Applied Learning: Undergraduate Research for Engineering Technology Students

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***Abstract*-Applied learning refers to an educational approach whereby students learn by engaging in direct application of skills, theories and models. Undergraduate research is a valuable applied learning approach. This paper presents research experiences for students enrolled in an Electrical and Computer Engineering Technology program, mentored by the author of this paper. Research projects in the areas of smart house systems and fault tolerant digital systems using computer-based tools are presented. The paper discusses results, including engaging strategies, challenges, lessons learned, and assessment of the undergraduate research experience.**

I. Introduction

Applied learning refers to an educational approach whereby students learn by engaging in direct application of skills, theories and models. Students apply knowledge and skills gained from traditional classroom learning to hands-on and/or real-world settings, creative projects or independent or directed research, and in turn apply what is gained from the applied experience to academic learning. The applied learning activity can occur outside of the traditional classroom experience and/or be embedded as part of a course [1]. Undergraduate research is one of the applied and experiential approach that institutions like State University of New York (SUNY) are interested to support, as part of the SUNY Applied Learning Initiative. The undergraduate research is defined as an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline [2].

Faculty members enhance their teaching and contribution to society by remaining active in research and by involving undergraduates in research, and students succeed in their studies and professional advancement through participation in undergraduate research [2]. The Boyer Commission suggested that research-based learning should become the standard for undergraduate education [3]. With the recent increased emphasis on applied learning activities, it is becoming more common for higher education institutions to include undergraduate students in research experiences both in and out of the classroom. Outside the classroom, many college, school and department-wide opportunities promoting undergraduate research experience are available [4].

This paper presents undergraduate research experiences for Electrical and Computer Engineering Technology students, enrolled at Farmingdale State College. The characteristics of student population at Farmingdale State College are presented in detail in reference [5]. According to this study, over 90 % of Farmingdale State College students are commuting on daily basis from the greater New York metropolitan area and they hold full time jobs. Around 35% are first-generation college students (e.g., neither parent has earned a 4- year degree), and 30% are minority. The student population includes large numbers of "New Americans" (i.e., they or their parents were born outside of the US). Many students have considerable financial need (with 30% receiving Pell grants). One of the conclusion of the study regarding student population at Farmingdale State College is: "*to educate today's new undergraduate student effectively, one needs to engage students in active, experiential learning*", which is the focus of the pedagogy presented in this paper.

Research projects in the areas of smart house systems and fault tolerant digital systems using computer-based tools and developed over several academic years are presented. Students engaged in the area of smart house design worked on research projects focusing on: (i) efficient use of resources; (ii) authentication and security; (iii) safety; (iv) human interaction, developing intelligent and user friendly interfaces; (v) increased comfort and support for vulnerable people. Students engaged in in the area of digital systems designed and implemented fault tolerant digital systems using FPGA (Field Programmable Gate Arrays) technology and HDL (Hardware Description Languages). In their research students applied knowledge from the digital design and microcontrollers sequence of courses and technical elective courses. The rationale for selecting these projects is presented in the next section of this paper.

The rest of the paper is organized as follows: Section II presents the social aspects of engineering education Section III presents related work. Section IV presents the research projects. Section V presents the results of undergraduate research based learning. Section VI concludes the paper.

II. Social Aspects of Engineering Education

Addressing the future of engineering and technological needs, higher education institutions face a great challenge. They have to build a strong technical curriculum and address the social consequences and implications of technological and engineering advances. Knowledge of the impact of engineering solutions in a societal and global context is an important objective supported by the ABET (Criterion 3) [6].

In an article published in 1975, Toba was advocating the socially responsible engineering model as a profession [7]. Toba said that engineering needed new minds that would combine science and human values to solve problems that technology might cause. Toba also stated that engineering is viewed negatively as a profession by the young people of the day and to change this perception, engineering needed to focus on social issues. In one of her presentations at ASEE conference and ECEDHA meeting, Leah Jamieson, past president of IEEE, presented data about the public perceptions of engineering which showed that engineering is viewed as a profession that creates economic growth but is not sensitive to social, environmental, and quality of life issues. While the data did not show a negative public perception, Jamieson presented irrefutable data that the public did not view engineering as a profession that was going to make a difference [8]. There is an extensive literature on the perception of the engineering discipline in general, such as [9-13]. According to Elrod and Cox, surveys of high school students show that engineering is perceived as a highly technical field that is not very multifaceted and has no connection to social issues. "*At a time when we expect students to be in a position to make a conscious choice regarding their proposed careers, many are ignorant of engineering with regard to discipline and overall career*" [9]. According to Dee and Livesay even college students who left engineering stated that they wanted to take classes that allowed them to express opinions and views and not just learn theories and equations [13].

In order to attract high school graduates to engineering, it is necessary to portray the satisfaction and reward of engineering profession. Many high school graduates want to make the world a better place but may not perceive that they can do this with engineering. In order to recruit them it is necessary to educate them on the social relevance of engineering and show them how technology enriches lives, help communities and make the planet a better place to live. According to Hynes and Swenson, *"one group of people associated with engineering projects are those for whom engineers engineer for"* [14]. Innovations have been paramount to the evolution of human society. Recent developments made possible by Internet technologies, such as Twitter, have provided means by which oppressed people can organize to protest their governments. The engineers and designers behind these developments may not have created their technologies specifically for such purposes, but, as in Twitter's case, they were aware that the real-time connecting of people and information was a breakthrough in the way people would share and receive information. Numerous other engineered innovations (e.g., electrical grids, the telephone, the automobile, the Internet, etc.) have had tremendous societal implications that engineers in one way or another addressed in their work [14].

One way to integrate societal needs and challenges into the engineering curriculum is through research project, as presented in reference [15]. At Farmingdale State College, faculty members are strongly encouraged to include undergraduate students in their research projects and strong institutional support is available through grants, mentorship and research stipend for faculty and students.

III. Related Work

Being considered one of the high impact practices, undergraduate research is routinely found on campuses today, being beneficial to expose as many students as possible. A large number of publications, including journals are dedicated to undergraduate research. Undergraduate research has been linked to retention in undergraduate programs, public speaking and increased participation in graduate programs [16].

While there is an overwhelming evidence provided by literature for the added value of undergraduate research for engineering students, the majority of the papers covering undergraduate research experience focusses on four years engineering programs. A large number of papers present Undergraduate Research Experience (REU) for electrical and computer engineering, industrial and manufacturing systems engineering, computer science, chemical engineering, biomedical engineering programs, etc. Only few papers address undergraduate research for engineering technology programs, to the best knowledge of the author of this paper.

Thomas and al. present the results of a study examining students' perception of SURE (Summer Undergraduate Research Experience) at The Citadel and assessment of students' perception based upon their gender for its Corp of Cadets [16]. Dean and Rawashdeh present a NSF REU funded program for electrical and computer engineering students at Oakland University. The authors share their approach running the 10-week summer program with an emphasis on techniques and tips for those seeking to start a new REU at their institution [17]. Porter and al. present a course based undergraduate research experience at Iowa State University, Industrial and Manufacturing Systems Engineering Department. Students address research problems in the context of a class. The project measures the increase in the number of students who have undergraduate research experience, retention rate within the department, and the number of students who enroll in STEM related graduate school [18]. Cao, Lowell and Morris introduce a deep learning-based term project in a software engineering course open to computer science students at Central State University. The authors claim that their project is a positive example of integrating modern technology and research into undergraduate education [19]. Richard and Yoon explore the impact of Summer Research for Undergraduate (REU) program on diverse national and international engineering students from USA and India, and evaluate the effectiveness of REU program in meeting its goal of encouraging students to attend graduate school [20]. Cousins and al. present a partnership between the University of Texas at Austin and Texas 4000, a nonprofit organization engaged in advocacy and philanthropy for cancer research. The goal of the partnership is to give REU students a better understanding of how researchers are trained and what the everyday experiences of research are like [21]. Follmer and al. examine students' outcomes for a REU program at University Park, focusing in the integration of biology and materials. The paper present strong assessment: measures of research-based skills and experiences, in-depth interviews, measures of REU program satisfaction and ratings of REU program [22].

Zhan and Lam present the results and benefits of the research experience for engineering technology students at Texas A&M University. Projects in the areas of sensor characterization, analog and digital filter design, pump jack closed loop control are under consideration [23]. Yeh and al. present three undergraduate research projects at Wayne State University, Engineering Technology Division. The paper presents the research problems, approaches taken and the roles played by students and faculty members. The impact of the undergraduate research is briefly discussed in the paper [24]. Berri, Zhang, and Gailani present the undergraduate research in mechatronics at City University of New York. Engineering technology students are required to work in teams and develop research projects in several courses. They learn how to design, fabricate and evaluate mechatronic products. Examples of successful projects and individual student's results are presented [25].

IV. Research Projects

The research projects presented in this paper were sponsored by the Provost Office, Renewable Energy and Sustainability Center, The Collegiate Science and Technology Entry Program (CSTEP) at Farmingdale State College. Additionally, the work was funded by the Research Aligned Mentorship Program (RAM) and “Students First Grants” Program. The Research Aligned Mentorship (RAM) program is a prestigious program funded by a major grant awarded to Farmingdale State College by the United States Department of Education. The "Students First Grants" program encourages and supports faculty in the development of active student-centered pedagogies across the curriculum and use of newer technologies that engage students both in and outside of the classroom.

The students who were selected to work on these research projects were enrolled in undergraduate courses taught by the author of this paper, were part of the RAM cohort of students or were recommended by the C-STEP program coordinator. Interviews were conducted to select highly motivated and hardworking students. Each project required strong commitment from students and mentor. Students met during summer intersessions and weekends for instruction on new concepts and techniques. These working sessions provided students with technical knowledge and skills not covered in the required undergraduate courses. Students received research stipends from the C_STEP program, RAM program and “Students First Grants" program.

Smart House Design

Students engaged in the area of smart house design worked on research projects focusing on: (i) efficient use of resources; (ii) authentication and security; (iii) safety; (iv) human interaction, developing intelligent and user friendly interfaces; (v) increased comfort and support for vulnerable people. While the majority of the research papers dedicated to smart house design focusses on one or two of the research areas previously enumerated, the smart house system presented in the next paragraph implements functions covering several areas of smart house research. Literature review on systems and techniques used to design smart houses is presented in reference [26].

The first small scale prototype of the Smart House was designed and implemented in the summer of 2015 and during the academic year 2015-2016. Four undergraduate EET and CET students were engaged in this research project. The entire system is built around the Arduino platform. The local control is achieved through a keypad and a LCD display, while the remote control includes an Arduino Ethernet based micro web-server, and an Android based app, which can be used from any Android supported device. The system is affordable, user friendly and easy to adapt, allowing to add new devices and functions, without altering previously built functions. All the functions of the smart house were tested and are fully functional, proving the feasibility and effectiveness of the design. Fig. 1(a) presents the prototype of the smart house, while Fig. 1(b) presents the hardware modules. The functions of the smart house can be controlled locally or remotely as seen in Fig. 1(c).

Figure 1(a). Smart House Prototype

Figure 1(b). Hardware Modules

Figure 1(c). Local and Remote Control of the House

For local control, a display (LCD screen) and a keypad are the user's interactive interface. The LCD shows a menu indicating different areas of the house that are being monitored by the subsystem such as first floor, second floor, balcony and garage. Every area of the house is allocated a sub-menu that displays the temperature, humidity, movement, light status, and fan speed for that specific location (rooms, garage). Each mentioned area has a character of the keypad assigned to it. In order to access a particular area, the user has to use the keypad and select that specific area. For remote control, the Arduino microcontroller uses an Arduino Ethernet shield module that behaves as an embedded server. A web graphical user interface was developed to allow remote control of different functions of the house. The GUI (Graphical User Interface) displays different areas of the house monitored by the subsystems previously mentioned. It displays temperature, movement, humidity. Currently the prototype is used for live demonstration during open houses and to raise public awareness regarding the advantages of an environmental friendly smart house as part of the mission of the Renewable Energy and Sustainability Center at FSC.

The second prototype of the Smart House System was designed and implemented in the summer of 2016 and during the academic years 2016-2017 and 2017-2018. Four undergraduate students were engaged in this research project. The focus of this project is the design of a smart house system fostering enhanced living experience for its inhabitants. Smart house research domain offers means for supporting special needs of people with disabilities Fig. 2(a) presents the prototype of the smart house system, while Fig. 2(b) presents the hardware modules. The entire system is built around the Arduino microcontroller platform and the following sub-systems were implemented and were demonstrated at various conferences: safety and security system, finger print scanner and door control system, elevator control system, and messaging system. Fig. 2(c) presents the finger print scanner and door control system.

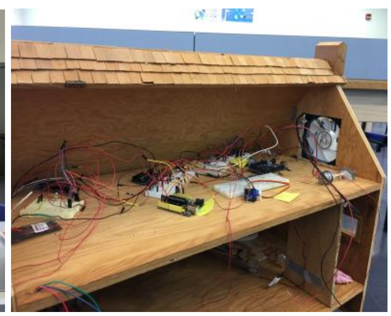

Figure 2(a). Second Prototype of the Smart House Figure 2(b). Hardware Modules

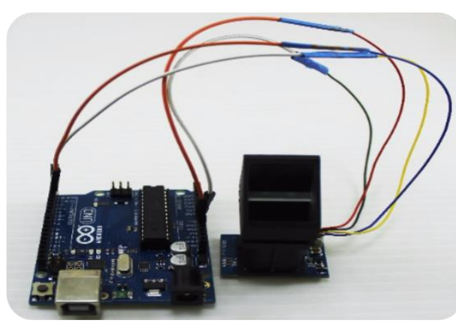

Figure 2(c). Finger Print Scanner and Door Control System

Fault Tolerant Digital Systems

In the last decades, digital systems have been incorporated into commercial and military flight control systems, forcing designers to find new ways to improve the dependability of these systems. Dependability issues are becoming important also for ground applications due to the continuous increase in the integration level of systems and the occurrence of faults that can dramatically affect the behavior of the system. Novel mechanisms are required to increase the dependability of digital systems with respect to possible errors occurring during their normal function. Adding fault tolerance attributes to a system is one of these mechanisms. A fault tolerant system is a system that continues to perform its functions in spite of faults.

The proposed research focusses on the design and implementation of fault tolerant digital systems, using computer based tools and portable platforms, such as Nexys3™ manufactured by DigilentInc. [27]. Finite State Machines (FSM) represent the "core" of digital systems. An errant FSM can cause considerable damage to the device is controlling. Even a well-designed state machine can be subject to random errors. The state encoding of FSM makes a difference in the susceptibility of the FSM to random errors, such as errors produced by radiation. There are various ways to encode the states of a FSM: Binary, Gray, One-Hot, Hamming. The addition of fault tolerance through state encoding (Hamming, One Hot) requires more resources and the state machine will operate slower [28].

Three undergraduate students were engaged in this research project during the academic year 2016-2017. The research continued in the following two academic years, another team of four students being involved. Students engaged in the first stage of the research project designed, simulated and implemented digital systems based on FSMs: controller for an elevator, vending machine, and display. Different methods of state encoding for FSMs were investigated, and area and hardware resources were compared. The focus was designing functional digital systems and understanding the concept of fault tolerant FSM through state encoding. Fig. 3 presents the Nexys3 platform used by students.

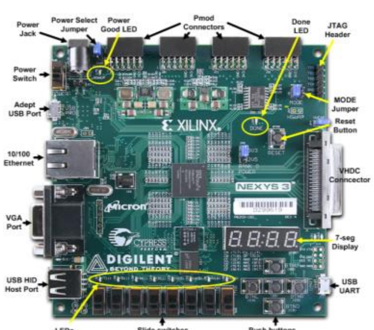

Figure 3. Nexys 3 Platform

In the second phase of this research (academic year 2017-2018, summer 2018 and academic year 2018-2019), students design new digital systems (water and ice dispenser, T-shirt vending machine, digital clock). Students learn how to use Analog Discovery platform, a computer based instrumentation tool that can successfully replace traditional equipment that can be found in a college lab, as seen in Fig. 4. The platforms can be integrated with lectures in the classroom or online, projects, or when students want to try out their own ideas, explore creative projects, using their own computers and associated free computer-based-tools [27].

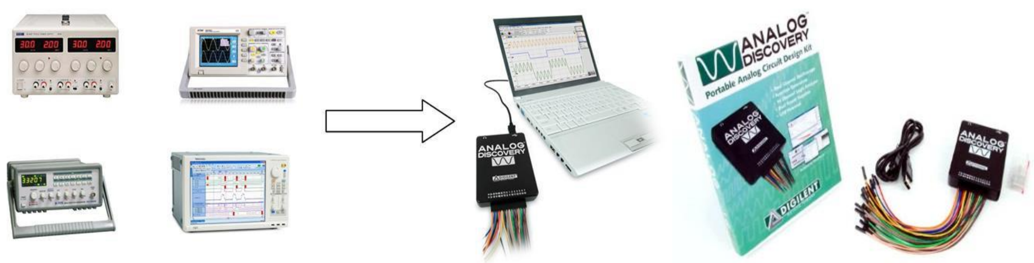

Figure 4. Analog Discovery platform

After designing and simulating FSMs, students can compare simulation results with real waveforms, using the Logic Analyzer from the Analog Discovery platform. Fig. 5 presents the settings of the experiments using the Analog Discovery and Nexys3 platforms.

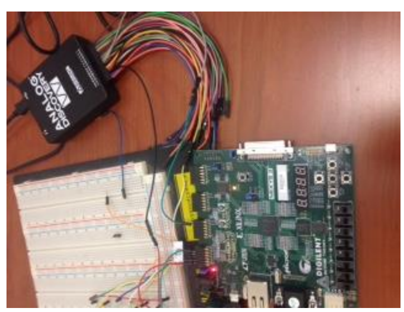

Figure 5. Setting for the Experiments using the Analog Discovery Board.

A synchronous error generator (fault generator) will be created in the near future, based on references [28-29]. The synchronous error generator uses a pseudorandom number generator based on a LFSR (Linear Feedback Shift Register) circuit. It generates a 16-bit random number. The random number is applied to the targeted state machines at an interval determined by a rate counter and the fault tolerance capabilities of the FSMs can be investigated.

V. UNDERGRADUATE RESEARCH RESULTS

The objectives of the research projects are: (i) to provide students with an opportunity to work on real-world problems using technologies and software languages currently used in industry and academia; (ii) to expose students to actual areas of research; (iii) to educate students how to communicate the results of their research, both written and oral communication.

The anticipated outcomes are: (i) students learn to design, implement, test and evaluate digital systems based on microcontroller and FPGA platforms. (ii) students learn how to do a literature review (literature gathering and screening, literature processing). (iii) students learn how to use various computer-based-tools so they can successfully present research results to an audience and as a written paper.

In order to assess the learning outcomes: (i) students document the progress of their research by demonstrating their fully working projects to large audiences (conferences, open houses); (ii), (iii) Students submit their work for publication in professional journals and/or presentations at professional conferences.

Table I summarizes the results of students' research: conference presentations, journal publication, awards, prizes.

TABLE I

RESULTS OF UNDERGRADUATE RESEARCH

Research Project	**Publications, Conference Presentations and Awards**
Smart Energy House	*"Smart Energy House"* - Poster and oral presentation at the IEEE International Energy and Sustainability Conference, Farmingdale, NY, October 2015. **The team of students won the Outstanding Student Poster Award.** - C_Step Conference, New York, April 2016. - Advanced Energy Conference, New York, April 2016. - Undergraduate Research Conference, Brookhaven National Laboratory, April 2016. "*Design and Implementation of a Reliable and Environmental Friendly Smart House System"* - Published in the International Journal of Smart House, vol. 1, January 2017.
Smart House System for Vulnerable People	"*Design and Implementation of Smart House System for Vulnerable People*" – Presentation at the 14th International Conference on Remote Engineering and Virtual Instrumentation – Columbia University, New York, March 2017. - Presentation at SUNY Undergraduate Research Conference, New York, April 2017.

	The team of students working on this research project enrolled in the New York State Business Plan Competition at Farmingdale State College, spring 2017. Inspired by this research project, the team entered the Business Competition with the project named ***"STACK HOUSE".*** The idea was to develop and market an educational coding toy to spark young girls' interest in STEM. **The team won the Long Island Business Plan Competition-regional level**. It was the first time for_ Farmingdale State College students to win the grand prize at the regional level, product category level. The team won $10,000 Grand Prize. The team advanced to the next level and presented their business project at the state level in Albany, April 2017. "*Smart House System: Enhanced Living*" - Student Poster Competition at the 2017 IEEE International Energy and Sustainability Conference, Farmingdale, NY, October 2017. - Celebration of Scholarship, Farmingdale State College campus, October 2017.
Fault Tolerant Digital Systems	*"Design of Fault Tolerant Finite State Machines"* - Celebration of Scholarship, Farmingdale State College, October 2018, - A conference paper is in work-to be submitted Spring 2019.

Fig. 6(a) presents the award ceremony at the IEEE International Energy and Sustainability Conference, Farmingdale, NY, October 2015. Fig 6(b) presents the team of EET students pitching their business idea inspired by their research to judges during the regional round of the 2017 NY Business Plan Competition.

Figure 6(a). Award Ceremony, IEEE IESC conference Figure 6(b). Competitors and judges, NY Business Plan Competition

Additionally, the mentor followed up with the students to see if the research experience helped them to secure internships, fellowships, admission to graduate programs. As a result of their outstanding work, students involved in the above mentioned projects received scholarships, internships and were admitted to graduate programs.

-Two students received the Barnes & Noble's STEM Scholarship (2015, 2016).

-Two students received internships at Brookhaven National Laboratory (2015, 2016).

-Two students received the D3 scholarship (2015, 2016).

- Two students received internships (and job offers) with NASDAQ, NY(2017, 2018)

- One student received an internship (and a job offer) with L3 Technology, Hauppage, NY (2018)

- One student received an internship with CANON USA, Melville, NY (2018)

- One student was accepted for the MS in Technology Management at Farmingdale State College (2017).

The process of developing solutions to the research problem, preparing abstracts, presentations and manuscripts as well as presenting their work in a conference setting proves to be a great learning experience for students and an excellent students engaging strategy [4]. Another excellent engaging strategy was to allow students to present their research findings as part of their Senior Project.

One of the main challenge of the research process was to keep the team of students interested to work on these projects on a long term, not only during the summer. "Navigating" students' busy work and school schedules during the academic year was another obstacle. Working with sophomore and juniors presented its own challenges in term of technical knowledge, limited written and oral communications skills, maturity level.

Some of the lessons that the author of this paper took away from mentoring undergraduate students are:

-Thoroughly interview every student before starting the research project.

-State clearly the goals and objectives of the projects.

-State clearly deadlines.

-Start very early preparing and rehearsing oral and poster presentations.

-Prepare written agreements between mentor and student, clearly stating schedule, reports deadlines, etc.

-Students showed genuine, intrinsic motivation to pursue research. According to P. Leggett-Robinson and al. students with intrinsic motivation tend to participate in certain activities voluntarily and enjoy the inherent pleasure which drives their participation. In contrast, extrinsic motivation refers to activities engaged to receive a reward [30]. Students engaged in the research projects presented in section IV of this paper were interested in the learning and challenging aspects of the research and the chance to improve their resume. Stipends were never an issue, students being motivated by the experience.

The benefits of involving students in research projects were assessed through exit surveys. An IRB (Institutional Review Board) protocol was secured. Only students who are not currently in any of the classes taught by the author were requested to complete the surveys. Five students out of eight completed the survey. Table II presents students' answers to questions assessing their research experience. Question 1 investigates the effects of the undergraduate research on students' professional development, while question 2 investigates students' motivation to enroll in research projects.

Table II

Research Experience

Question	Answers
1. How did participation in an undergraduate research project at Farmingdale State College affected **your professional development** and present or future career?	A1: "***I was able to get experience going to professional events, presentations, speaking to groups, tracking a groups work, etc.*** *I feel significantly more prepared, experienced, and more well spoken, than I would have been without my undergraduate research.* ***This work also allowed me to enter my internship feeling more confident, knowing that I had hands on experience".*** A2: *"**It enabled me to become more social**. Participating in the research project allowed me to be more involved in school. Working with people in a group setting gave me the ability to learn from them. This research project allowed me to test theories and concepts."* *A3: "**Participating in an undergraduate research project at Farmingdale State College helped me to stand out from all the other applicants especially during the job interviews** I always had something to talk about during the interviews even though I never had on field work experience".* *A4:* **"*Participating in an undergraduate research program at Farmingdale helped me decided what career path I wanted to take*.** *The research program helped me expand my knowledge in programming, hardware implementation, circuit building, networking. I would recommend doing undergraduate research to every student as it strengthens critical thinking, creates connections in the engineering sphere (through conferences) and overall expands the individual's knowledge of their field. The knowledge I have gained from the research program has served me positively in my career as it has provided experience with hardware, troubleshooting, and problem solving.* *A5**:" Getting involved in an undergraduate research project involved planning, structuring and completing a project from the scratch**. Making sure that all the deadlines were met in a timely manner and coordinating with my team to drive it to successful completion inculcated and challenged my organizational and interpersonal skills... Presenting this project to my peers and superiors enhanced my communication and presentation skills. In my present career as a Project manager, this research opportunity has improved my managerial abilities as well as my*

	confidence in handling a large team and multiple tasks.
What was your **motivation** to enroll in the undergraduate research?	A1:" *Before I attended Farmingdale, I was running an engineering club in my high school. When I started here, I was no longer doing that. When the opportunity was offered to me, I jumped on it mostly because it seemed interesting, was a* ***good way to gain experience quicker****, and also to satisfy my desire to work with others like I had done prior. Overall, it just seemed like a good experience that I would gain a lot from."* *A2:" I wanted to be more involved in school activities, the research seemed like the best way to do this and get* ***more opportunities to learn****."* A3: *"I actually never thought of doing research at college. The reason I started doing research was because of my professor. She encouraged us especially girls in engineering department to participate in undergraduate research program. I was glad to be part of the team and over the years I have learned a lot from both my team members and from my professor. At this point of my life I think participating undergraduate research program was one of the best decision I made in my college career.* ***This really helped me to get lot of outside exposers and helped me with my public speaking****. All those experiences is now helping me at work to make better decisions."* A4:" *My motivation for enrolling in the research program was* ***to gain more in-depth knowledge of my field*** *and better understand the career path I wanted to take. I wanted to experience as many sectors of Computer Engineering as possible so that I would be able to make my decision with the highest of confidence. I believe that the research program has helped me tremendously in doing so."* A5:*" My motivation was to challenge myself* ***to complete a large project from start to end in the technology field****. Contributing in the development to grid technology was also a major motivation."*

Students rated their knowledge gain, by answering the following question: "*In which areas-Hardware-digital, Hardware-analog, Software languages(VHDL, C, C++, assembly language)- do you think that you improved your engineering knowledge?"*. Use a scale from 1 to 10 to rate your improvements, 1 being the lowest, 10 being the highest. Table III presents the scores for students' rating of knowledge gain.

TABLE III

Students' Rating of Knowledge Gain

	Hardware Digital	Hardware Analog	Software Languages
Student 1	8	3	5
Student 2	9	7	10
Student 3	10	7	10
Student 4	10	10	10
Student 5	1	5	9
Average Score	**7.6**	**6.4**	**8.8**

Due to the nature of the projects, the average score for languages (C++, C, VHDL) was higher than the average score for Hardware-Digital and Hardware Analog. Examples of significant comments are:

-*"I believe that during my research I improved immensly with microcontrollers and further strengthened my understanding of FPGAs. I believe that my ability to design and use analog circuits has greatly improved and I am confident in my abilities to design and implement an analog solution if neccessary. While I believe I was a fairly strong programmer before I started the research program, I think it has only improved my skills by giving me real hardware to work with rather than a virtual simulator."*

-"*Implementing the code and using it in a more realistic way was much more valuable to me than creating code for the sake of the code like in class. "*

Students rated their engineering skills improvement, by answering the following question: "*What engineering skills did you improve by participating in the research project*?" Use a scale from one to 10 to rate your improvements. The engineering skills rated by that students were: (i) Problem solving; (ii) Creativity and spirit of innovation; (iii)Team work; (iv) Time management; (v) Communication skills, both written and oral. Table IV presents students' rating of engineering skills improvement.

TABLE IV

Students' Rating of Engineering Skills Improvement

	Problem solving	**Creativity**	**Team work**	**Time management**	**Communication Skills**
Student 1	10	7	7	7	5
Student 2	10	10	10	8	10
Student 3	8	8	10	7	9
Student 4	10	10	10	10	10
Student 5	10	7	10	0	8
Average Score	**9.6**	**8.4**	**9.4**	**6.4**	**8.4**

Students appreciated the improvement of their problem solving skills, teamwork, creativity and communication skills. As expected time management was an issue. Navigating part-time or full time jobs, school, and research, proved sometimes difficult for the students. Examples of significant comments are:

-*"It enabled me to plan and delegate tasks to different team members."*

-*"It helped me to work on a timely and planned manner to reach goals in a defined time frame."*

-*"My communication skills improved since I was constantly in presentations and research contests."*

Mentoring students was extremely rewarding for the author of this paper also. She was awarded the C-STEP *Research Mentor Award* in 2016 and CTLT (Center for Teaching and Learning and Technology) *Outstanding Faculty Mentorship Award* in 2017. She was selected as research mentor for the prestigious RAM (Research Aligned Mentorship) program at Farmingdale State College.

VI. Conclusions

This paper presents undergraduate research experiences for Electrical and Computer Engineering Technology students at Farmingdale State College mentored by the author of this paper. The goal of the undergraduate student research is to nurture students' desire for knowledge and commitment to long life learning. One of the benefits of involving undergraduate students in research is that is helps make learning relevant and useful to the students by establishing connections to life outside the classroom, addressing real world concerns, and developing real world skills. The author is confident that engaging students in research and solving real world problems is a solid path to academic success, and improve students' chances to pursue successful professional careers. Faculty interested in applied learning may benefit and consider the challenges and rewards of mentoring undergraduate students research. This paper is a revised and updated version of the paper presented at the ASEE Annual Conference [31].

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