborating effectively in a team environment.

To make the Quanser system fully operational, all the mechanical, electrical and software subsystems must be designed and coordinated. The students are expected to have or to gain the necessary background on their own before they start their design using the Quanser systems. This provides students with an opportunity to engage in the independent study necessary for life-long learning. As such, the students at NYIT spent the fall semester focusing on building the necessary theoretical foundations by going through the customized Quanser experiments. In so doing they became familiar with the system and were able to drive motors, design and apply feedback control, calculate desired parameters in order to balance the ball on a one-dimensional beam.

During the fall semester, NYIT students were given the opportunity to get involved in every aspect of the project from assembling and calibrating the control hardware to installing the QUARC software. With help from faculty and Quanser engineers, they were able to successfully set up the lab, and debug hardware and software issues.

The students also gave suggestions to the Quanser engineers as to how to improve the hardware design of the Quanser equipment based on their own experiences with it. This open-ended project is providing a valuable opportunity for students to have hands-on experience in applying the knowledge gained in their control theory course to a practical design. Students are working closely with faculty and Quanser engineers to resolve issues in their learning process. This has brought them one step closer to where they must be in order to communicate effectively in a professional setting.

The interdisciplinary design challenge for students posed by the project encouraged students to collaborate with students and faculty from other disciplines such as Mechanical Engineering and Computer Science. Students will implement their two-dimensional ball stabilization system in the second semester of the one-year design project. Collaboration and competition with design groups at other NYIT campuses will provide the concept of a Global campus in an engineering senior design project.

Dr. Farshid Delgosha[4]

The goal in this project was to design a control system that was able to balance a ball on a plate. For this purpose, a camera was mounted on top of the plate that frequently captures pictures of the ball. Using some image processing techniques, the position of the ball on the plate was detected. The feedback control system triggers two perpendicular servo motors that tilt the plate in order to balance the ball.

Quanser provided the equipment for the one-dimensional ball balancing problem, in which the goal was to balance a ball on a beam. Using the experience gained in the one-dimensional case, students were expected to design a control system for the two-dimensional problem. Quanser provided QUARC to interface their equipment with Simulink in MATLAB. The equipment was accompanied with step-by-step lab experiments that introduced the students to both the theoretical and the practical background of the ball balancing problem. The close integration of theory and practical aspects provided a fertile environment for practically learning control theoretic concepts such as the design of a proportional-integral-derivative controller. Using the Simulink environment, students visualized the control system and observed the signals at various points of the system. This feature significantly improved the learning process.

Through this project, students learned the key aspects of system design starting from the theoretical design to fine tuning the components to meet the desired criteria that are difficult to formulate in theory. The use of Quanser equipment removes the burden of designing everything from scratch that would significantly divert attention from the essential theoretical and practical aspects of the design.

The four students who have been using the equipment have shown great interest in this project. The feedback collected from them demonstrates they have gained confidence in and a deep understanding of control theory as applied to design. Students not only enjoyed experimenting with the equipment but also came up with alternative designs for the two-dimensional ball balancing problem. Therefore, the use of Quanser equipment, in addition to greatly enhancing the learning process, stimulated creativity and critical thinking.

In conclusion, the use of learning-aid equipment significantly accelerates the learning curve, boosts students' confidence, and essentially engraves the material in their memory. These results were anticipated as progress in science mostly occurs by experimenting and observing the results. The use of such equipment creates a positive environment for training engineers that are able to efficiently use their knowledge and think critically.

Assessment

This process has both course-embedded and constituency-based assessment tools. The course-embedded assessment is the Faculty Course Assessment Report (FCAR), the components of which are illustrated below. The FCAR is the primary tool used to determine student outcome achievement. FCARs are the actual Microsoft Excel™ spreadsheets which the faculty are required to use when entering the FCAR component information.

It should be noted that the department has limited the FCARs to only those courses within the program which are offered through our department. This does not imply that faculty is precluded from recommending modifications in courses offered outside of the department if the assessment analysis provides data to support it.

For each course in the program the instructor is required to submit a Faculty Course Assessment Report (FCAR) every term. The FCAR requires:

- Each faculty member to identify course specific Learning Outcomes (LO's) for his/her course and to establish Appropriate Performance Tasks (APT's) with appropriate documentation to assess to what extent the course outcomes are being met. These APTs may be quizzes, exam questions, reports, projects, presentations, etc. Each student's APT is then scored with the rubric described below in Table 1, to create an EGMU (excellent, good, minimal, unsatisfactory) vector for that specific course outcome and a corresponding assessment metric.

- Each faculty member to satisfy a minimum set of student outcomes (a-k) for his/her course as established by the department. This is accomplished by using a subset of the Appropriate Performance Tasks (APT's) used to satisfy the LO's. Here, the faculty member is required to show what part of each APT is being used to form a metric for the outcome (a-k) with appropriate documentation. To accomplish this task, the department formulated a set of scoring guidelines for each outcome that can be used as a rubric to explain and help faculty evaluate what that outcome requires for an EGMU score of 3. EGMU scores of 2, 1, and 0 represent partial satisfaction of the outcome.

The EGMU Vector is obtained as follows:

Table 1 - EGMU Rubrics

EGMU	Rubric	Score
E - Excellent	• Fully demonstrates/accomplishes the attributes and behavior in the rubric	3
G – Good	• Mostly demonstrates/accomplishes the attributes and behavior in the rubric	2
M – Minimal	• Minimally demonstrates/accomplishes the attributes and behavior in the rubric	1
U - Unsatisfactory	• Does not demonstrate/accomplish the attributes and behavior in the rubric	0

A typical EGMU vector for a class with 19 students in which the APT was the third problem of the first exam might be (8, 9, 1, 1) which would signify that 8 students demonstrated a complete and accurate understanding, while 9 students applied appropriate strategies etc. The average score in this case being 43/19 = 2.26 which is Good.

These course-embedded assessments serve as the primary tools at our assessment meetings to determine student outcome achievement and to afford a direct link between course outcomes and ABET student outcomes as one aspect of curriculum change.
Inputs from the previous assessment process as well as the current faculty's comments and recommendations that might be used to close the loop on the assessment process are also included on each FCAR.

The data from FCARs are then evaluated at faculty assessment meetings. At these meetings all full-time faculty members and those regular part-time faculty members wishing to participate identify and propose strategies to improve ABET student outcomes and, hence, our program through course work.

Consequently, the department has determined that the minimum level of quality that it felt was necessary in order to produce graduates that will ultimately achieve our Program Educational Objectives is **an EGMU score of 1.5 for each ABET student outcome**. This score of 1.5 was chosen by the department because in the EGMU scoring it falls midway between the Minimal and Good indicators and therefore represents what a student would need in order to satisfy the requirements for graduation. (If each of the EGMU scores is adjusted to correspond to the grade points associated with A, B, C, D, a 1.5 is a C.)

While many courses may satisfy a particular ABET outcome, the assessment committee has picked a subset of these courses that it finds most appropriate to determine the minimum metric for each outcome.

The recommendations of the assessment committee meetings are generally of two types. One set of recommendations can be implemented solely through the faculty member making internal changes to the courses (i.e. textbook changes, pedagogical changes). The other set of recommendations would need to be forwarded to the curriculum committees of the School of Engineering and Computing Sciences and then to the Academic Senate for adoption (i.e. new course, prerequisite/co-requisite changes, catalog description).

We have found that each of our assessment tools must be used in conjunction with one another if we are to undertake changes that are meaningful.
As an example of how a faculty member is expected to interpret the EGMU scores for a student outcome, the following, developed by the faculty of School of Engineering and Computing Sciences, serves as a rubric for those outcomes which are of particular importance for the senior design project classes.

ABET Outcome c: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (an EGMU score of 3)

Is able to use engineering, computer, and mathematical principles to develop alternative designs taking into consideration economic, health, safety, social, and environmental issues, codes of practice, and applicable laws.

ABET Outcome f: an understanding of professional and ethical responsibility
(an EGMU score of 3)

- Student is familiar with the IEEE and ACM Code of Ethics and the NYIT Students' Code of Conduct
- Takes personal responsibility for his/her actions
- Is punctual, professional, and collegial
- Attends classes regularly
- Evaluates and judges a situation using facts and a professional code of ethics
- Uses personal value system to support actions, but understands the importance of using professional ethical standards for corporate decisions

ABET Outcome g: an ability to communicate effectively
Written (an EGMU score of 3)

- Articulates ideas clearly and concisely

- Organizes written materials in a logical sequence (paragraphs, subheading, etc.)to facilitate the reader's comprehension
- Uses graphs, tables, and diagrams to support, interpret, and assess information in the proper format
- Written work is presented neatly and professionally, conforms to the prescribed format (if any), and grammar and spelling are correct

Oral (an EGMU score of 3)

- Presentation has enough detail appropriate and technical content for the time constraint and the audience
- Presents well mechanically: makes eye contact, can be easily heard, speaks comfortably with minimal prompts (notecards), does not block screen, no distracting nervous habits
- Uses proper American English and visual aides effectively
- Has a professional appearance
- Listens carefully and responds to questions appropriately

ABET Outcome h: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (an EGMU score of 3)

- Is familiar with the current trends in the engineering disciplines and the historical aspects of engineering solutions and their impacts
- Is able to evaluate political solutions, or scenarios using a series of different measures - e.g., economic, quality of life; number of individuals affected; political ramifications; etc.
- Can demonstrate a personal perspective on the importance of engineering in today's world

ABET Outcome i: a recognition of the need for, and an ability to engage in life-long learning (an EGMU score of 3)

- Demonstrates an understanding of the need for and the ability to learn independently (i.e. goes beyond what is required in completing an assignment; brings information from outside sources into assignments; etc.)
- Participates and takes a leadership role in professional and technical societies available to the student body

With respect to the assessment of the above ABET student outcomes (c), (f), (g), (h), and (i), our partnership with Quanser directly affects outcome (c) and as a result of our assessment activities at the end of the spring 2011 semester we found that students lacked the following professional skills:

- A sufficient background in Matlab/Simulink
- CAD design skills
- Program Management (PM) tools

which interfered with the success of the CUC pilot study's experiments and challenges.

Continuous Improvement

From the perspective of each partner, to facilitate continuous improvement with respect to outcome (c) we addressed the following question:

- How should, the pedagogy change to meet the unique challenges of the CUC pilot study's experiments and challenges?

The following recommendations/commitments were then completed over the summer 2011 semester and were ready for full implementation during the fall 2011 semester.

1. **Quanser Recommendations**

    - Write Matlab/Simulink guide and or video tutorials to show students how to design their controller
    - Set prerequisites for team:
        - One person w/ CAD skills
        - One person w/PM skills
    - Set milestones
    - Integrate monthly status reports
    - Supply students with a Gantt chart and basic PM information

2. **Next Steps**

Quanser Deliverables

- Practical Control Guide (Aug. 19, 2011): Quanser to write "Practical Controls" guidebook to ensure students learn how to design and implement A PID-based control in Matlab/Simulink and QUARC.
- Mechanical Design Primer (Sept. 30,2011)
- Project Management (Aug. 19, 2011): Supply a basic Gannt chart of the project that students will be able to use and modify.

NYIT Deliverables

- Include a mechanical engineering student in the group?
- Have students take IENG 251 (Project Management) as an elective prior to taking the course.
- Review "Practical Controls Guide" and "Mechanical Design Primer"

At the end of the spring 2011 semester the assessment committee will meet to determine if the above steps created a more successful pedagogical result for this pilot study.

Preliminary Observations

While everyone agrees that student exposure to industry practice is important to prepare students for entering the engineering/technology industries it is also important to develop a set of criteria that will validate the success of industry/university partnership engagements.

In that regard, the knowledge we have gained, so far from the Quanser partnership leads us to believe that for a successful transfer of knowledge it is important to have a partnership in which a formal agreement between the two parties is signed that includes:

- The identified objectives of and benefits to both parties
- How those objectives will be measured (in our case through the assessment of program outcomes)
- The commitments each party makes to ensure that those objectives and benefits will be met (for many Higher Education Institutions(HEIs) they must be able to achieve these results on what may be limited resources)

This implies that:

- The HEIs capabilities and course offerings should be aligned to the particular industries business needs
- Industry as a constituent must inform the contents of the curriculum (an ABET/ASEE criterion)
- Knowledge transfer should exist between both parties.

Bibliography

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2. Susan Sear, “Contextual Teaching and Learning: A Primer for Effective Instruction”, Phi Delta Kappa Educational Foundation, 2002
3. Cecilia Dong is Assistant Professor of Electrical & Computer Engineering at the NYIT. She teaches the senior capstone design courses EENG 489,491 at the Manhattan Campus of NYIT and has collaborated with Quansar to integrate their QTLs into these two sequence design courses.
4. Farshid Delgosha is Assistant Professor of Electrical & Computer Engineering at the NYIT. He teaches the senior capstone design courses EENG 489,491 at the Old Westbury Campus of NYIT.