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Collaborated Efforts in TI ARM M4/32Bits Microcontroller Curricula Developments and Assessments

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Collaborated Efforts in TI ARM M4/32BIT Microcontroller Curricula Development and Assessment

Introduction

These collaborative efforts in curriculum development were an extension of several NSF funded projects that focused on the cyber enabled learning in the academic community build up. Two previous funded NSF projects: (1) TUES Type 2: "Dissemination of Microprocessor Courses through Classroom and Interactive Cyber-Enabled Technologies" and (2) I-Corp L: "Transform the Innovated Design and Development of an Embedded Design Training System and Associated Support Curricula into a Commercial Available Product" addressed the issues of outdated microcontrollers (68XXX and 80XXX series) with new microcontrollers from Microchip PIC and Arduino ATMEL. The introduction of the Texas Instruments (TI) ARM M4 series was a direct reflection of the I-Corp L project results that the academic community is still in need of an advanced microcontroller platform to meet industry technical training demands [1]. This TI ARM M4 based curriculum design and development project illustrates how the collaborated efforts between faculty at different institutions can be beneficial in developing and instructional materials that lead to effective teaching and improved student learning.

The cyber enabled learning takes many shapes and forms. It is commonly described as Distance Learning, Hybrid Learning, eLearning, or on-line learning [2]. Whichever terminology that is used, Internet based assisted learning can be used as standalone on-line instruction or used in conjunction with traditional face-to-face instruction. This learning environment offers real-time distance learning experience and provides learners the availability of asynchronous course materials that assist learning 24/7 via archived database [3]. It provides a wide range of opportunities in the on-line learning community for teacher-student experiences as well as student-to-student and student group learning experiences. In addition, it enables educators to collaborate in a distance environment despite of geographical locations. Educators can share experiences, develop programs; collaborate in research activities, and improve faculty professional development. This article is an example of such described collaboration between faculty in different institutions to accomplish the common shared teaching goals and improve learning.

Initiation of the Collaborated Efforts

The needs for advanced microcontroller content and training in the academic community were identified during the NSF I-Corp project. The discovery of the initial needs was the result of the "Configurable Space Microsystems Innovations & Applications Center" (COSMIAC), where the efforts of these initiatives were funded by NSF through the University of New Mexico. With the assistance of COSMIAC [4] and several text books published by Dr. Johnathan Valvano at the University of Texas in Austin. The text books were "Embedded Systems: Real-Time Interfacing to the Arm Cortex-M3" [5] and "Real-Tine Interfacing to ARM Cortex-M Microcontrollers, 2nd Edition" [6]. The collaborated efforts originated by Old Dominion University (ODU), Norfolk, Virginia and Farmingdale State College (FSC), Farmingdale, New York faculty as a team effort to design and develop the course and lab modules based on the Texas Instruments' Tiva C Series LaunchPad [7] with the ARM Cortex-M4 microcontroller. The dissemination of the instructional materials was made through a Learning Management System (LMS) [8] that was developed by Ohio Northern University (ONU) faculty. The preliminary assessments included ODU and FSC students who were introduced to this new microcontroller for the first time in either a traditional on-campus face-to-face environment or synchronous distance delivery.

Common Hardware and Software Platform

Collaboration in course and faculty professional development and deliverable content through synchronous distance learning require a common hardware and software platform as fundamental components. An *uC Training System* was designed and implemented based on a PIC training system that was developed through previous funded NSF projects [9]. The *uC Training System* hardware has the capability to integrate the TI Tiva C Series LaunchPad and perform the same as well as new experiments as compared to the PIC microcontrollers. A comparison of the features and differences between the microcontrollers is available on www.ucdistancetraining.org web site under the "what's new" option. The free microcontroller development software that is readily available and downloadable through manufacturer web sites, www.microchip.com or www.ti.com, is an important consideration in developing instructional materials. In this case, TI is the choice of the software to use. All the guides and step-by-step procedures for downloading the software and hardware manuals are provided through the Learning Management System used for collaboration and is accessible to teachers and students. A significant consideration is the importance of the common platform, *uC Training System* hardware, and dissemination web site toward achieving effective and realistic collaboration. Photo 1 shows the common platform for the *uC Training System* and TI Tiva LaunchPad that was used in the lecture and lab classes at ODU and FSC.

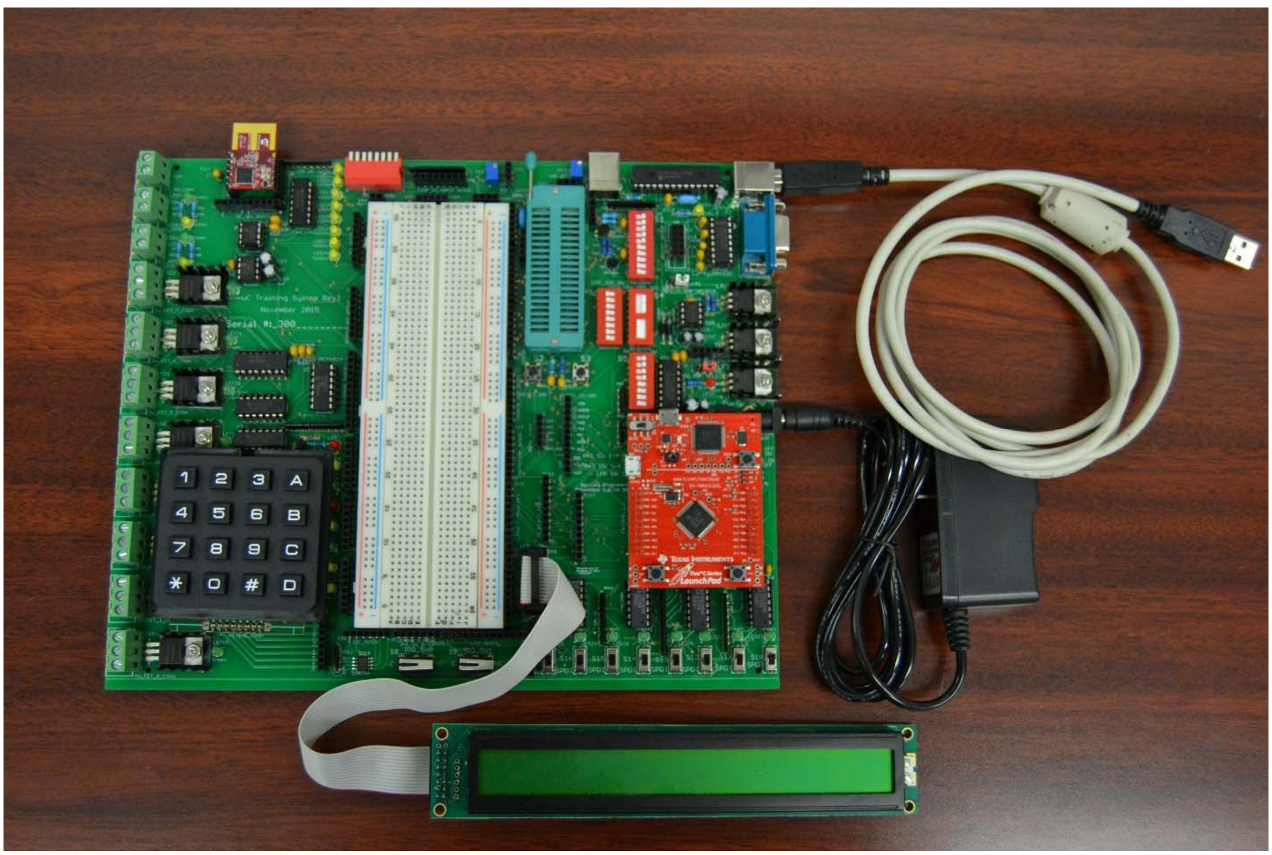

Photo 1. uC Training System and TI Tiva LaunchPad

Design and Development of the Curricula Modules

The course modules were developed by researching and reviewing available software, hardware, data sheets from Texas Instruments, other reference materials [10], and books. The goal was to take the initial complex material and concepts and synthesize that content into a sound instructional format that can be used directly as class and laboratory lecture material. The collaborated effort resulted in different course and lab modules that can be used directly in class lecture, discussion, or in a real-time distance teaching environment. The initial labs were referenced from the COSMIAC workshop material and further refined and developed into more detailed step-by-step guides that students can follow. All the course materials were tested by faculty at ODU and FSC before being disseminated through the project LMS platform. Faculty at ODU developed the initial lecture material and several lab modules and FSC added additional labs with same format that are deliverable as distance learning products through an LMS or traditional handouts. The objectives are not to cause confusion in neither on-campus nor distance offering at different institutions. All the available course and lab modules are available at www.ucdistancetraing.org.

Implementation Strategies and Planning for On-Campus and Distance Hands-on Approach

The EET 470 "Microprocessor/Microcontroller Based Designs" offered at ODU was in a real-time, hands-on distance delivery format where instructor lectured via Adobe Connect web-based video conferencing application. All the lectures were recorded and accessible online to students without restriction. All students were given handouts and homework assignments based on fixed hardware on the TI Tiva C Series LaunchPad and *uC Training System* with interfacing to the peripherals through BlackBoard or the project LMS. The requirements are the C code designs with specified functions that must work with the ARM M4 platform. The software is based on TI C Code Composer Studio (CCS) [11] with the factory function libraries. The students verify their software designs on the specified hardware and turn in their C code designs according to the assignment requirements. The instructor checks the student's code assignment by running it on the same hardware and interface and grades the work based on the end performance on the hardware.

The hands-on exercises include basic I/O controls, SPI to EEPROM (25LC256) [12] and 2.4 GHz RF wireless module (MRF24J40MA) [13], I^2C to temperature sensor – TCN75A [14] communications, different MCUs (between PIC and ARM M4 microcontrollers), display devices, and communication protocols. Technical difficulties were resolved through one-on-one video conferencing sessions using Adobe Connect [15] in much the same manner as student assistance that may be provided through faculty office-hour appointments or meetings. It is important to note that this is a senior elective course and that the student is expected to have previous experiences with microcontrollers and have completed EET 320 "Microprocessors and Microcontrollers" and EET 325 "Microprocessor Laboratory" before taking this class.

FSC faculty offered their EET 418 class which is similar in content and experiences to ODU's EET 470 class, but presented it in a traditional on-campus, face-to-face format. The Farmingdale State College EET 418 "Microprocessor Interfacing and Control" is a senior required course for both electrical and computer engineering technology students at FSC. Students are required to take EET 251 "Microprocessor" and EET 110 "Introduction to Computer Application" before registering EET 418. All students were given labs exercises based on the hardware interfaces available on TI Tiva C Series LaunchPad and *uC Training System*.

There were 11 labs been implemented in the EET418 in two different sessions taught by different instructors.

1. TI Tiva C Series LaunchPad ARM M4 Hardware and Software Setup
2. Flashing LEDs Controls with Tiva *uC Trainer*
3. GPIO and LEDs Controls
4. Interrupts and the Timer
5. ADC12
6. Generate SOS type coding via Tiva *uC Trainer*
7. Hibernation Mode
8. Floating Point
9. Lower power modes
10. USB
11. PWM

Most of the lab experiences were run in a debug mode. All students were required to code in C using the TI Code Composer Studio environment and execute their program code on the hardware directly.

Dissemination Approach to the Academic Community

The primary mechanism used to disseminate the instructional materials is the project web portal at www.ucdistancetraining.org. The project web portal serves as the centralized location for users to access instructional materials. The website provides general information to all users and also includes member-based information access. The structure of the project website is shown in Figure 1 and includes hardware and software product information, project videos, previous workshop information, community partners, course curriculum, FAQ, contact information, and a resource download page.

The resource page includes downloadable links for software applications such as an Initial Trainer Test, MPLAB IDE, XC8, PICKit2, TI ARM M4, Arduino, and PIC/*uC Training System* manuals. Users can download the software applications and step-by-step guides that are considered necessary to start their learning process. They can communicate with the instructor through a variety of media technologies such as telephone communication, email, or face-to-face video conferencing for individualized assistance. It was also realized an important consideration that the learner's capability to communicate with the researchers directly during the learning process. Consequently, instructions for using on-line video conferencing applications are included on the web site to assist learners in setting up their audio and video equipment.

Learners can access Arduino Rover and 3D printer tutorials through the home page on the web portal. The tutorials include project photos, project descriptions, and step-by-step instructions. These tutorials are open to all audiences where all instructional materials are accessible. The Arduino and 3D printer instructional materials are another example of a collaborative effort to develop materials for a summer camp project for tenth and eleventh grade high school students. They are categorized as follows:

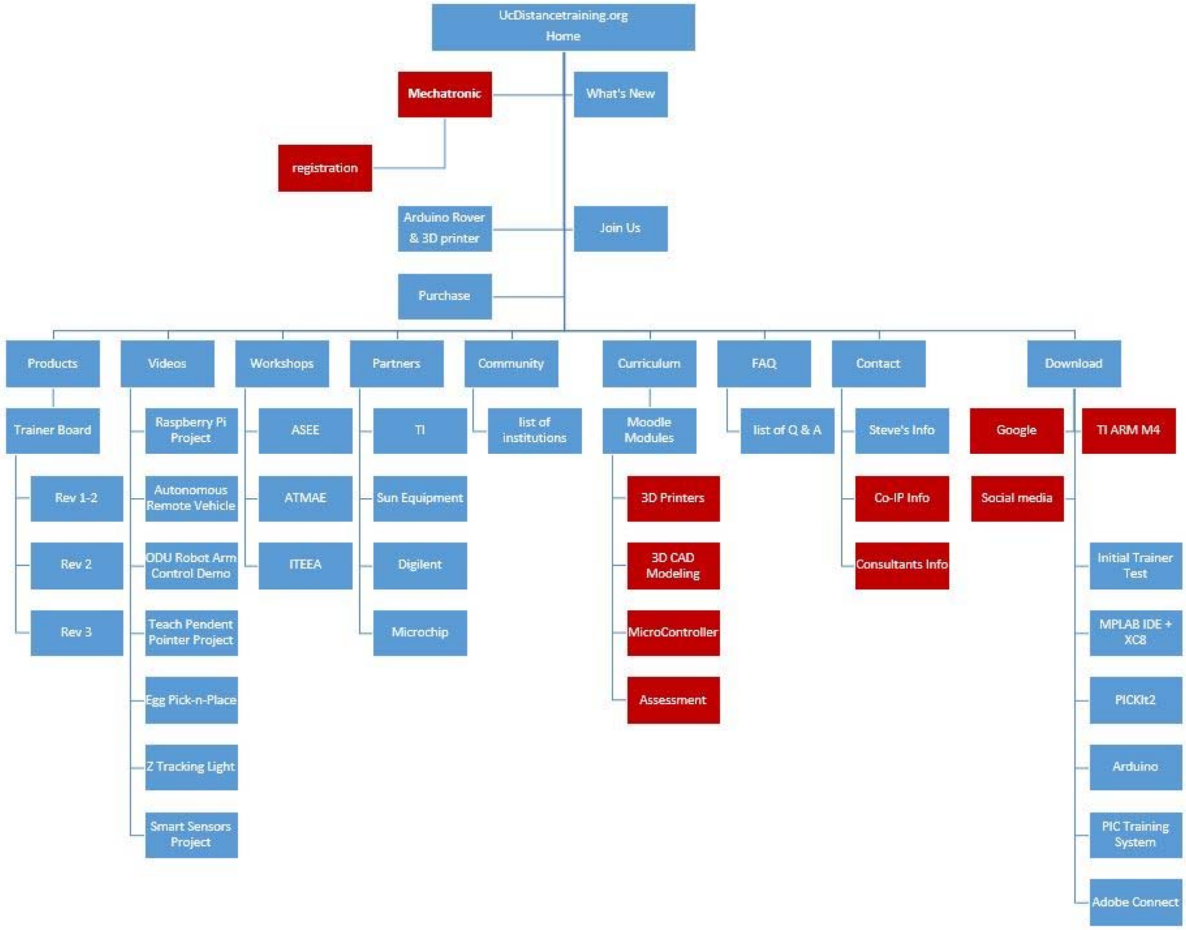

Figure 1. The LMS (Learning Management System) Platform

- 3D Production Files for Rover
- Arduino Sample Programs
- Rover Robot Assembly
- Preparing the 3D Printer
- Assembling the Rover Chassis
- Connecting and programming Arduino

The instructional materials for teachers and faculty are located in the curriculum section of the LMS that is hosted on the Web Portal. Teachers and faculty that desire to access these instructional materials must submit a permission request to the webmaster. The webmaster and other team members will review the request for eligibility based on the requestor's status and grant or deny access. When access is granted, the user will be provided with user account and password to access the curriculum modules in the LMS. Access to the curricula materials is restricted to teachers and faculty. All other materials such as data sheet, manuals, demo videos, step-by-step instruction on how to use PIC and ARM M4 hardware are free and accessible to any interested users. Typically, students at other institutions can access these resource materials.

The LMS on-line community environment provides learners with the opportunity to view instructional videos to learn new topics, download programming codes in various languages, lab demo videos, and download instructional materials and lab modules. The online forum allows learners to communicate with other users and share their project ideas and comments.

Preliminary Assessments of the Teaching and Learning at ODU and FSC

A simple preliminary ten-question questionnaire was designed and implemented to assess the effectiveness of the collaborative professional development experience and teaching effectiveness of these new subjects taught during the past two years. The purpose of the questionnaire was to identify the effect of the change from PIC to ARM M4 microcontrollers and the change in software design from PIC assembly to C language used with ARM M4 controllers and determine if they are appropriate and effective. Additionally, the student's learning experience on the *uC Training System* and TI Tiva LaunchPad is also a strong interest to the instructors.

The assessment questionnaire was distributed to students at ODU that were enrolled in EET 470 "Microprocessor/Microcontroller Based Design" that incorporated the ARM M4 microcontroller platform for the first time during the fall of 2016. The FSC students used the same AMR M4 platform in two class sections of their EET 418 "Microprocessor Interfacing and Control" that was also offered for the first time during the fall of 2017. The data presented in Tables 1 and 2 are the questionnaire questions and response results from ODU and FSC students respectively, where FSC, EET 418 is the combined results of two class sessions taught by different instructors.

Table 1. ODU Students' Survey Results/EET470

#	Question	N = 10			
		Yes			No
1	Do you have previous experience of using high level language such as C or CPP?	**7 (70%)**			**3 (30%)**
2	Did you use high level language in the interfacing control application in other classes or curriculum?	**7 (70%)**			**3 (70%)**
3	Do you think it is effective and necessary of using C to do the hardware interfacing control applications?	**10 (100%)**			**0**
4	Do you think the communications interfacing between the C/CPP and ASM on an ARM M4 will be beneficial to you?	**10 (100%)**			**0**
5	After learning the materials in EET470, are you capable to use high level language (C) and ASM in the bits and bytes control applications?	**10 (100%)**			**0**
6	Do you like to see more applications of C/CPP in EET470? What are those subjects?	**8 (80%)**			**2 (20%)**
7	How much ARM M4 should be introduced in the EET470? 20%, 50%, 100%, or Not at all	20%	50%	100%	**0**
		4	**4**	**2**	
8	Do you think the C should be concentrate on PIC C or ARM M4?	PIC	Both	ARM	**0**
		2 (20%)	**2 (20%)**	**6 (60%)**	
9	Do you think the *uC Training System* assisted you in learning the required material provided in EET470 class?	**9 (90%)**			**1 (10%)**

Table 2. FSC Students' Survey Results/EET418

#	Question	N = 69	
		Yes	No
1	Do you have previous experience of using high level language such as C or CPP?	**53 (77%)**	**16 (23%)**

2	Did you use high level language in the interfacing control application in other classes or curriculum?	**47 (68%)**			**22 (32%)**
3	Do you think it is effective and necessary of using C to do the hardware interfacing control applications?	**58 (84%)**			**11 (16%)**
4	Do you think the communications interfacing between the C/CPP and ASM on an ARM M4 will be beneficial to you?	**54 (78%)**			**15 (22%)**
5	After learning the materials in EET418, are you capable to use high level language (C) and ASM in the bits and bytes control applications?	**52 (75%)**			**17 (25%)**
6	Do you like to see more applications of C/CPP in EET418? What are those subjects?	**53 (77%)**			**16 (23%)**
7	How much ARM M4 should be introduced in the EET418? 20%, 50%, 100%, or Not at all	20% **7**	50% **11**	100% **49**	**2 (3%)**
8	Do you think the C should be concentrate on PIC C or ARM M4?	PIC **6 (9%)**	Both **9 (13%)**	ARM **49 (71%)**	**5 (7%)**
9	Do you think the *uC Training System* assisted you in learning the required material provided in EET418class?	**54 (78%)**			**15 (22%)**

Based on the review of the above survey data, ODU has over 88% overall responses that are in favor of using the ARM M4 and C as the programming language. FSC has 62% in favor in the same categories as ODU students. All the data indicate that the *uC Training System* is a necessary hardware platform to be used in class. This is particularly important to ODU students who took this EET 470 class in a distance learning, real-time, synchronous format. This means that the ODU students were required to complete their project designs and assignments with the specified hardware. Accordingly, the instructor only required students to turn in the C code design which was graded by the instructor using the same hardware platform to evaluate the performance of the assignment. The required use of a common platform was a critical element in making the course distance delivery functional and successful. It can be inferred the assessment from the ODU students showed a stronger preference of 90% in survey question #9 on the *uC Training System* to be used in this class over FSC students of 78%. The data also demonstrates that almost all students at both ODU and FSC prefer C language over ASM coding when using complex microcontrollers for experimentation and project design. This is also in line with industry recommendation for C language skills as a preference for related job employment.

Recommendations of Potential Adoption of the Development

It is going to be overwhelmed to start from scratch to develop new curriculum materials or use a different microcontroller platform to meet the new challenges in industry, if doing this alone. The purpose of this article and presentation is to disseminate results of a collaborative study to the academic community who can use and share with others. The goals of this presentation are directed toward the academic community and may include faculty and other interested parties that share a common interest in microcontroller or embedded system designs, who can speak the same technical language, ask questions, provide answers, and even collaborate on projects.

There are many situations where faculty professional development begins with a good start in attending a training workshop or seminar but end up with little or no further interest because there is no continuous support. Sometimes it may simply be there is no one to talk to when there is a "glitch" in the technology or a technical problem. Even when technical support is available, there are times where the support person does not understand or care about academic issues and concerns. Often assistance that may be provided is not applicable or beyond the faculty capability to resolve the problem or issue. However, an effective LMS can provide the capability to address and resolve many issues and problems. Suggestions and solutions can be posted to the LMS and shared and updated through links to other faculty that can provide suggestions or answers that lead to problem and issue solutions. This makes the problem solving or trouble shooting much easier and less stressful. Since the academic community consists of faculty in the same or similar classes, the discussion can be more open and with less frustration. The researcher's experiences and success lead us to recommend that readers try this LMS platform and use the same hardware, software, and experiments that has been developed and posted. Additionally, suggestions, recommendations, critic, and modifications can provide a path toward making the LMS work more efficiently and effectively.

Continuous Improvement of Teaching and Learning in Academic Community

The curriculum development process for planning for new courses or revising existing courses is challenging. Generally, the development process takes considerable time and effort and additionally, its implementation stage is even longer. This article is an introductory example used in developing new courses using a collaborative approach with common goals and outcomes. The collaborative process provides the opportunity to share evaluations, refine materials, and make appropriate corrections as necessary. An added benefit in using a collaborative strategy is it can reduce the time and provide a wider review of materials that are created during the development process.

This approach offers an alternative model in the development, verification, evaluation, and implementation using a team effort and a LMS to disseminate the materials to the academic community. Thus, benefiting the broad community members and bringing the students more closely to the real world of work. The collaborative curriculum effort, as presented here, e.g. the course materials and lab modules are far from complete. It is expected that a continuous improvement will follow, and questions and suggestions are anticipated through the LMS. It is also expected prospective users of these materials will request explanations about the content and hardware and themselves contribute to the development process thus resulting in a better product.

Conclusion and Recommendation

The curriculum development process takes a significant amount of time and effort to produce effective high-quality materials. First, the instructor or developer must thoroughly learn and understand the theory and application of the new material. Second, the preparation of handouts, lecture materials, homework assignments, quizzes, and exams take additional time and energy to create.

This is particularly challenging when developing materials for laboratory classes as there are frequently glitches, unanticipated interference, or component issues that cause unintended outcomes and must be addressed and corrected at the last moment to continue the experiment. Imagine all of the factors that must come together to result in a realistic and effective experiment. The lab experiment content, software and hardware, miscellaneous components all must work together to end in the desired learning experience. Additionally, it is important to realize that in our ever-fast-changing technology era, it is necessary to offer degree programs that reflect the changes in industry and the job market. This realization in a large measure is the responsibility of the instructor to update and maintain course and program relevance to the real world.

The intent of changes of the course content were based on the suggestions from engineers and technical sales representatives during annual ASEE conferences on the skills needed in the embedded systems design field. Further, it was recommended that students have programming skill in both ASM and C along with hardware understanding on different manufacturer parts in system designs and applications. These recommended changes took place over a period of two years to actively implement them. Because of an NSF funded project in 2012 – 2013 [16], an academic community that share a common interest in embedded systems designs was established. Additionally, an existing development platform enabled the feasibility of a collaborative curriculum development project. The collaborative initiative, shared interests, and common development platform became the foundation of the curriculum development project.

The other outcome of this collaboration is the distance delivery either between faculty-to-faculty on curriculum or project or faculty-to-student in lecture or lab activities. Once this connection has been established, the sharing, using, improving, and changing of all the developed concepts become easier without the limitation geographically. Certainly, any unexpected incident or technical difficulty can be easily resolved among faculty or students with simple Q and A, email, or traditional phone calls. A real-time video conferencing can be added easily whenever there is a need to resolve more complex problems and issues.

The overall goal of this project is to create an on-line learning community for faculty members nationwide. An active on-line learning environment provides the opportunity for the team to achieve their instructional goals. Many faculty members have developed the knowledge and teaching practices of embedded system designs by integrating these materials into research or application projects. The research team embraces others who are interested in teaching about microcontrollers to enhance collaboration on these topics. The team had designed a common hardware platform for laboratory modules at an affordable price to learners, which reflects the concepts of active learning. Thus, learners are motivated to engage in the activities and experiments because they can follow the instructional steps well and maintain interest.

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