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Pedagogy in undergraduate cosmic ray research projects with hands-on explanation of engineering versus engineering technology for community college students

Dr. Raul Armendariz, City University of New York, Queensborough Community College

Associate professor of physics

Corey Stalerman

Physics instructor at Queensborough Community College.

Prof. Tak Cheung

Tak Cheung, Ph.D., professor of physics, teaches in CUNY Queensborough Community College. He also conducts research and mentors student research projects.

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Abstract

A cosmic ray research project with the detection of high energy muon showers can serve as a hands-on explanation to the question of "What is the difference between engineering and engineering technology" asked by community college students. Conducting a variety of student projects in parallel within a semester is necessitated by the complexity of the muon shower detection technology, already documented by several detection centers around the Globe. Our unique community college setup includes the remote tracking of the Sun by a muon telescope moving along the ecliptic, and the inclusion of high school students in the Outreach mission of our community college. The pedagogy analyzes a student engineering project as having three components, namely, engineering science, engineering math, and engineering technology. The science aspect of data analysis would span from correlational study of the solar activity with measured cosmic ray flux to the analytical study of ultrahigh-energy cosmic ray (UHECR) data and Alice Collaboration pion decay data, depending on the students' backgrounds. The engineering designs in terms of the measurement science of photomultiplier and counting circuit are covered in the first few practical lessons on the designs of data collection. The engineering math aspect typically spans from Landau distribution analysis to Monte Carlo muon trajectory simulation, consistent with the different math requirements in the ABET accredited programs. The building skills of detection and tracking systems are compulsory as the engineering technology component in the pedagogy. The compulsory component is consistent with the engineering technician job requirements listed on indeed dot com and the relatively larger enrollment of engineering technology students in our community college. The variation of the percentage of each of the three pedagogical components (science, math, technology) to fulfill the DEI mission in an open-admission community college setting is presented with assessment. Expansion of the pedagogy for medical related student projects as orthopedic robots is discussed, consistent with the relatively high demands from the high school students in our Outreach and DEI mission in an urban community college setting.

Introduction

The community college engineering technology students in our local New York City area lack the opportunity to acquire hands-on experiential experience to apply for jobs related to calibration. A search of calibration technician on indeed.com showed that there were 100 job openings in New York City, while calibration engineers showed 25 jobs (last assessed Aug 20, 2024). According to the US Bureau of Labor Statistics, calibration technologists and technicians are expected to be at 4% increase in growth rate from 2022 to 2032 [1]. In comparison, there is a drop of 3 % in growth rate for Electro-mechanical and Mechatronics Technologists and Technicians 2022-2032 [2].

The instrumentation of cosmic ray detection is well-known using expensive fast oscilloscopes to capture the fast PMT signals. In the study of cosmic ray showers with many muon detectors, Fermi Lab used printed circuit PCB boards to replace the scopes for compact mobility and also for budget. We at Queensborough Community College (QCC) have improved the Fermi Board PCB Board design to enable the detection of ultrafast cosmic rays. The interface process of the PCB, Arduino and PMT in a muon detection system offers an excellent opportunity for a student to acquire hands-on learning of calibration, on top of the basic skills used in mechanical and electrical technology jobs.

A cosmic ray research project with the detection of high energy muon showers can serve as a hands-on explanation to the question of "What is the difference between engineering and engineering technology" asked by community college students. Our unique community college setup includes the remote tracking of the Sun by a muon telescope moving along the ecliptic, and the inclusion of high school students in the Outreach mission of our community college. The project learning objectives are designed to give a clear hands-on explanation.

Learning Objectives

The project objectives are the learning of the following skills by the students:
(1) preparation of scintillator, technician
(2) PMT interface and testing, technician
(3) PCB interface for coincident counting, technician
(3) pulse shaping for the Arduino, engineer
(4) Arduino microcontroller programming for data management, engineer
(5) Counting statistics on a computer as the final product, ready for data analysis in high energy physics as the customer, engineer
(6) photon counting subsystem testing via simulation of PMT signal, engineer
(7) system testing in the field for muon coincident counting using two scintillators, technician
(8) field tracking of muon telescope with altitude/azimuth control, technician
(9) submission of a report summarizing the issues in each of the above objectives, engineer
(10) resubmission upon comments from faculty, engineer

Pedagogy

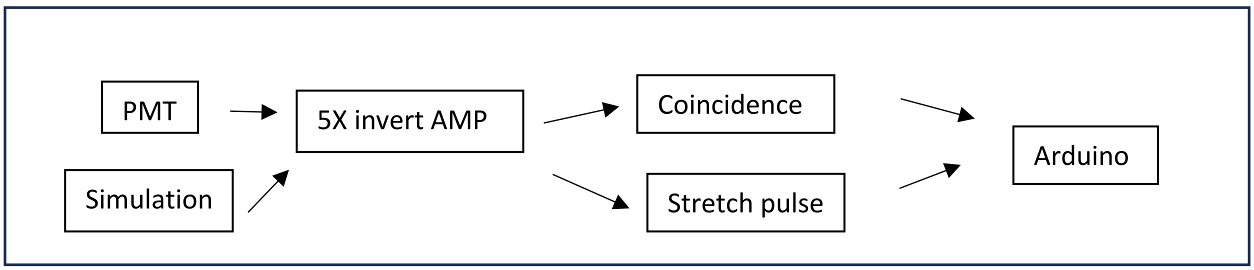
Hands-on Activities

The student education actives include drilling, soldering, programming, reading, and writing to build the entire system from scintillator to computer output. The operational principles of each of the steps, listed in the Objective Section, are shown to the students in the style of appendices shadowing of a skill-master [3].

The pedagogy analyzes a student engineering project as having three components, namely, engineering science, engineering math, and engineering technology. The science aspect of data analysis would span from correlational study of the solar activity with measured cosmic ray flux to the analytical study of ultrahigh-energy cosmic ray (UHECR) data and Alice Collaboration pion decay data, depending on the students' backgrounds.

The engineering designs in terms of the measurement science of photomultiplier and counting circuit are covered in the first few practical lessons on the designs of data collection. Briefly, the photomultiplier tube would generate a negative pulse of about 0.1-volt amplitude at 20 nanosecond pulse width. An inverted 5X conversion (with pulse inversion) would be applied for two different purposes, namely, (1) the logic counting for coincident pulses within a millisecond window given the stacking of two scintillators, (2) and to stretch the pulse to 0.5 micro-second for reading by the Arduino, at a max rate of about 30 coincidence counts per second.

The engineering physics measurement entails the understanding of the following: the scintillator photo-electron process, the photomultiplier mechanism, the Boolean logic in coincident counting circuit, the necessity of the pulse stretching by the RC filter principle to match the processing speed of the Arduino, and the codes in the Arduino data management. Simulation exercises could be conducted, for instance, at the 5X invert stage, see diagram below.



The engineering math aspect typically spans from Landau distribution analysis to Monte Carlo muon trajectory simulation, consistent with the different math requirements in the ABET accredited programs.

For instance, SUNY Farmingdale requires more calculus knowledge than CUNY City Tech in mechanical engineering technology, judging from writing in the catalogs. The Landau distribution data fitting could be handled with technical calculus knowledge while the Monet Carlo simulation requires regular calculus knowledge in any engineering programs across the country.

Assessment

The building skills of detection and tracking systems with calibration are compulsory as the engineering technology component in the pedagogy. The compulsory component is consistent with the engineering technician job requirements listed on indeed dot com and the relatively large enrollment of engineering technology students in our community college.

The other two pedagogical components (science and math) would vary with a relationship with the already taken pre-requisite courses. Those students with technical calculus knowledge did well in data fitting while those with college calculus did well in simulation and programming. An assessment rubric with two rankings of “did well” and “improvement needed” was used, consistent with the DEI mission in an open-admission community college setting. The faculty time effort has been unevenly distributed among the students so as to maintain an equity outcome. Out of some 100 participated college students in the last 10 years, all those who completed the projects were in the “did well” ranking. All of the participated college students continued to senior colleges. About 10 students asked for job recommendations after graduating from senior colleges. Although the job success rate was not tracked, three students showed that they were successful as engineers. The high school participants, under QCC College Now Program PH450 Research Project, had about 5 students (N = 48) in the “improvement needed” ranking, probably related to “absences”

Would the students (college and high school) acquire a clear understanding of technicians versus engineers in a project? All of the assessed students were able to classify the learning objectives into the technician and engineer categories correctly.

How successful was the delivery of the three pedagogical components? Using an equity rubric, all the college participants were in the “did well” ranking. There were two reasons. Firstly, the students with strong math background would do more on engineering math component, while those with physics background would do more in the science component. The other reason was traced to the fact that faculty members interested in the muon project were around 5 days a week to answer all of the students’ questions, unlike the high school participants who are facing with scheduling conflicts and could only be on campus on designated time slots with extra demands from High School System-wide exam and training schedules.

Discussion

Expansion of the pedagogy for medical related student projects as orthopedic robots is planned for the College Now students. The plan has been based on survey data which showed a relatively high demand from high school students in the field of medical physics. The college CSTEP Program of New York State also recruited students interested in medical related disciplines. Given the DEI mission in an urban community college setting, faculty members should be prepared to switch from “teaching equally to every student” to “putting unevenly distributed efforts among the students” to achieve an equity outcome; and that skill-learning projects such as muon detection measurement as proxy for cosmic rays would be very effective.

Conclusions

We have concluded that the reported muon measurement skill-learning project is very effective to show community college students about engineering science versus engineering technology. All the implementation details are in open sources to encourage the participation of community college faculty in the use of muon detection in their pedagogies.

Acknowledgments

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