Software Training Outreach In HEP

Sudhir Malik[1,*], *Danelix* Cordero[2], *Peter* Elmer[3], *Adam* LaMee[4], and *Ken* Cecire[5]

[1]University of Puerto Rico Mayagüez, Mayagüez, PR 00681, U.S.A.
[2]CROEM High School Mayagüez, Mayagüez, PR 00680, U.S.A.
[3]Princeton University, Princeton, NJ 08544, U.S.A.
[4]University of Central Florida, Orlando, FL 32816, U.S.A
[5]University of Notre Dame, Notre Dame, IN 46556, U.S.A.

Abstract. The NSF-funded IRIS-HEP "Training, Education & Outreach" program and QuarkNet are partnering to enable and expand software training for the high school teachers with a goal to tap, grow and diversify the talent pipeline from K-12 students for future cyberinfrastructure. The Institute for Research and Innovation in Software for High Energy Physics (IRIS-HEP) is a software institute that aims to develop the state-of-the-art software cyberinfrastructure for the High Luminosity Large Hadron Collider (HL-LHC) at CERN and other planned HEP experiments of the 2020's. QuarkNet provides professional development to K-12 physics teachers in particle physics content and teaching methods. The two projects have recently built a collaborative relationship where a well-established community of QuarkNet K-12 teachers has access to a wide training on software tools via its Data and Coding Camps supported by IRIS-HEP. The paper highlights the synergistic efforts and future plans.

1 Introduction

IRIS-HEP [1] software training and workforce development activities are contributing to the preparation of a highly qualified STEM workforce. Its software training programs in HEP are training not only to scientists, early career and incoming graduate and undergraduate students but also high school students via their teachers. It is providing opportunities for high school teachers to improve coding skills and explore how these could be embedded in instructional materials implemented in classrooms; and to help foster the coding skills of their students. Several outreach programs were offered, initially in person and co-organised with FIRST-HEP [2] and then switched to online/remote style during the COVID-19 era. A list of IRIS-HEP outreach activities is here [3]. Subsequently, partnership between QuarkNet [4] and the IRIS-HEP has led to the organisation of workshops called, "Coding Camp" [5] that enhances and extends the coding skills of QuarkNet high school physics teachers offered by "Data Camp" [6]. The symbiotic engagement with QuarkNet has helped quickly reach a wider networks of STEM teachers that has potential to facilitate create a robust pipeline of students pursuing STEM careers equipped with software awareness.

*e-mail: sudhir.malik@upr.edu

2 Training Workshops

In the initial phase of Software Training Outreach, workshops were organised mostly in Puerto Rico and the exploration phase of collaboration with QuarkNet was largely limited due to the onset of COVID-19 pandemic. However, this gave a great opportunity to reach out to teachers in Puerto Rico who had something exciting to do with their peers while working remotely from home. The very first teacher's workshop [7] in 2019 was in person and introduced ideas and concepts behind programming (using python as an example) including tools and examples that one could use or modify and incorporate into the classroom. With sudden onset of pandemic, online workshops became the workshop style. In these workshops teachers analyzed real datasets from the CMS Experiment [8] at the Large Hadron Collider (LHC) [9] and interpreted their findings by making plots. The quantitative and software experiences helped build skills that are useful in classroom and lab settings of a Physics course. Several coding examples in python using Markdown embedded with LaTeX formulas were designed using Jupyter notebooks in Google Colaboratory. Based on the feedback from teachers, workshop on Arduino Programming [10] using C++ language and Machine Learning Basics [11] were organised. Arduino programming is needed for school students interested in electronics and robotics projects while Machine Learning can equip students to learn coding skills to tackle complex topics. Several teachers who participated had prior experience of QuarkNet Masterclasses [12] that offers hands-on experience to statistics, visual identification and classification of particle physics data and excel spreadsheet based analysis.

3 Partnership

In addition to Masterclasses, QuarkNet organises an annual in-person Data Camp at Fermilab that offers an authentic HEP data analysis experience with a goal to challenge the teachers and prepare future lead teachers. Lead teachers have experience, skills and knowledge to lead QuarkNet activities independently. With onset of COVID-19 pandemic in-person Data Camps were not possible and hence a new week-long virtual Coding Camp [13] was designed that introduced Python and Google Colaboratory to teachers with minimal to no software skills. The content was tailored to meet the needs of all attendees and provide a supportive learning environment. Using the resources and skills learnt, teachers could in turn provide programming concepts to their classroom.

After in-person QuarkNet workshops resumed, the virtual Coding Camp continued in 2022 [14] and supplemented with an in-person 5-day Coding Camp 2 at Fermilab. Prior participation in Data Camp, the online Coding Camp during pandemic or equivalent skills were pre-requisite so that teachers are ready to learn advanced topics. Teachers also experienced Fermilab facilities and tours as well. To build a strong collaboration with QuarkNet IRIS-HEP started funded this in-person Coding Camp 2 in 2022 [14] and 2023 [15].

Since the week-long Coding Camp 2 was based at FNAL, it was also thought to offer scaled down 3-day in-person versions of the coding workshops at several established QuarkNet centers in the US. Instead of bringing teachers to Fermilab, this enabled bring coding experiences to teachers in their local area. Scaled down does not imply less teaching content or time but absence of Fermilab tours and facilities as these happen at other QuarkNet centers. With the support of IRIS-HEP 3-day coding camps were held in summer of 2023 in Puerto Rico, University of Washington, University of Alabama and Rice university and a total of about 65 teachers were trained.

4 Coding Camp

Coding Camps focus on how coding can be augmented in physics classes through an introduction and an opportunity to practice and is done in two phases. During the first phase, participants engaged as active learners, "as students." In partner groups, participants run Python code using a pre-written scaffolded Jupyter notebooks. The notebooks are interactive and shareable software written in the Python language and is designed to teach specific skills and concepts that participants need. Examples include how to make a histogram in Python,import large datasets, use Matplotlib and utilize various libraries. Building on these activities, participants designed their own notebooks to perform an analysis of CMS large dilepton datasets, calculating invariant mass, testing the effect of different cuts on charge, transverse momentum, pseudorapidity, and muon reconstruction type. Following this analysis they worked cooperatively to interpret their results and draw conclusions. As the last exercise of this first phase, participants conduct an open-ended exploration (i.e., structured inquiry) of their own choosing, "with the only requirement that they create new notebooks of their own using a new dataset or a deeper analysis of a dataset that they'd already used." After completing these explorations, teachers share results collaboratively and offered constructive suggestions to each other.

In the second phase, teachers develop implementation plans for their own classrooms. This begins with writing a Jupyter notebook or a series of notebooks with scaffolding and differentiation appropriate to the teacher's school and demographics, followed by a brief companion document that explains how notebooks works, and how these activities fit into the scope and sequence of the course and/or their educational standards. At the end of the workshop, participants shared their work with each other and offered constructive comments. Throughout Coding Camp, guest speakers visit via Zoom or in-person sharing their professional and research use of coding.

5 Participation

The participation of teachers in IRIS-HEP led outreach program has increased since its inception in 2018 as shown in Figure 1 left. In addition Figure 1 right shows that teachers participating are not only from Physics background but also from Math and other STEM areas and this fraction has diversified over the years. With with recent Coding Camp collaboration with QuarkNet these trends are expected to grow further. The varied levels of coding activities teachers work through during the workshops has helped teachers bring these experiences directly to their students, regardless of the age or level of class they teach. The *Intro to Coding* notebook developed for Coding Camp has been useful for many teachers as an easy 'on ramp' for a broad range of classes. Some teachers of either higher level courses or dedicated computation courses are using the full suite of notebooks, including visualization with the object-oriented Matplotlib interface and the invariant mass reconstruction with CMS dilepton events, along with notebooks the teachers have designed themselves. These participating teachers report their students quickly overcoming hesitation or preconceptions of coding as being too difficult given the accessible nature of the notebooks provided and their editable format so the teachers can tailor them to the needs of their particular students.

6 Conclusions

The collaboration and synergy between IRIS-HEP and QuarkNet is symbiotic. A vast network of QuarkNet teachers across the US are accessible and this would facilitate scale up

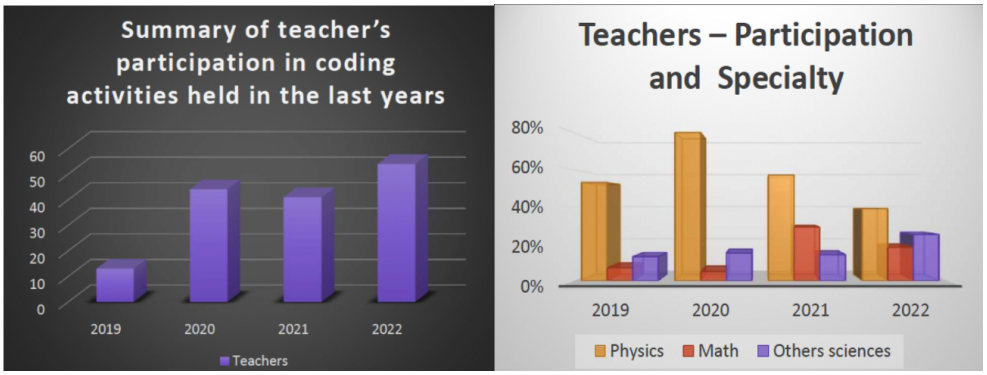

Figure 1. Teachers participation over years (left) and area speciality (right)

IRIS-HEP software training outreach activities. IRIS-HEP support for Coding Camps at Fermilab and across the US QuarkNet Centers has enabled not only bringing teachers to Coding Camps but vice versa as well. It is planned to scale up the Coding Camps across the nation and design coding content in Spanish language as well. The outreach activities can be easily modulated to length of days from 2 to a week long and in-person to online, as the situation and need may arise.

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