Inspiring Innovative Aspirations among Undergraduate Students

using Self-Motivated Project-Based Learning

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Abstract— **Current computer science curricula primarily focuses on formal aspects of computing that are essential for IT professionals and CS researchers, but are weak in developing innovative thinking which is more important for the new generation workforce to cope with soft-power revolution. We believe that students will gain valuable experience through Project-Based Learning (PBL) with their initiative, and this will enable them to achieve success on their projects. The Discovery Lab at Florida International University (FIU) has provided creative activities and research environment for undergraduates with cutting edge technology and active learning. It allowed them to be trained for creativity and innovation as well as with expertise for IT and CS professions. In this paper, we present our approach to foster innovative aptitude among undergraduate students to meet the challenges of emerging technologies. Outcomes of this approach demonstrate the effectiveness of the proposed educational methodology.**

Keywords: Project-Based Learning, Capstone, Teamwork, Self-Motivation, Cascade Mentoring

I. Introduction

Traditionally computer science curricula in most of the academic institutions adhere to Accreditation Board for Engineering and Technology (ABET) guidelines that strike a balance between foundations of computing and emerging technologies. Capstone project recommendation from ABET[1] integrates industry needs with academic knowledge for students. Since the capstone project provides practical application orientation only at the end of the degree program, students do not engage during most of their initial study, which in turn, limits their ability to cope with real-world application in jobs.

The recent advances in IT have accelerated the adoption of new technologies in industries. For instance, the exponential growth of unstructured data in social networks led to new data representations such as NoSQL and distributed file systems (e.g., Google and Hadoop Distributed File Systems). Additionally, for interoperability among heterogeneous systems, several data formats such as XML, JSON, and BSON have been used for data interchange. Further, for large scale big data processing, configuring virtual machines on cloud platforms (Amazon Web Services, Google Cloud Platform) is vital for management decisions. Since most of the IT companies widely adopt all of these technologies, it is essential for IT professionals to gain experience with the recent technologies to meet the technical skills required for IT jobs.

From a computing perspective, several processing advancements are emerging to meet the challenges of modern systems. Notably, computing for mobile devices offers efficient bandwidth utilization, small memory footprint, and power management. Predictive approaches use machine learning and artificial intelligence (AI) to increase sales and improve operational systems. Further, backend server side processing employs query optimization, load balancing, concurrency, synchronization, and distributed computing. Moreover, for a secure system that can be resilient to modern cyber-attacks, security at different layers of the system needs to be improved. CS professionals need to have an in-depth experience with these computing trends so that they can contribute meaningfully in CS research and practice.

John Dewey, a philosopher and educational reformer stated that an educational experience is a relationship between our action in the learning environment and the consequence (events) in the environment. Further, he emphasized that an ideal learning experience stems from interacting with the learning environment and reflecting on the consequences of our interaction. He believed that learning through active interaction would improve problem-solving skills that would be applied in all areas in future [2,3].

Ed Coyle from Georgia Institute of Technology introduced the Vertically Integrated Program (VIP) to engage students in research during the early stage of their Bachelor program [4,5]. Several institutions successfully adopted this integration of multidisciplinary project-based research with the curriculum through a VIP consortium.

Rick Posner and Fredric Posner believe that the creative spirit of educators and the intelligence, passion, and engagement of students can lead to learning at the highest level, through Project Based Learning (PBL) [6]. The testimony of successful career placement of their students over three decades endorses this approach. In this paper, we present a student-centered PBL approach that provides innovative experience to students and inspires them to propose creative ideas towards effective results.

II. METHODOLOGY

We believe that the PBL is more efficient when we trust students and scaffold self-management skills, allowing them to be more in charge than we are. Once students overcome the initial learning curve and make a student-centered culture, this PBL approach boosts their self-learning, encourages them to propose innovative ideas, and allows for creative teamwork. We developed a four-stage student learning based on PBL as below:

1) Do It Yourself (DIY) learning with hot/fun topics
2) Small/Individual scale PBL guided by teachers
3) Large/Group scale PBL led by teachers
4) Medium scale PBL led by students

In the first stage, DIY learning stage, hot and fun topics such as drone, hacking, etc. are proposed to students so that many students can align their interest in the subject more deeply. However, during this stage, teachers provide only very fundamental principles and let students learn through “Do It Yourself.”

In the second stage, small/individual scale PBL guided by teachers, project topics can be extended from what is learned in the first stage and add new features from student’s ideas. Additionally, teachers guide students to find solutions and implement their solutions in the project.

In the third stage, teachers propose existing or new large scale projects to students. They also lead the project and create sub-projects for students by forming student teams and allowing them to work on these sub-projects by themselves.

In the fourth stage, medium scale PBL led by students, students propose and conduct their own project. Furthermore, they recruit their team members as per their needs and train them with technical lectures taught by lead/senior students. Teachers can be involved in the proposed projects but should minimize their advice and remain as observers.

III. IMPLEMENTATION

We have created a PBL based research experience program for undergraduate students at Discovery Lab at Florida International University (FIU). The Discovery Lab founded in Spring 2012 which provides sufficient resources to students to solve real-world challenges, enhances student-led research experience, fosters students’ entrepreneurial skills, and trains a new generation of IT professionals.

The Discovery Lab evolved through four phases and transformed into a research initiative front-end at FIU. In the first phase, we established the lab as a research incubation center with a focus on an interdisciplinary theme. This process involved in creating a lab environment with adequate space and needed accessories for students to meet and exchange ideas. In the second phase, to improve research aspiration among students, we conducted several hands-on computational thinking based tutorials using micro controllers (Arduino/Mbed/RaspberryPi). This process improved students’ passion in computing and increased their participation in lab activities.

In the subsequent phase, we formed students into groups, based on their interests, and enabled brainstorming sessions in each group to formulate research projects and to identify project goals. Further, we followed monthly project evaluation cycles where each group, records its progress, technical solutions/challenges, resource availability/limitations, group dynamics, etc., and analyzes them to refine short-term project goals.

In the fourth phase, experienced researchers steered each group with periodic discussions and encouraged students to pursue their research projects with research focused questions on efficiency, optimization, modeling, etc.

With the establishment of the Discovery Lab, we have developed undergraduate research programs that attract many talented students and provide fascinating interdisciplinary projects with cutting edge technology. In this program, we initially organized several robotics workshops with favorite student topics such as “How to build a quadcopter” to recruit more students as well as to identify brilliant students. Figure 1 depicts some selected Discovery Lab DIY workshops. Once participated in a workshop, students enjoyed the topics and learned fundamentals with hands-on-experience, most students were excited to propose many creative ideas for their projects. After those workshops, all participated students were

1) forming a research group by themselves,
2) ideating and brainstorming topics and options,
3) documenting their learning process,
4) deciding on checkpoints and deadlines, and
5) designing and managing their final exhibition.

Figure 1. Selected pictures from the Discovery Lab DIY Workshops.

Some research findings [19,20,21] of the successful projects were published and presented at Florida Conference on Recent Advances in Robotics (FCRAR - 2012). Figure 2 shows three project posters used at the conference. Later, one of the outcomes of those projects, Air Aquarium [19], was filed in the United States Patent and Trademark Office on April 29, 2015 (US 14/699,526) for a patent [22].

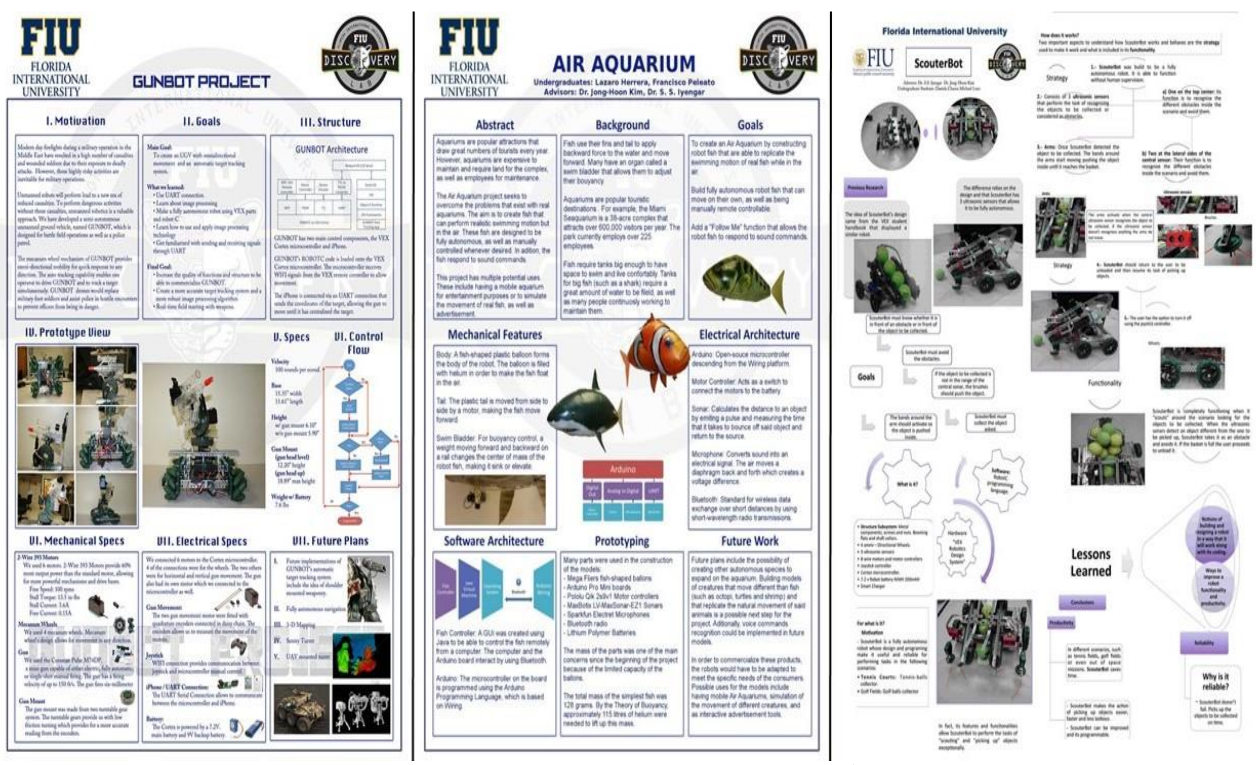

Figure 2. Presented student project posters at FCRAR-2012 conference.

After completing their projects, they joined an advanced and large scale project, the TeleBot Project [9,10,11,12,25], and collaborated with other teams. Each team has its own team goal that is part of the final goal of the project. During this TeleBot project, students involved in many outreach activities for exhibiting their team contributions on the TeleBot and demonstrated TeleBot operations to the public as shown in Figure 3.

Figure 3. Selected pictures from field demonstrations of the TeleBot at different outreach activities

After the successful completion of the advanced project, some of the lead students proposed their research projects to other lab students as well as faculty advisors in Discovery Lab. Through rigorous discussion and thoughtful evaluation process, we selected the outstanding proposals submitted by lab students. Each project leader recruited their team members, organized their teams, and trained their teams for their project requirements. Senior students who had research experience under the TeleBot project, presented many technical seminars during their projects. Figure 4 shows selected pictures from some of the technical seminars.

Figure 4. Selected pictures from technical seminars conducted by senior students

Further, four selected students served as workshop assistants and mentors at Google sponsored CS4HS workshop (Figure 5). They interacted with CS4HS workshop attendees for assisting workshop instructors and became a mentor to an assigned group for encouraging and guiding the final challenge of the workshop. They performed their duties very well and received compliments from the workshop attendees as well as their mentees.

Figure 5. Selected pictures from Google CS4HS workshop

After the CS4HS workshop, all four students stated their mentoring experience that it was a great opportunity for thinking and understanding the concept and technique, which they had learned in classes as well as the projects, to guide their mentees efficiently. Eventually, their mentoring experience helped themselves to learn and understand critical concepts and skills better.

IV. Analysis and Results

In the first stage of student learning period, all participants in the workshops were able to build their custom design robots such as custom designed quadcopters with their programmed controller. Many of them later applied to the Discovery Lab for expanding their knowledge and research experience.

In the second stage, six students contributed in three regional conference papers with their research findings from their projects as the first or the second author [19,20,21].

In the third stage, fourteen students participated in the TeleBot project as core developers and successfully finished the first phase of the TeleBot project. During this phase, the TeleBot project had more than 400 international press coverages from all around the world including Yahoo News, MSNBC, Fox News, etc. [27] (Figure 6).

Figure 6. Pictures from some selected press coverages of the TeleBot project

In the last stage, three selected projects were conducted by student leaders, and the results were published in the proceedings of the three international conferences [7, 23, 24, 26] and one journal. Five selected students admitted to NSF REU program at FIU. Out of the contributed three projects, REU program at FIU selected the project “Smart Prosthetic Arm” as one of the best project (Figure 7).

Figure 7. Selected pictures from the REU program for the academic year 2013 and 2014

Since the establishment of the Discovery Lab at 2012, many alumni of the lab have joined top graduate schools including Stanford University, Georgia Tech, Columbia University, FIU, etc. and have continued their research activities.

Figure 8. An illustration of the Cascade Mentoring Program

We have received very positive feedback about mentorship experience from many students who served as a senior mentor in the lab or gave technical seminars as a project team leader for training their junior team members. These testimonies indicate that a quality mentorship experience can provide opportunities for mentee students to learn and practice new skills as well as to develop their career interests.

As mentees in the mentorship program, the mentee students are required to give back to the program as a mentor. This Cascading Mentoring Program (depicted in Figure 8) enables to pass both knowledge and experience from the student mentors to mentees, then down to the youth who will be a potential computer science professional.

V. Conclusion

We have presented an overview of the student-centered PBL-based research/educational program that has been employed at the Discovery Lab at FIU after its establishment in 2012. Further, we outlined our experience in establishing the laboratory along with various phases of the implementation of this research/educational program.

With students initiation of projects, their passion and commitment have increased significantly. Many undergraduates have shown their leadership in their research projects and have made major contributions. This resulted in eighteen research publications with students as the first or significant authors.

We observed that students proposed a variety of creative ideas and some of them were not realizable due to resource and time constraints. In such cases, advisors guide them appropriately to scale down their projects or refine projects towards realistic outcomes.

Currently, the Advanced Tele-Robotics (ATR) Laboratory at Kent State University after its inception in January 2017 is adopting the PBL approach and is actively collaborating with the Discovery Lab at FIU.

In the immediate future, we are planning to extend the PBL-based research/educational program with the enhanced Cascade Mentoring Program. We believe that this will enable vertical integration from high school students to graduate students under mentee and mentor relationship, and early engagement in challenging projects.

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