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Digital Technology Education Collaborative Third Year Progress Report

Dr. Nasser Alaraje, Michigan Technological University

Dr. Alaraje is an Associate Professor and Program Chair of Electrical Engineering Technology in the School of Technology at Michigan Tech. Prior to his faculty appointment, he was employed by Lucent Technologies as a hardware design engineer, from 1997- 2002, and by vLogix as chief hardware design engineer, from 2002-2004. Dr. Alaraje's research interests focus on processor architecture, System-on-Chip design methodology, Field-Programmable Logic Array (FPGA) architecture and design methodology, Engineering Technology Education, and hardware description language modeling. Dr. Alaraje is a 2013-2014 Fulbright scholarship recipient at Qatar University, where he taught courses on Embedded Systems. Additionally, Dr. Alaraje is a recipient of an NSF award for a digital logic design curriculum revision in collaboration with the College of Lake County in Illinois, and a NSF award in collaboration with the University of New Mexico, Drake State Technical College, and Chandler-Gilbert Community College. The award focused on expanding outreach activities to increase the awareness of potential college students about career opportunities in electronics technologies. Dr. Alaraje is a member of the American Society for Engineering Education (ASEE), a member of the ASEE Electrical and Computer Engineering Division, a member of the ASEE Engineering Technology Division, a senior member of the Institute of Electrical & Electronic Engineers (IEEE), and a member of the Electrical and Computer Engineering Technology Department Heads Association (ECETDHA).

Prof. Aleksandr Sergeyev, Michigan Technological University

Aleksandr Sergeyev is currently an Associate Professor in the Electrical Engineering Technology program in the School of Technology at Michigan Technological University. Dr. Aleksandr Sergeyev earned his bachelor degree in Electrical Engineering at Moscow University of Electronics and Automation in 1995. He obtained the Master degree in Physics from Michigan Technological University in 2004 and the PhD degree in Electrical Engineering from Michigan Technological University in 2007. Dr. Aleksandr Sergeyev's research interests include high energy laser propagation through the turbulent atmosphere, developing advanced control algorithms for wavefront sensing and mitigating effects of the turbulent atmosphere, digital inline holography, digital signal processing, and laser spectroscopy. Dr. Sergeyev is a member of ASEE, IEEE, SPIE and is actively involved in promoting engineering education.

Dr. John Reutter III, J.F. Drake State Community and Technical College

Dr. John Reutter is Dean of Research and Planning Drake State Community and Technical College with responsibility for guiding the College's strategic planning process and developing and administering grant projects. Over the past five years, Dr. Reutter has secured more than $20 million in grant funds for the college. Previously, he served as Dean of Instruction for two Alabama community colleges and also taught computer science classes for over 28 years at various colleges and universities in California and Alabama. He is a Senior Fellow of the IEEE Society and the founder of two Silicon Valley software companies. Dr. Reutter began employment at Drake State in 2006 as Dean of Instruction and assisted the President in spearheading the campus efforts to achieve regional accreditation with the Southern Association of Colleges and Schools Commission on Colleges. He was previously involved in SACSCOC reaffirmation efforts at three other Alabama colleges before joining the Drake State family. He is the author of Data Processing Systems and Concepts, a McGraw-Hill textbook published in 1977 and earned his doctorate in higher education administration from the University of Alabama in 2004.

Mr. Craig J. Kief, COSMIAC at UNM

Mr. Craig Kief (PI) is the Deputy Director of COSMIAC and the Program Manager for the ORS Squared Satellite. Kief is a Research Scholar on the faculty at the University of New Mexico. Mr. Kief has more than 32 years of experience in computer and satellite communications, including voice and data networks, testing, troubleshooting, debugging, system administration, embedded software development, software/hardware integration, and network monitoring. Mr. Kief has an extensive background in the design of systems based upon microcontrollers and FPGAs. Kief retired from the Air Force in 1998 following 20 years of military service. His final military assignment was at the Air Force Operational Test and Evaluation Center (AFOTEC) at Kirtland Air Force Base. Kief holds a B.S. and M.S. in Computer Engineering from the University of New Mexico. He has published and taught in the areas of digital and programmable logic, satellite design, and system verification and validation. He is also an IEEE senior member.

Mr. Bassam H Matar, Chandler Gilbert Community College

Bassam Matar started his career at Glendale Community College (GCC) teaching engineering, electronics and semiconductor classes. Through his eleven years teaching at GCC, Bassam developed a variety of courses in these fields. He served on several committees, such as budget, computer technology, advanced technology partnership and industry advisory. Also, he served as assistant chair for the last five years before transferring to Gilbert-Chandler Community College (GCCC). He implemented GCCC's engineering program in Fall 2001 and is responsible for its success. He has served as a PI or Co-PI on seven NSF-funded grants. Mr. Matar is also a lecturer faculty for the Electrical Engineering Department at Arizona State University. Bassam Matar, has taught for more than 26 years. Mr. Matar received the following awards:(Summer 1999) Motorola Educator of the Year award; (Spring 2000) National Institute for Staff and Organizational Development award; (Fall 2009) Gilbert Community Excellence Awards; (Spring 2010) Electronic Engineering Times (EE Times)– Educator of the Year Award. Mr. Matar is a member of Engineering Articulation Task Force, and the American Association of Engineering Education.

Mr. David M. Hata, TEMPlaTe Educational Consulting

David M. Hata is an independent contractor specializing in evaluation of National Science Foundation funded projects. He currently serves as External Evaluator for the DigiTEC Project, the Mentor-Connect Project, the South Carolina ATE Center of Excellence, and three small ATE projects. Mr. Hata taught at Portland Community College for 32 years before retiring in 2003. He is a life member of ASEE and the IEEE.

Digital Technology Education Collaborative Third Year Progress Report

Abstract

The electronics world is undergoing a transformation in the underlying technologies used to create new products for the world's consumers. The movement to reconfigurable digital systems using Field Programmable Gate Arrays (FPGAs) and microcontrollers is sweeping the electronics world in the rush to create smaller, faster, and more flexible consumer and industrial devices. J. F. Drake State Community College has put together a team of educational partners spanning the country with the background and skills necessary to create a vibrant virtual center. Team members include colleges and universities with a history of reaching out to minority and under-served student populations. Partners on this project have years of successful National Science Foundation project implementations educating and training hundreds of instructors and introducing thousands of students to advanced technologies. The goal of this project is to offer an unprecedented opportunity to bring America's technicians directly to this cutting edge of reconfigurable electronics technology.

This project will substantially update digital logic courses by providing the tools and curricular materials needed to replace the now outdated materials most commonly used. The updated curriculum will greatly enhance competitiveness for community college graduates seeking to enter the job market or undergraduate engineering programs. Secondly, the project will provide colleges with educational equipment up-to-date with current technological solutions. Most importantly, the project will bring new excitement to education by introducing reconfigurable electronics with a new world of possibilities for student projects, such as robot competitions, video game design, embedded systems and more. Finally, the project will develop industry, K-12 and university partnerships to facilitate pathways to careers in the exciting field of reconfigurable electronics for first-generation, minority and other under-served populations, including veterans. In summary, this project will provide the training and educational resources and promote best practices for community college, university, and high school instructors to enable them to teach new hardware technologies to a broad range of students, including those who have not previously had access to this level of training and career choice.

The paper will address third year project activities including the Faculty Professional Development workshop on Field Programmable Gate Arrays (FPGAs) and ARM-based microcontrollers, assessment results and lessons learned, the summer outreach activity happened at partner institutions, and finally, the undergraduate research internship experience.

I. Introduction

In general Programmable Logic Devices and FPGA-based re-programmable logic design became more attractive as a design media during the last decade, and as a result, industrial use of FPGA in digital logic design is increasing rapidly. Considering the following technology trend in industry, the need for highly qualified logic designers with FPGA expertise is increasing rapidly. According to the United States Department of Labor, the job outlook is on the rise and will continue to expand for at least the short- to medium-term future [1]. To respond to the industry needs for FPGA design skills, universities are updating their curriculum with courses in hardware description languages and programmable logic design. Although most traditional electrical and computer engineering programs have updated their curriculum to include topics in hardware description language and programmable logic design (FPGA/CPLD), only 19.5 % of 4-year and 16.5 % of 2-year electrical and computer engineering technology programs at US academic institutions currently have a curriculum component in hardware description language and programmable logic design [2].

To effectively meet the next generation's workforce needs, the electrical and computer engineering technology curriculum must be current, relevant, and teach technology that is widely used in industry. Responding to this need, J. F. Drake State Technical College and its partner institutions (including Michigan Technological University, University of New Mexico, and Chandler-Gilbert Community College) proposed utilizing highly-qualified academic and industry-experienced resources to develop and implement online and technology-enabled courses and learning projects that will be scaled up to reach significant numbers of diverse instructors and students over a large geographic area. These collaborative efforts will satisfy this critical need for trained instructors and students in the technology of reconfigurable solutions. Additionally, the project will expand and improve the delivery of education and training material and provide students and workshop participants with the critical skills sought by diverse electronics industries across the United States. Strategic partnerships in key geographic areas will help underrepresented and unemployed populations advance their skills and training to become eligible for high-wage, high-demand positions in reconfigurable electronics systems. The participating universities and community colleges serve large minority populations (Hispanic, Native Americans, and African-American) in the Southwest and Southeast regions of the United States.

To expand their capacities and create a sustainable educational system for developing electronics technicians, partner institutions will be equipped with reconfigurable electronics laboratories dedicated to delivering curriculum, professional development, and outreach activities that will draw high school students into programs to expand the number and diversity of highly-skilled workers for the targeted industries and accelerate the introduction of qualified workers into the pool of skilled technicians needed by electronics firms. This pool of highly-skilled technicians will be built and sustained by strengthening and expanding community college and university partnerships with K-12 systems, affiliate community colleges, and established industry partners. The partnering universities will assist the community college partners in implementing this already successful workforce development model into their local geographic areas, leveraging the impact of ATE funds, expanding the geographic reach of the proposed program, and developing a nationwide model of successful partnership.

II. Faculty Professional Development Workshop

Hardware Description Languages (HDL), microcontrollers, and FPGAs have revolutionized the way digital logic design should be taught and implemented. Traditional ways of teaching logic design using discrete components (e.g., TTL and CMOS) have been replaced by Programmable Logic Devices. Today, a more standard development process is widely used in industry, incorporating HDL as a design entry to describe the digital systems. In the past 20 years electronic devices have gone from thousands of logic gates to millions of logic gates. Similarly, solutions that previously required boards full of electronics are now available through single-chip solutions. The two largest FPGA manufacturers are the Xilinx and the Altera Corporations. The

Project team has subject matter experts on all forms of FPGA technology, including system-on-a-chip and embedded processor capability.

It is clear that the old way of teaching digital electronics, with 7400 series logic gate chips, needs to adapt to the influx of new technology. This cost effective path of reconfigurable electronic development is not going away, it proves to be the most efficient and adaptable components in many industrial applications. For these reasons, industry will continue to employ these tools for years to come. Community college and 4-year technical program graduates must be prepared to work with these devices throughout their career. It is imperative that they receive the proper training on these devices to draw employment opportunities back to this country. By providing a state-of-the-art learning environment, technicians and technologists can become more competitive within the workplace. The project will help community colleges and 2- and 4-year university-based technical programs to update curricula to meet the expectations of industry by supplying qualified technicians and technologists who have extensive hands-on experience with current design tools. By developing a curriculum that includes hands-on re-configurable electronics laboratories, we will be able to provide students in these programs state-of-the-art training tools that match the expectations of industry.

FPGAs

FPGAs were created approximately 15 years ago by the Xilinx Corporation [3]. Xilinx is still the largest manufacturer of this technology in the world [4]. FPGAs are not only programmed through a traditional schematic fashion, they are also programmed using HDL. HDL is used to describe the behavior of the circuits that are being created. Although HDLs describe nearly all advanced circuits, certain circuits can be automatically synthesized, meaning that HDL code can be rendered from a computer directly into a working design. This is particularly true of "reconfigurable logic," which includes structured Application Specific Integrated Circuits (ASICs) and the highly versatile FPGA. Many types of FPGAs are reprogrammable, so it is possible for a talented designer to change a digital circuit with instantaneous results. Government and industry have great interest in the many uses of FPGAs; applications range from telecommunications to automotive. Additionally, FPGAs are an ideal teaching tool; they are well-suited as an introduction to the basic digital logic design skills required from today's technician. Inexpensive FPGAs can train students in these exciting digital design concepts while allowing them to rapidly move toward advanced design subjects. FPGAs are rapidly assuming the role of the new "breadboard." They are inexpensive enough that students can have their own hardware at home. Figure 1 shows the basic block diagram of an FPGA [5]. The FPGA has two main components. The input and output (I/O) blocks provide formatting and interconnection to the outside world. They handle a wide range of different

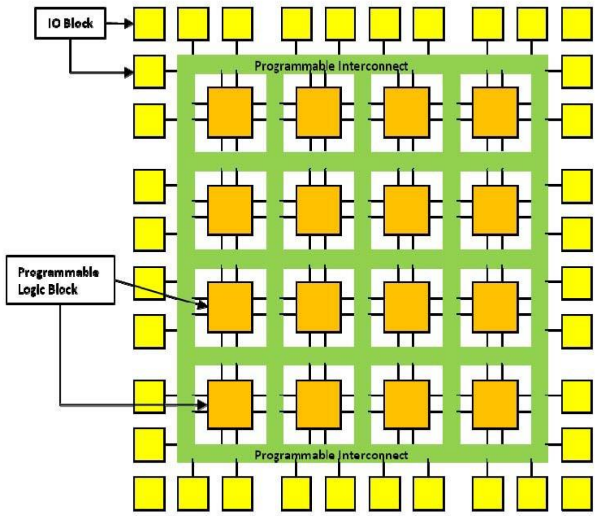

Figure 1. FPGA Block Diagram

voltage and data formats. The logic blocks are composed of three basic elements: a look-up table, a D flip-flop, and the carry logic. There are hundreds of thousands of these on even the most inexpensive FPGA. Finally, the FPGA contains programmable interconnects that dynamically connect the I/O blocks to the programmable logic blocks. There are many ways to design for FPGAs. Figure 2 shows the standard design flow for working with these devices. The hardware and design flow for FPGAs will be explored during both the beginner and advanced workshops offered through this project.

Although FPGAs are only one type of reconfigurable logic, their importance can't be overstated. According to the EE Times [6], "more than 90% of all ASICs today are either partially or completely prototyped as FPGAs before proceeding to creation of an ASIC." FPGAs allow companies (large and small) to respond directly to the market with instant gratification in complex advanced circuitry with very low barriers to entry (the design tools introduced in the courses are free). Estimated sales of FPGAs reached $1.9B in 2005, with predictions showing growth of 20% through 2015 [7]. The demand in the FPGA field alone has created an enormous unsatisfied demand for engineers and technicians skilled in this modern art. Median salaries for FPGA designers with three years of experience are approximately $90,000 and technicians with these most modern skills are very rare and command starting salaries of $50,000 [8].

Recent research corroborates that the VHDL and FPGA design skills are industry-relevant. In one study, Furtner and Widmer conducted an employer survey to rank currently taught logic design concepts at Purdue University. The survey included questions about many topics that are heavily explained in logic design courses such as Boolean algebra, design simplifications using K-Maps or Quince-McCluskey, and design implementation using discrete gates. Each was given a low priority from the employer perspective. In contrast, topics covering design with hardware description language (such as VHDL or Verilog) received high-priority rankings [2].

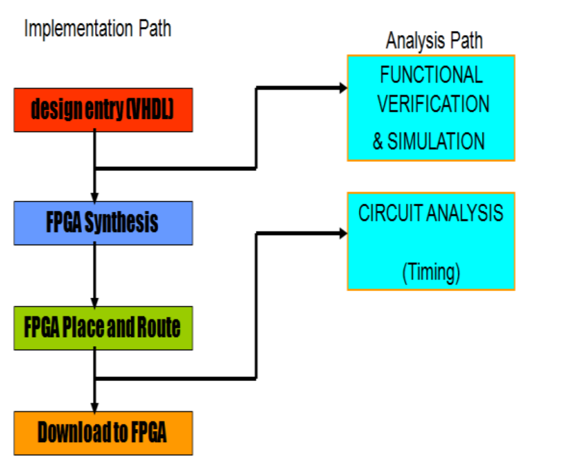

Figure 2. Design Flow

Another very popular form of configurable electronics systems is the microcontroller. Microcontrollers are the 'little brother' to an FPGA. These low-power systems provide a cost-effective, simpler alternative to the thousand-pin high performance processing capability of FPGAs—this less-expensive technology can be used to control smaller systems. They are often the device of choice when teaching controls courses as they are easy to understand and less complicated to work with than traditional microprocessors.

Microcontrollers

Microcontrollers are rapidly becoming one of the most exciting devices in history. The average homeowner of the future will most likely have every aspect of their home designed around them. While an FPGA can serve as a control system, every other device in the home – from lights, home electronics, and appliances – will be interfaced through microcontrollers. With these tools, a homeowner will be able to log into their "home" and control every electronic component from the convenience of their handheld device. This same analogy can be applied to cars, businesses, and limitless other possibilities through the use of microcontrollers. One microcontroller can manage hundreds of sensors through a single I^2C bus. A microcontroller is a small computer on a single integrated circuit, containing a processor core, memory, and programmable input/output peripherals, as shown in Figure 3. The microcontroller that the team proposes using for the courses is the TI ARM [9], which is based on an ARM processor. The ARM processor is an industry standard. Isuppli, a well-known market research firm, has confirmed that sales of ARM core processors are currently at 5 billion units per year and sales are predicted to increase as the demand for powerful, low-power electronics also increases [10, 11]. An engineer's and technician's exposure to and training in this new technology is critical in order to remain competitive in the ever-changing marketplace.

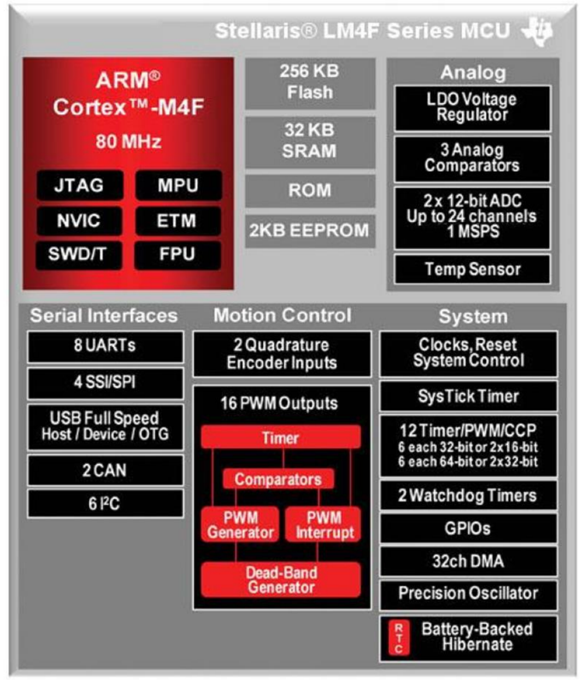

Figure 3. ARM Overview

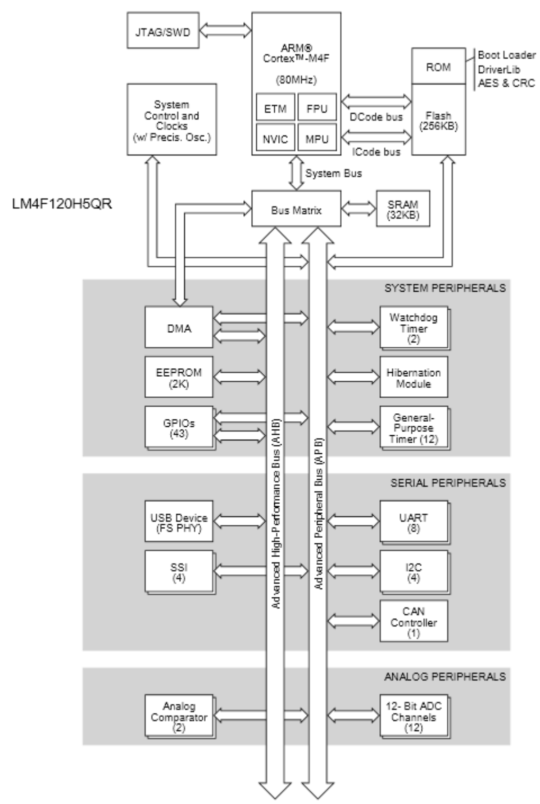

Figure 4. ARM Block Diagram

The benefits that microcontrollers have over FPGAs are their small size, low power consumption and analog capability. Figure 4 shows some of these capabilities. Microcontrollers can be mounted into everything from light switches to microwave ovens. Large, complex systems often have an FPGA as the main control system (a hub) and microcontrollers to control individual components (spokes). It isn't necessary for technicians to be experts in all aspects of these two technologies; however, it is crucial for them to have at least a working knowledge of these new systems.

Course Format

All workshops were two days in duration and were taught on Friday and Saturday. This has proven over the years to be the right amount of time for maximum instructor training without removing instructors from the classroom longer than necessary.

III. Year 3 Project Activities:

1. Faculty Professional Development Workshops:

During Project Year 3, the DigiTEC Project presented four ARM Microcontroller Workshops. These workshops were held at North Seattle Community College (WA), SUNY – Farmingdale (NY), Lorain Community College (OH), and J.F. Drake State Technical College (AL). Fifty-one educators attended these workshops. Approximately half of them were currently teaching microcontroller technology, albeit not ARM processors. Over half of the faculty indicated that they plan to integrate workshop material and/or lab experiments in the courses that they teach.

Assessment is a vital part of any curriculum reform project and helps provide useful information for workshop enhancements and determining if the workshop has met its objectives. An evaluation plan has been implemented for the project that uses a value-creation evaluation framework to determine the merit or worth of the project. To date, evaluation activities have measured the “Immediate Value” and “Potential Value” of the project sponsored activities. Evaluation activities are now focusing on measuring the “Applied Value” by tracking students impacted by outreach activities and surveying educators who participated in the microcontroller workshops. The “Realized Value” produced by the project will focus on the number of students from outreach activities that enter two-year technical programs and the number of graduates from two-year technical programs who have a working knowledge of microcontroller technology.

Workshop attendees gain “immediate value” by participating in workshop activities. This immediate value is gained through the information presented and the activities, e.g. presentations and laboratory exercises. Immediate value is assessed through pre-workshop and post-workshop surveys. The post-workshop surveys will also point to “potential value,” i.e. the intent to integrate workshop material into the classes that they teach or in other professional activities if they don’t teach. The “Applied Value” surveys have been conducted during fall semester 2014 and spring semester 2015. The survey queried all educators who have attended the microcontroller workshops since the project began. Over one-fourth of the educators who attend a workshop apply their knowledge and deliver microcontroller instruction at their institution. During the 2014-15 academic year, these educators reported that approximately 23,000 student-hours of microcontroller instruction were delivered. This instruction in microcontroller technologies impacted 225 students in two-year colleges and 235 students at four-year institutions. Regarding immediate value, 48 faculty attended (25 community college instructors, 23 four-year engineering technology professors). Twenty-nine out of 48 (60%) educators currently teach microcontrollers in their classes. On the other hand, for potential values, 39 out of

48 (81%) educators plan to incorporate workshop material into the classes that they teach, either during the 2015-16 academic year or the 2016-17 academic year.

"Realized value" is the number of potential students who actually enroll in two-year technical programs and the number of graduates from two-year technical programs who enter the technician workforce. Enrollment data and graduate information will be obtained via surveys sent to partner sites and workshop participants. Table 1 summarizes the survey data for community colleges and Table 2 summarizes the survey data for four-year colleges and universities. Note: A "student-hour" of instruction equals one student receiving one hour of instruction and is computed on a class-by-class basis.

Category (Community Colleges)	**Fall 2014**	**Spring 2015**	**Total for Year**
No. of Educators	6	7	13
Students Impacted	119	106	225
Instructional Hours	322	114	436
Student Hours	5,749	1,532	7,281
Gender:			
Male	100	99	199
Female	8	7	15
Ethnicity:			
Caucasian	71	87	158
Hispanic	13	8	21
Asian/Pacific Is.	7	6	13
African-American	8	3	11
Native-American	0	1	1
Other Ethnicity	9	1	10

Table 1. "Applied Value" survey results for fall semester 2014 and spring semester 2015 at community colleges.

Category (Four-Year Colleges)	**Fall 2014**	**Spring 2015**	**Total for Year**
No. of Educators	4	7	11
Students Impacted	127	108	235
Instructional Hours	349	372	721
Student Hours	7,419	8,301	15,720
Gender:			
Male	116	97	213
Female	11	11	22
Ethnicity:			
Caucasian	49	63	112
Hispanic	35	25	60
Asian/Pacific Is.	26	12	38
African-American	7	5	12
Native-American	0	0	0
Other Ethnicity	10	3	13

Table 2. "Applied Value" survey results for fall semester 2014 and spring semester 2015 at four-year colleges.

A total of 23,000 student-hours of microcontroller instruction was delivered at the college level during the 2014-15 academic year. The number of student-hours of instruction delivered at the four-year level was double that delivered by community colleges and may reflect a greater ability to apply the technology or the need for greater depth of instruction at the four-year level.

The gender data shows that females are a distinct minority in microcontroller classes and that the class is composed mainly of students of Caucasian ancestry. Students of Hispanic and Asian/Pacific Islander ancestry make up a higher percentage at the four-year level than in two-year community college microcontroller classes.

Interest in professional development workshops similar to those offered through the project seems to remain high. Registrations are adequate to fill workshops and the project continues to draw educators from across the country. To date, over 100 community college and university faculty members have been trained to provide deeper instruction to their students utilizing the modules provided during the workshops. Several thousand secondary school students have been exposed to career information about the electrical engineering technology field. Reports on the best practices developed by the project team have been disseminated through publication in related journals, through presentations at conferences, and through local workshops conducted by the team members. Students trained on the technologies discussed at the workshops will be better prepared to develop new products and push the envelope of technology evolution in the electrical engineering field.

2. Outreach

The project objective is to increase enrollment in electrical engineering technology programs to create growth in the number of electronics technicians entering the workforce. Partner institutions are addressing its role toward this goal by developing and implementing outreach programs that will not only stimulate greater interest in secondary students seeking electronics technician careers but also in better preparing secondary students for successful entry into and retention and completion rates in electrical engineering programs at the postsecondary level.
An outreach model has been developed with the expectations to result in growth of enrollment in electrical engineering technology programs. The model has three parts: (1) university articulation, (2) high school student outreach, and (3) high school curriculum and teaching enhancement.

<u>Summer Bridge in STEM Subjects for High School Students</u>
A summer Manufacturing Engineering Academy was held with three, three-week sessions of ten participants each. In that academy, high school rising juniors and seniors were trained in SolidWorks 3D modeling software and guided through the design of their own scaled-down industrial robots. Upon completion of their design, the students printed their designs using 3D printers and fabricated their robots into working prototypes. They then integrated their robots with an Arduino PC board and programmed their robots to do pick and place operations. They videotaped their working robots and placed their videos on YouTube.

A summer Computer Engineering camp was also held for high school rising juniors and seniors. The participants were exposed to current PC desktop computer design and assembly. They were provided with a motherboard, a power supply, a hard drive, cables, and other components. They assembled their computers, installed Microsoft Windows 8, and took their computers home at the completion of their summer camp activity.

Summer Technology Institute (STI)

Drake State immerses the educators in the STEM discipline educational activities of the college, including visits to industries that hire STEM graduates, panel presentations by local and state economic and workforce development agencies and other governmental agencies, panel presentations by faculty, students, graduates, and industry professionals, classroom lecture and interaction activities and lab experiments performed by the Institute participants under the guidance of college faculty and students. The participants are required to develop a portfolio of ideas and lesson plans that can be implemented in their secondary school classes and counseling sessions during the following academic year. Each participant provides a brief impact statement at the end of the program that documents the personal impact and educational growth experienced during the two weeks of the Institute. In addition, each participant makes a 3-minute summary impact statement that is video-recorded for a permanent record maintained by the Institute.

During 2014-15, Drake State held the 2015 Summer Technology Institute designed to expand awareness of area STEM careers and postsecondary programs leading to STEM careers. The institute was attended by 22 secondary school counselors and teachers. Participants expressed great surprise as to the variety and extent of STEM careers available in north Alabama, in particular those careers focused on knowledge and skills related to engineering technologies. Many of the participants documented statements of intent to increase the number of their students that they will encourage to consider postsecondary STEM programs.

Engineering Technology Research Internships

Drake State sponsored one electrical engineering technology intern who worked with the College's IT Services team to set up computer labs, install network switches, and diagnose network problems. The intern not only received a valuable work experience, but he also performed services of value to the institution. Having observed the benefit to the student and the institution, the College's administration encouraged the DigiTEC team to continue offering student internships of this type.

3. Enrollment Services

A new enrollment services management function has been developed utilizing software and successful practices of colleges and universities with similar population demographics, where persistence, retention, and completion issues of first-generation and minority students prevent these students from completing their educational plans. This new function incorporates the Starfish student retention tracking software to expedite the identification of needs for intervention, streamline the communication among faculty members, counselors, academic advisors, and counselors, and provide quantitative and longitudinal data for analysis and summative evaluation of retention initiatives. The Enrollment Services function will integrate outreach, advising, counseling, and student coaching into a seamless service for at-risk students to help them deal effectively with academic and other barriers and thus improve their chances to complete their educational plans.

Drake State expanded the number of career coaches assigned to work with local high schools from one coach to three. These coaches spent the majority of their time in middle schools and high schools assisting students through career exploration, career interest assessment, career planning, college curriculum research, and career goal setting.

IV. Conclusion

Digital systems sit at the heart of the technologies that most enrapture the young. The objectives of this project are to substantially update digital logic courses by providing the tools and curricular materials needed to replace the outdated materials most commonly used. The updated curriculum will greatly enhance competitiveness for community college graduates seeking to enter the job market or undergraduate engineering programs. The objectives of this paper were to present the third year project activities including faculty professional development and outreach activities at partner institutions. This project in its following years will provide the training and educational resources and promote best practices for community college, university, and high school instructors to enable them to teach new hardware technologies to a broad range of students, including those who have not previously had access to this level of training and career choice.

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