AC 2011-2342: CREATING A GLOBAL COMPUTER ENGINEERING CURRICULUM BASED ON VITAL ELECTRONICS

Patrick Kane, University of New Hampshire and Cypress Semiconductor

Patrick Kane Bio

Patrick Kane is the director of the Cypress University Alliance Program and has recently applied for the PhD program in Systems Engineering at the University of New Hampshire . The Cypress University Alliance Program is dedicated to partnering with academia and universities to ensure that professors and students have access to the latest Cypress PSoC technology for use in education and research. Patrick joined the Cypress team in July 2006. Prior to joining Cypress Patrick spent 13 years at Xilinx in a variety of roles including Applications Engineer, Aerospace and Defense, Automotive, Technical Training and managing the Xilinx University Program. He currently holds ASEET, BSEE and MBA degrees.

Thadeus Paul Kochanski, Vital Electronics Institute

Thaddeus P. Kochanski, Ph.D., (Ted) Thaddeus P. Kochanski, founding Director, Vital Electronics Institute, long-term member of the IEEE Boston Section Executive Committee (2005 Chair), co-founder of CIDLab at UNH, and "IEEE 3rd Millennium Awardee." He coauthored with Profs. Andrzej Rucinski, and Don Bouldin, the chapter, "Paradigm Shifts in the Design of Microelectronic Systems," in Pursuit of the 21st Century Golden key: Nurturing Young Generation to Grasp Opportunities in the 21st Century, National Chaio University Press (Taiwan). Much of his current work involves developing curriculum and supporting technology for Critical Embedded Systems along with Professor Andrzej Rucinski at UNH CIDLab. Recently, Kochanski has been involved with organizing conferences, presenting invited lectures and collaborating on diverse topics with universities, national research centers (Poland, Germany) and EU organizations. In 2008, Dr. Kochanski co-edited with Prof. Andrzej Stepnowski, Marek Moszynski and Jacek Dabrowki of the Gdansk University of Technology, the Proceedings of the 2008 1st International Conference on information Technology (GUT, 2008).

Andrzej Rucinski, University of New Hampshire

Prof. Andrzej Rucinski represents a growing category of "transatlantic professors" defining the role of academia in the global education and global engineering era and developing global innovation and technology solutions. He was educated both in Poland and the former Soviet Union and has conducted his academic career in both the United States (University of New Hampshire, USA) and in Europe (France, Germany, Hungary, Poland, Russia, and Ukraine). His service has been with high tech industry, NGOs, ranging from the state level (National Infrastructure Institute) to a global level (NATO, United Nations Organization). He is a member of the Executive Committee (Innovation Chair) of the IEEE Computer Society's Design Automation Technical Committee. He chaired the 2009 Conference on Microelectronics Systems Education (MSE'09) in San Francisco. At the University of New Hampshire, he is the founding Director of the Critical Infrastructure Dependability Laboratory, the Professor in the Department of Electrical and Computer Engineering and the Space Science Center. He was the Member of the US State Department/Fulbright National Screening Committee and he is the Fulbright Senior Specialist.

Creating a Global Computer Engineering and Science Curriculum Based on Vital Electronics

Introduction

This paper discusses the motivation for and the process of creating a Global Computer Engineering and Science Curriculum (GCESC) founded on the implementation of the Internet of Things (IoT)[1,2,3,4,5] using the principles and practice of Vital Electronics.[6,7,8,9]

Gérald Santucci, Head of Unit "Enterprise Networking and RFID“ for the European Commission Directorate General Information Society and Media, has authored a definition of the IoT, “....we are now heading to the third and potentially most "disruptive" phase of the Internet revolution.... [the IoT] links the objects of the real world with the virtual world, thus enabling anytime, anyplace connectivity for anything....where physical objects and beings, as well as virtual data and environments, all interact with each other in the same space and time.[3]

Vital Electronics is defined as the study and use of electrical components, circuits, networks, and systems to achieve a design goal of protecting, saving, and improving critical infrastructure, and hence the quality of life. The Vital Electronics domain is a heterogeneous computing environment derived from sensors networks, embedded systems, and ambient intelligence with intelligent, robust, and trustworthy nodes capable of building Vital Electronic Computers (“VEC”) from “off-the-shelf” virtual computational and networking components.[6,8] Vital Electronics can be viewed as the conceptual toolbox to enable building reliable application-centric embedded computers from virtual computational and networking parts implemented with Programmable Systems on a Chip (PSOC). In turn these vital electronic computers provide physical systems with real-time sensing, control and communications functions and are the practical embodiment of the Internet of Things.

This paper explains how as IoT, Vital Electronics, and related initiatives gain traction in academia and industry internationally, that the process can lead to the definition and implementation of the ABET, Inc., (Accreditation Board for Engineering and Technology) accredited Global Computer Engineering and Science Curriculum and the IEEE Certified Global Computer Engineer. An operational definition of an IEEE Certified Global Computer Engineer – is a practicing engineer possessing a dated certificate issued through an IEEE entity (could be web-accessible) stating that the holder of the certificate is sufficiently versed in the state-of-art of the topic or topics to enable him or her to successfully function in global environment.

The remainder of the paper outlines a roadmap for development and implementation of the curriculum, provides several examples of recent progress, and finally summarizes the current status of the process.

The Significance of Internet of Things

Cellular telephones[10] and the traditional World Wide Web (“W3”)[11] are focused on delivering media, conversation and data to /from human users. Both fostered innovation by offering global-scale connectivity and an open development environment [W3 managed by an informal international consortium (W3C)[11] while the several so-called 3G / 4G smart phone platforms (essentially a small personal computer with an operating system optimized for multimedia and embedded cellular radio)[10,12] controlled by one or more corporations or corporate membership groups.[12] The global development community created a cornucopia of applications from the micro-scale to macro-scale, based on their technical skills and local subject-matter expertise. Global consumers, in turn made some companies and their products wildly successful with applications ranging from games and e-commerce to those targeted at energy conservation and emergency responders.

In contrast, the IoT is the fabric enabling the networking of everyday objects (e.g. toys, tools, clothes, vehicles, household appliances, utilities, public buildings, industrial apparatus, etc.) and commonly used electromechanical systems.[1,3,13] In an article, "That 'Internet of Things' Thing," Kevin Ashton, confounder and executive director of the Auto-ID Center at MIT (the creators of the RF-ID initiative, the progenitor of the IoT)[14] writes, " In the real world, things matter more than ideas...We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory. RFID and sensor technology enable computers to observe, identify and understand the world—without the limitations of human-entered data...The Internet of Things has the potential to change the world, just as the Internet did. Maybe even more so."

Through automating the monitoring and control of our critical infrastructure and systems [Note the IoT often is couched in other related terminology such as sensor networking and Cyber Physical Systems],[13] the IoT can directly support solutions to some of the most vexing problems facing the majority of the world such as how to get a drink of clean water. The keys to this kind of success are: the shear weight of numbers;[1] advanced silicon and other core technologies for micro and nano-scale sensors and actuators (MEMS), locally embedded computation and storage; standardized interfaces for transducers, local processors; multi-scale ad hoc and pre-organized wireless communications technologies including RFID, Bluetooth, LIN, CAN, and rapidly solidifying de facto standards such as NFC;[15] a globally accessible development environment incorporating tools and libraries; and an educated development community with its local subject matter expertise.

Need for Global Education

With the economic and societal potential so great, major investments are being made worldwide by industry to develop the core technologies. What is missing are the people with the right set of engineering and systems development skills to provide the local expertise and innovation to capitalize on the silicon, nanotubes and the like. As Brig (Dr.) RS Grewal, VSM (Retd.), Vice Chancellor of Chitkara University has said,[16] "...for several reasons, India missed the Industrial Revolution – However, we are determined to do what is required to not miss the Silicon Revolution … a key step is changing the pedagogical paradigm from what to think and learn by listening to how to think and to learn by doing."

One hundred and fifty years ago William Barton Rogers founded the Massachusetts Institute of Technology (MIT),[17] with the motto of "Mens et Manus" (i.e. Mind and Hands). MIT's 150 year-old model for successful engineering education has been driven by a close coordination of theoretical concepts and laboratory exercises incorporating industrial best practices. During the past decade there have been a proliferation of well funded national and even regional universities focused on science, engineering and technology. These new "MIT's" espouse Rogers' ideas and seek to attract and international faculty, staff and student body (e.g. Saudi Arabia's King Abdula University of Science and Technology, African University of Science and Technology in Abudja Nigeria) As AUST's website states)[18] "AUST is a private, pan-African, coeducational, research university located in Abuja, Nigeria.....that combines rigorous academic study and the excitement of discovery with the support and intellectual stimulation of a diverse international and diaspora community....has tight links with industry, a strong corporate governance structure, and focuses on producing men and women with the entrepreneurial flair and compassionate spirit to help transform local communities and improve the human condition across the African continent.“

Jeffrey A. Joerres, Chairman, CEO and President, Manpower Inc., presentation at World Economic Forum, Davos Switzerland 2011 said,[19] “As the global economy shifts into recovery... A new, collaborative approach is required from government, companies and individuals to together find a way to unlock the raw human potential within their reach and then nurture and shape that potential to lead them to success...” He identified a number of steps to meet the global demand of industry for highly skilled individuals who are trained to international standards and in particular have specific skills and behaviors: 1) to engage and motivate older workers to remain in the workforce longer

2) to motivate and more effectively train the young with skills required by employers
3) to motivate individuals to maintain a “learning mindset” throughout their career

Thus today the successful curriculum must not only accommodate the needs of a global economy, it must be attractive to the best students who have many options. Some of the students will be traditional, others will be older students seeking to return to the civilian workforce, some will be practicing engineers or technicians seeking to improve their status. All will have different backgrounds and levels of motivation or accessibility to the place of education. In addition, the costs associated with the traditional engineering laboratories have priced the MIT model out of reach of the majority of potential students, many universities and even some countries. A new more “democratic”approach to computer engineering and science is needed, while continuing to adhere to the hands-on and industrial-strength laboratory principles of William Barton Rogers.

Vital Electronics Institute, Inc.

To attempt to address some of these issues the Vital Electronics Institute, Inc., (“VEI-Inc”) was established on January 06, 2011, as a Massachusetts Non Profit Corporation, to improve the global quality of life through support of education and research in Computer Engineering. The founders of VEI-Inc, and others have proposed the “Global Computer Engineering and Science Curriculum (GCESC) Capacity Building Process“ which employs the leitmotif of implementing the Internet of Things to create an environment for training Global Computer Engineers who can be successful on the world stage.

Overview of the Global Computer Engineering and Science Curriculum Capacity Building Process

The Global Computer Engineering and Science Curriculum (GCESC) Capacity Building Process capitalizes on the growing global interest in the Internet of Things to provide student motivation through a focus on entrepreneurism and practicality. It has the potential to foster community economic development through “grass-roots” entrepreneurship involved in locally implementing and taking advantage of the enabling technology of the IoT. This vital electronics initiative aims to exploit this overlap for the purpose of the fostering the creation and dissemination of a new Global Computer Engineering and Science Curriculum (GCESC) and Science Curriculum.

There are several key aspects of the process which makes it relevant both in the OECD (Organization of Economic Cooperation and Development) countries as well as the developing world.

1. It incorporates US industry “best practice” and state-of-the-art content, based on industrial technology – not just toy-based pedagogical technology.

2. It is Web-based, with publicly accessible curriculum materials and employs Programmable System on a Chip (PSoC)-based home-labs it is compatible with distance-learning and home-based education. In fact, the combination of the TakeHomeLab™[20] kits and web-based material can be delivered through traditional university classrooms, faculty or executive-style workshops, or by distance learning, wherever there is Internet access and the kits can be delivered by FedEx or the post.
3. Through the use of open source hardware and software it shares the attraction of GNU, Arduino,[21] Mbed,[22] etc., to encourage contributions from both traditional and global participants including: India, China, Brazil and the former Soviet Republics.
4. Through the hand-on approach to learning and teaching both core technology and practicum, it fosters the creation of new enterprises through innovation "Sandboxes"[23] where the future IoT implementers can learn to apply and benefit from local subject matter expertise.
5. Finally, because of the open-access for global content in tools, demonstrations and reference design libraries it can server as a conduit for the "give-back" of technological innovation developed overseas to aid the economic redevelopment of traditional industrial centers in the US.

Approach:

The basic approach to develop a scalable, state-of-the-art Computer Engineering and Science Curriculum with IEEE Certification of participants and ultimately ABET-accreditation:

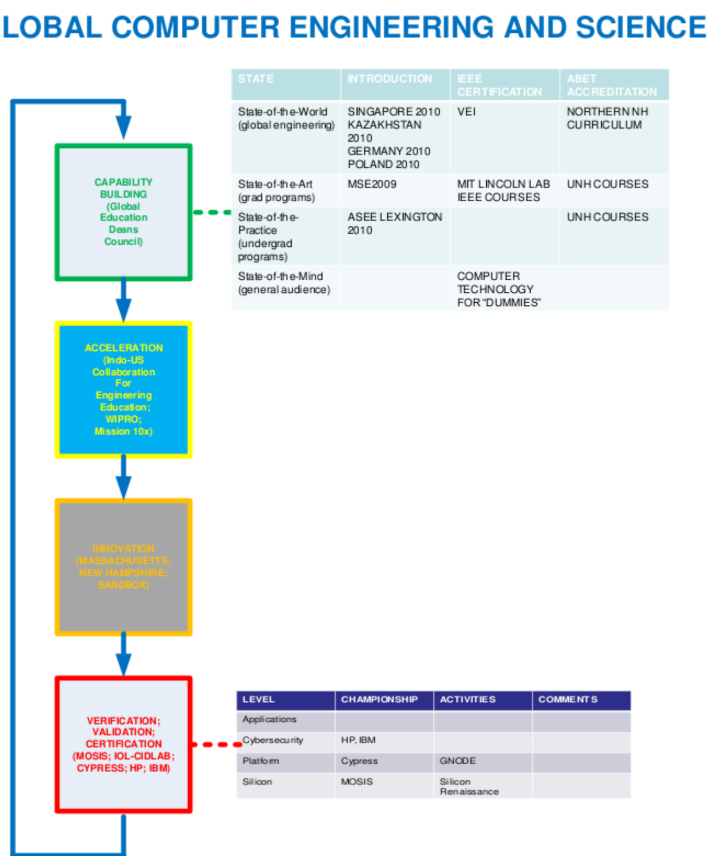
6. Begins with developing elements of the prototype curriculum using off-the-shelf tutorials, laboratory exercise, development tools and hardware where-ever possible
7. Testing these at the "alpha-state" by experienced educators and where -ever possible with experienced students
8. Begin to globally disseminate the curriculum via staged, hierarchical – IIDEA-style capacity building "Teaching the Teachers of the Teachers" seminars and workshops for faculty
9. Offer IEEE completion certificates to the faculty participants
10. Offer IEEE completion certificates to the graduates of formal university courses taught by "Certified Faculty" and also to students in continuing education courses for practicing engineers
11. Continually update both the content and means of delivery with the state-of-the-art in distance-learning and home-based education technology and practicum
12. Share the lessons-learned through IEEE, ASEE, IFEES (e.g. IIDEA workshops)[24] and other sponsored workshops, pilot courses and conferences organized by and with interested parties

Roadmap

Fig. 1 shows the four phases of the overall Global Computer Engineering and Science Curriculum Capacity Building Process: 1) Capability Building – through workshops; 2) Acceleration – through "Teaching the Teachers"; 3) Innovation – through the "sandbox" model where entrepreneurs can be fostered; 4) Verification, validation and Certification – delivering a globally dissemination product – and then the process restarts to constantly keep up with evolving technology and applications.

Figure 1:

Showing four phases of the overall Global Computer Engineering and Science Curriculum Capacity Building Process



STATE	INTRODUCTION	IEEE CERTIFICATION	ABET ACCREDITATION
State-of-the-World (global engineering)	SINGAPORE 2010 KAZAKHSTAN 2010 GERMANY 2010 POLAND 2010	VEI	NORTHERN NH CURRICULUM
State-of-the-Art (grad programs)	MSE2009	MIT LINCOLN LAB IEEE COURSES	UNH COURSES
State-of-the-Practice (undergrad programs)	ASEE LEXINGTON 2010		UNH COURSES
State-of-the-Mind (general audience)		COMPUTER TECHNOLOGY FOR "DUMMIES"	

LEVEL	CHAMPIONSHIP	ACTIVITIES	COMMENTS
Applications			
Cybersecurity	HP, IBM		
Platform	Cypress	GNODE	
Silicon	MOSIS	Silicon Renaissance	

Milestones

The concept of Vital Electronics

Created by the microelectronics education community meeting at the 7th IEEE International Conference on Microelectronic Systems Education (MSE 2009), in San Francisco in July 2009. The MSE attendees were reacting to decline student enrolling in computer hardware development and VLSI design classes has declined, while the number of students enrolling in primarily software and webware development courses continues to rise. The Vital Electronics based curriculum seeks to connect "State of the Art" to "State of the Practice". The initial push is to develop standards for the interfaces between sensors, actuators and Programmable System on Chip and various local networks. With such standards it will eventually be possible to develop self-configuring smart environments by combining these techniques with the IoT and Cyber Physical Systems.

Introduction of the concept of "In situ Hardware Development"

One of the goals of the Vital Electronics Initiative is to balance the enrollments between hardware and software development courses and areas of concentration. In-situ Hardware Development takes advantage of the rapidly evolving and maturing core microelectronics, sensors /actuators (e.g. MEMS), and networking technologies. Vital Electronics through In situ Hardware Development provides a set of rules and a design methodology to enable, reliable, efficient, inexpensive systems and systems of systems. These enable the cost-effective, efficient and globally-accessible implementation of the Internet of Things and Cyber Physical Systems, capitalizing on local subject matter expertise. As a consequence Vital Electronics has the potential to re-ignite hardware-based entrepreneurship and re-energize the teaching of Computer Engineering.

The Draft Global Computer Eduction Curriculum

Currently is being piloted through traditional university courses, executive-level 1 or two day classes, and as IEEE-sponsored continuing education short courses for practicing engineers. In the last twelve months, Vital Electronics based curricula have been taught at two Boston Area IEEE short courses (e.g. "Building the Internet of Things (IoT) with Vital Electronics: Hands-on Introduction to using Cypress

PSoC® to Interface Sensors / Actuators”) as well as UNH ECE994. “Vital Electronics: Computing Using Programmable System on Chip” is a graduate level course taught by Dr. Andrzej Rucinski at the University of New Hampshire in the Fall 2010 term. A textbook is being developed along with the course material.

In order to produce global computer engineers, the curriculum needs to include: 1) Web-based tutorials on theory and up-to-date underlying technology fundamentals; 2) Teaching the “state of the art,” through hands-on home-laboratory exercises and then "spreading the wealth" with capacity building; 3) Applying “state of the practice,” skills to solve real problems using industry-standard technology; 4) encouraging global innovation and creating new breeds of enterprises taking advantage of subject matter expertise and relevant local knowledge; 5) Appropriate political and financial support from governments and NGOs. The combination of a home lab kit and web-based content engages students who have left the university for full-time employment, or who can only spend a brief time at the university before returning to their remote home area.

ECE994 multidisciplinary course

Taught in the evenings with the Far View distant learning option. Some of the course sessions were taught with the instructor as far away as Poland and Singapore and with students on the US East and West Coasts and as far away as Beijing China. ECE students focused on the development of a vital electronics design methodology (integrating sensing, processing, communicating and controlling) whereas non-ECE students concentrated on in situ hardware development of Cypress PSoC®-based Vital Embedded Computers (exploring innovation and entrepreneurship), and practical applications. There were four mandatory laboratories associated with the course. Two projects came out of the inaugural ECE994 class.

Enhanced Precision Maritime Data Acquisition Based on the PSoC Environment

A tremendous amount of various data types are required in order to effectively analyze the dynamics of the earth’s oceans. Accurate coastal ocean data has a wide variety of essential applications in modern society. Such data may be used to reduce a search radius during a search and rescue mission or to better track weather patterns and storm trajectory, effectively minimizing damage and casualties. Furthermore, during the aftermath of such a disaster, data may be used to track masses of ocean debris, such as an oil slick. Through extensive analysis of accurate ocean dynamic data, these functional analyses are certain to increase in efficiency and accuracy over time.
It is proposed that a network of nodes is deployed in a grid formation in areas where ocean dynamics are of high interest. Areas of such interest may include popular tourist destinations, high traffic commercial waterways and coastlines with high tropical storm or similar natural disaster frequency. Nodes may also be deployed “on demand” in the event of a natural disaster or search and rescue mission. A grid of nodes may be deployed in an area of interest in order to gather pertinent data that might be used in order to narrow down a search radius or track debris on the ocean surface.

2. CubeSAT Discriminator Project

The goal of the project is to create a 12-bit magnitude sorter a system that will serve as a critical part of CubeSAT hardware. Specifically, the element will compare data to a number of ranges. The number of values that fall in each range is counted, and the data is stored in a memory system associated with each range. It will be prototyped using PSoC and when the design meets the specifications, the part will be implemented using VLSI as an ASIC.

Course Results

While both of these projects were not completely successful, they provided some solid “alpha-level” test of the experimental course (general tenor of the student feedback – did they feel they learned something in the course?) Since the course was taught literally all over the world (Europe, Asia, USA), the proof of concept that this type of course can be web based is validated. 2) and 3) are partially addressed by the fact that the problems are addressed by using “state of the art” technology and “state of the practice” skills (some of which were learned in ECE994) to partially at least solve two real world problems. 4) will take time to develop as 1), 2), and 3) are implemented.

Figure 2:

Collage of images collected during the UNH “ECE994 multidisciplinary course,” October – November 2010, including vignettes of students working on projects at the UNH CIDLab; and a Far View presentation broadcast from CIDLab to remotely located students

IEEE Lecture Series

In the Fall of 2010, much of the developing material was presented to practicing engineers at an IEEE lecture series sponsored by the Boston Section, “Building the “Internet of Things” (IoT) with Vital Electronics: Hands-on Introduction to using Cypress PSoC® to Interface Sensors / Actuators,” held at MIT Lincoln Laboratory (15 hours of material presented on 6 evenings, one night per week).
From the promotional literature:

> *“ The course enables the subject matter expert, you, to create The Internet of Things, using the principles of Vital Electronics and Cypress PSoC devices....*
>
> *Objective: To learn the “tricks of the trade” to design and implement practical embedded system applications incorporating sensors/actuators and Cypress PSoC 3/5*
>
> *Approach: Hands-on in-class Tutorial & “TakeHomeLabs” with Cypress PSoC® Development Kit (CY8CKIT) employing the 4 Step Vital Electronics education process:*
>
> *1. Learn about: Vital Electronics, Application-centric computers, PSoC 101, Embedded Systems, Sensors, Communication and Networking*
>
> *2. Teach yourself and then others in-situ hardware development (Software/Hardware Co-design, Reconfigurability)*
>
> *3. Apply your knowledge of Vital Electronics, PSoC’s and in-situ hardware development to your field of expertise*
>
> *4. Create new enterprises based on local solutions to Globalization Challenges*

However, due to the extended time available for homework, and the high level of systems engineering expertise of the attendees, this was essentially an advanced alpha test of the tutorial material – but not the format. In addition, due to the fact that the silicon and software tools were still being updated frequently by Cypress, not all of the hands-on laboratory exercises were finalized.
Fig. 3., shows a number of individual vignettes associated with the IEEE lecture series. The series included lectures on the fundamentals, hands-on tutorials using the assisted by local Cypress

Semiconductor engineers, demonstrations by graduate students

Figure 3:

Collage of images collected during the IEEE lecture series sponsored by the Boston Section, “Building the “Internet of Things” (IoT) with Vital Electronics: Hands-on Introduction to using Cypress PSoC® to Interface Sensors / Actuators,” held at MIT Lincoln Laboratory, October – November 2010

Incorporation of Vital Electronics Institute, Inc.

The Vital Electronics Institute, Inc., (“VEI-Inc”) was established on January 06, 2011, as a Massachusetts Non Profit Corporation, to improve the global quality of life through support of education and research in Computer Engineering.

Current status

Projects currently underdevelopment for 2011 include:

IIDEA – compatible capacity building workshops [ref IFEES IIDEA] in: Europe; Kazakhstan (Kazakhstan National University, East Kazakhstan Technical University); India (under the auspices of the Indo-US Collaboration for Engineering Education with cooperation and support of the Mission 10X); China; US (Merrimack Valley “sandbox”)

Curriculum development with World Bank, South Asia Region

Conclusion and Looking Forward:

In this paper, we have presented a program for motivating, teaching and disseminating a Vital Electronics-based Computer Engineering and Science curriculum for global audiences. Using the challenges and opportunities associated with the Internet of Things offers a motivation and mechanism to teach practical problem solving and enable innovation which is compatible with countries having a low level of technical infrastructure. Through the curriculum, students learn the concepts of In-situ Hardware and firmware design, and how they can be utilized to build Vital Electronics Computer-based systems to protect, save and improve critical infrastructure. The next steps in the process are: to complete the textbook and curriculum; test it locally; revise and then test again at some remote [preferably foreign] site which is unfamiliar with the traditional US /EU development environment.

REFERENCES

1. Sensors empower the "Internet of Things," Margery Conner, EDN, pp. 32–38, May 27, 2010, www.edn.com/file/25268Sensors_empower_the_Internet_of_Things_pdf.pdf

2. Internet of Things Strategic Research Roadmap, Cluster of European Research Projects on the Internet of Things (CERP-IoT), Patrick Guillemin, CERP-IoT Coordinator, Peter Friess, CERP-IoT EC Coordinator, European Commission, Ovidiu Vermesan, Mark Harrison, Harald Vogt, Kostas Kalaboukas, Maurizio Tomasella, Karel Wouters, Sergio Gusmeroli, Stephan Haller,15 SEPTEMBER, 2009 , on the web at http://www.internet-of-things-research.eu/

3. Vision and Challenges for Realising the Internet of Things, Edited by Harald Sundmaeker, Patrick

Guillemin, Peter Friess, Sylvie Woelfflé, For further information: Information Desk European Commission - Information Society and Media DG, Office: BU25 02/59 B-1049 Brussels, http://europa.eu/information_society, Luxembourg: Publications Office of the European Union, 2010, ISBN 978-92-79-15088-3, doi:10.2759/26127, © European Union, March 2010

4. internetofthings.org is an online publication for Internet of things field. Our slogan is “Everything on Internet of Things”. Latest news, research activities on Internet of things. We also provide consultancy for customers http://www.internetofthing.org/

5. The Internet of Things Council, Council is a thinktank, consultancy, accelarator and forecasting group http://www.theinternetofthings.eu/

6. A Pilot Course in Vital Electronics, Jerry Gulley, Friedrich Holl, Thaddeus P. Kochanski, Andrzej Rucinski, presented at the 8th European Workshop on Microelectronics Education, EWME2010, May 10-12, 2010, Darmstadt, Germany, available on the web http://www.mes.tu-darmstadt.de/conf/ewme2010/proceedings/proceedings.en.jsp

7. PSOC Embedded Systems and its Potential Application in Wireless Sensors Network, Krzysztof Bikonis, Andrzej Rucinski, Ted Kochanski, proceedings of the Special Session on Vital Electronics of the 2nd International Conference on Information Technology, Gdansk University of Technology Faculty of ETI Annals, Information Technologies, vol. 18, pp. 249, Alicja Konczakowska, Lech Hasse, ed., Wydzial ETI Politechniki Gdańskiej, 2010, Gdańsk, Poland

8. Vital Electronics: Application-Centric approach to Computer Engineering and Computer Science, Krzysztof Bikonis, Harry Charache, Stephen Doran, Ted Kochanski, Douglas McMillan, Wolfgang Rehak, Andrzej Rucinski, Andrzej Stepnowski, Jerzy Zurek, proceedings of the Special Session on Vital Electronics of the 2nd International Conference on Information Technology, Gdansk University of Technology Faculty of ETI Annals, Information Technologies, vol. 18, pp. 255, Alicja Konczakowska, Lech Hasse, ed., Wydzial ETI Politechniki Gdańskiej, 2010, Gdańsk, Poland

9. Responding to Global Engineering Education Challenges, Alex Doboli, Ted Kochanski, Karen Panetta, Andrzej Rucinski 9th Annual ASEE Global Colloquium on Engineering Education, October 18-21, 2010, Singapore - Marina Bay Sands Hotel

10. The Smartphone reborn at CES? 10 Jan 2011 by Arthur Goldstuck, Filed in Goldstuck on Gadgets, http://www.gadget.co.za/pebble.asp?relid=2546

11. Standards, W3C develops technical specifications and guidelines through a process designed to maximize consensus about the content of a technical report, to ensure high technical and editorial quality, and to earn endorsement by W3C and the broader community, http://www.w3.org/standards/

12. Android is an open-source software stack for mobile devices, and a corresponding open-source project led by Google. Android 2.3.3 adds enhanced Near-Field Communications support to the Android APIs. The source code for the Android 2.3 platform and software stack has been released Here you can find the information and source code you need to build an Android-compatible device. http://developer.android.com/index.html

13. Foundations of Cyber Physical Systems, Center for Hybrid and Embedded Software Systems, http://chess.eecs.berkeley.edu/cps/

14. RFID Journal That 'Internet of Things' Thing; In the real world, things matter more than ideas, By Kevin Ashton June 22, 2009, http://www.rfidjournal.com/article/view/4986

1. NFC Forum The Near Field Communication Forum was formed to advance the use of Near Field

Communication technology by developing specifications, ensuring interoperability among devices and services, and educating the market about NFC technology. http://www.nfc-forum.org/aboutus/

2. Brig (Dr.) RS Grewal, VSM (Retd.), Vice Chancellor of Chitkara University, "Imperatives for an Operative Engineering Pipeline" presented at the "9th Annual ASEE Global Colloquium on Engineering Education" in Singapore, article in Tribune of India, [edition pub in Chandigarh, India] http://www.tribuneindia.com/2011/20110208/edu.htm#2] and private communication.
3. Objects and Plan of an Institute of Technology, William Barton Rogers Papers, MIT Libraries. T171.M44 1860 (MC 1), box 12, folder 183, See also MIT Corporation Records (AC 278), box 1, vol. 1, pp. 43-44.
4. http://aust.edu.ng/content/about-aust
5. Jeffrey A. Joerres, Chairman, CEO and President, Manpower Inc. from his presentation at World Economic Forum, Davos Switzerland 2011 and also his introduction to electronic book "ENTERING THE HUMAN AGE: Thought Leadership Insights; Introduction by Jeffrey A. Joerres" available @ http://www.manpower.com/humanage/index.html
6. TakeHomeLab™ is a trade mark of the Vital Electronics Institute, Inc., for a family of laboratory kits containing all of the elements necessary to teach the method of In-situ Hardware Development using the Cypress PSoC technology platform
7. (Merrimack Valley "sandbox")
8. The International Federation of Engineering Education Societies (IFEES), 1818 N Street, N.W., Suite 600, Washington, DC 20036-2479, see http://www.ifees.net/news/IIDEAversionFINALJune262010.docx
9. http://www.arduino.cc/
10. www.mbed.org