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IOT Platform to Facilitate Student Innovation

Dr. Ciprian Popoviciu, East Carolina University

Dr. Ciprian Popoviciu has over 26 years of experience working in various technical and leadership roles in the IT industry. He founded and led Nephos6, the first company to enable OpenStack for IPv6 and deploy it in production. Prior to starting Nephos6 he worked for CIsco and he is an industry recognized IPv6 subject matter expert. Currently he is an assistant professor in the college of engineering at East Carolina University and his research is focused on IoT and cybersecurity.

Mr. Colby Lee Sawyer, East Carolina University

Current Software Engineering MS Student at East Carolina University

Mr. Joshua Edison Pitzer, ECU College of Engineering and Technology

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Ciprian Popoviciu, Colby Sawyer, Joshua Pitzer

Abstract: The Internet of Things (IOT) holds the promise of enabling truly transformational increases in productivity like those enabled by steam power and electricity. IOT can enable significant optimizations of workflows and processes across a wide range of domains and activities. Educators face the challenge of providing students with both the knowledge to understand the capabilities of IOT but also with providing students with practical, hands-on experiences with IOT that would reinforce theoretical knowledge and facilitate innovation. The later dimension of technical education requires access to an IOT infrastructure and the mentoring and resources that can support students in validating new ideas. At East Carolina University, we architected and implemented a multi-campus IOT platform that makes it easy to deploy and manage most types of sensors. The platform makes it easy to analyze collected data and implement automation of workflows based on insights extracted from the data. This platform transforms the campus into a lab where the Digital Lounge and the Isley Innovation Hub can mentor students to innovate on this IOT platform. The Digital Lounge is the initiative of the College of Engineering and Technology (CET) while the Isley Innovation Hub is run by the Miller School of Entrepreneurship and provides the space, the tools and the guidance students need to test their ideas. This paper describes the results of this collaboration and the benefits of combining innovation mentorship with campus wide IOT platform facilitating experimentation and education. This collaboration includes awareness activities, IOT training and management of ideation and prototyping.

Key words: IOT, Technology Innovation, Entrepreneurship.

1. Introduction

Like many other universities, East Carolina University (ECU) [1] has a strong commitment to encouraging and enabling students to innovate and to explore new skills and fields of knowledge. This support manifests itself at various levels, from university wide initiatives to department level resources and it consists of physical resources, mentoring networks and innovation focused events. Each initiative, program and resource do of course, emphasize the types of support typically provided by the organizer. The graduate school stimulates innovation through its annual Research and Creative Achievement Week (RCAW) [2], the Research, Economic Development and Engagement (REDE) department is running NSF I-Corps [3] programs to stimulate entrepreneurship, while the College of Business is organizing a Pirate Entrepreneurship Challenge [4].

The availability of all these efforts to encourage and support student innovation and entrepreneurship is not a guarantee of their success [5]. Innovation and entrepreneurship are complex undertakings which require participants with certain traits and concerted guidance and specific support throughout the entire lifecycle of innovation [6]. Universities face challenges such as in [7].

- Students, educators and industry partners are often unaware of initiatives and resources available to them. Despite each of these resources being promoted to a greater or lesser extent across the campus, they frequently are advertised in isolation
- Resources are often not presented in the context of the various stages of innovation in order to demonstrate the availability of support throughout the entire process. This incomplete picture can deter creative students who lack certain skills needed to pursue an idea
- Lack of clear identification of target innovation domains, areas ripe for both business and technological disruption. Helping students focus on specific opportunities makes it easier to undertake what in a broader scope might seem an insurmountable challenge
- Availability of larger scale test environments where prototyping can be taken from the lab bench and integrated into a system, combined with other resources into more compelling and exciting solutions.

The Internet of Things (IOT) is emerging as a rich innovation space with the potential to revolutionize entire industries in a way not seen since the industrial revolution. IOT enables granular observability and monitoring of key variables for various human activities, environments and production processes which can be combined with analytics to deliver significant insights. Moreover, IOT makes it possible to automate data collection, data analysis and event driven responses into completely automated workflows. IOT can bring together diverse types of innovators, of expertise and experience to lead to multidisciplinary solutions to major societal, environmental, and business challenges. IOT provides a great opportunity to stimulate multi-disciplinary innovation.

In most cases, the ingredients for a successful strategy to enable student innovation are present, the challenge is to align them into a coherent and effective story. At ECU, the coordinators of three facilities focused on promoting and supporting student innovation and entrepreneurship partnered to raise awareness of the resources available for students, to open the door to a fertile and rapidly growing field of innovation, the Internet of Things, and to demonstrate the availability of support throughout the innovation journey, from ideation, to prototyping and testing, to pitching and the development of a business model. This paper is a case study on the use of a competition to engage students and an in-house developed, campus wide IOT platform to support student innovation.

2. Case Study

A wave of technological innovation in the IOT space has made sensors and technologies connecting sensors inexpensive and versatile. These resources provide the tools for new, disruptive ideas and would be a great environment where students can be encouraged to explore new ideas. For this study we

decided to leverage a campus wide IOT platform to facilitate technology innovation and entrepreneurship and to address two related challenges:

1. Student lack of awareness of resources available to support innovation and entrepreneurship
2. Availability of resources for each stage of the innovation and entrepreneurship process

To explore pathways to address these challenges, three resources were brought together to support a two-phase student competition that would incentivize, educate, and mentor students through the process of solving real world problems.

2.1. The Competition

The competition is called “The Amazing Techno Race” and it consists of the following phases:

- **Phase 1** – The main goal of Phase 1 is to acquaint students with the participating facilities supporting innovation, get them comfortable with the available tools and identify teams that can pursue innovative ideas from multiple perspectives (technology, business, operations, etc.). This first phase of the race will have teams race against time to build sensing solutions.
- **Phase 2** – The main goal of Phase 2 is to bring back the participants in Phase 1, with their newfound knowledge in technology and innovation, potentially within the same teams to compete on developing solutions to unresolved problems. The format of this Phase is like a hackathon.

In this project we want to explore the best mechanisms to communicate with students in order to encourage them to innovate and consider entrepreneurship. We also wanted to make them aware of the resources available for them to develop a Minimal Viable Product (MVP) and test in an existing IOT environment. Phase 1 is meant to provide the students with the tools they need to innovate and Phase 2 is meant to have them apply these tools to solving new problems.

In this paper we cover our findings related to Phase 1 of The Amazing Techno Race completed on November 16, 2022.

2.2. ESDN – The IOT Platform

The Environmental Sensing Data Network (ESDN) [8] is an infrastructure and a service developed and managed by the Center for IOT Engineering and Innovation (CIEI) [9] within the department of Technology Systems in CET. The main mission of ESDN is to enable the concept of Campus as a Lab [10], a platform facilitating easy deployment and management of networked sensors, to facilitate data collection and data analytics in support of research and education. ESDN was designed to accommodate four specific use cases:

1. Users, scientists, and educators can deploy sensors that do not have wireless communications options. CIEI developed a small form factor communications shim which intermediates and processes communication between the digital/analog interface of a sensor and the LoRaWAN based ESDN network
2. Off the shelf LoRaWAN fitted sensors can be integrated
3. Sensors using other dedicated networks can be used
4. External data sets can be imported to facilitate analytics

The ESDN architecture is modular [11] to provide the flexibility to adapt as new requirements emerge, as components are developed internally, and scalability requires (Figure 1). ESDN platform is also meant to facilitate innovation related to its own components and technologies.

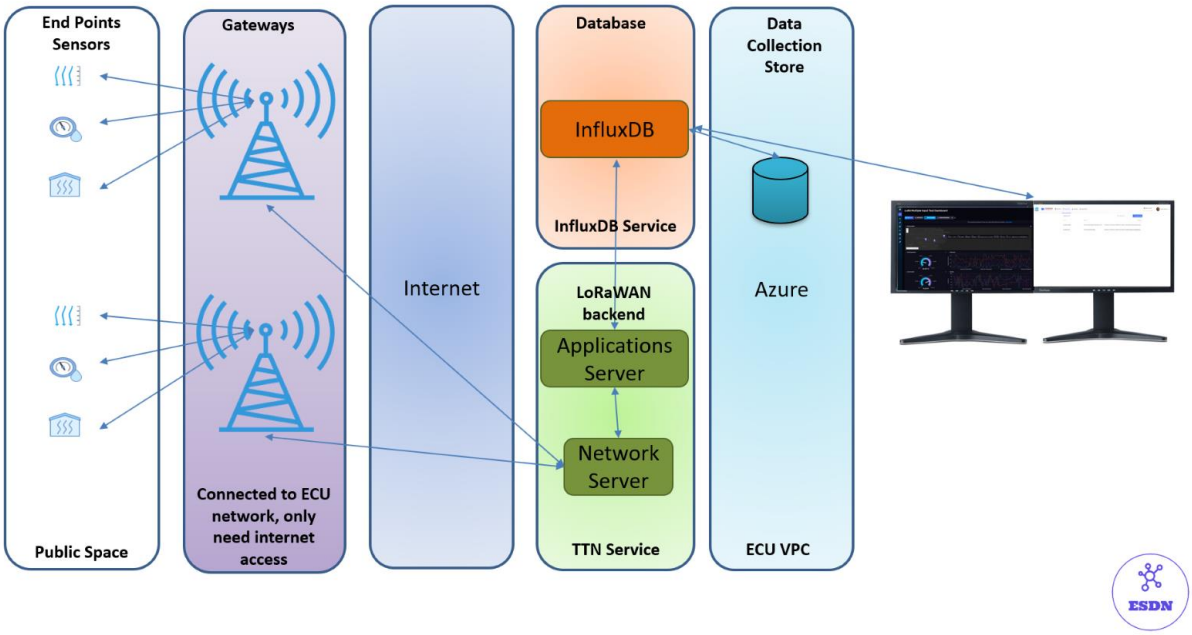

Figure 1. High-level architecture of the ESDN end-to-end service

ESDN provides users with multiple options to build, and test point IOT solutions or entire end-to-end services. Full IOT projects can be easily set up with access provided to the various components of the platform. With these projects, users can deploy the sensing devices they developed or off-the-shelf products, collect the data, visualize and analyze it.

Multiple and diverse innovation opportunities are provided by the platform:

- Explore the use of inexpensive, networked sensors that are flooding the market in search for interesting applications
- Build edge computing applications on the ESDN compute shim which is based on the Raspberry PI platform
- Develop and refine new sensor data analytics that would provide valuable insights
- Create and validate new workflow automations that can support new business models.

Additionally, the ESDN user community is constantly submitting requests for new functionality thus generating a running list of innovation topics. The topics selected for Phase 1 of this case study are problems resolved for ESDN users by the CIEI group while the topics planned for Phase 2 are new requests that have not yet been addressed.

The role of ESDN is to define, document and prepare the tasks the students will complete for the race and the environment to test the results.

Dedicated equipment was purchased to support this project. The list included multiple sensor types, breadboards, cables, and the components of a LoRa end node [12]. The equipment supports ten distinct projects, and the cost of the equipment was $77.

2.3. The Digital Lounge

One component in the CET [13] strategy to encourage students to explore new technologies, develop a

passion for prototyping and collaborate across disciplines is a dedicated space called the Digital Lounge [14]. The Digital Lounge is a partnership between the CET student success center and all four departments of CET, yet it's open to students from across the university, not just CET students. Its role in the project is to provide the students with an environment where they can put together the hardware and develop the software for the competition. This space fulfils multiple roles: it gives students assistance with registration questions and with Degreeworks [15], it is used to house the Counselor and Adult Education (COAD) 1000 [16] classes which help students transition to ECU, and a meeting space for college tours. On the innovation support side, the Digital Lounge has multiple work benches with Arduino kits, Raspberry PIs, a multitude of circuitry sensors and components, as well as Virtual Reality (VR) headsets including Oculus [17], Hololens [18] and HTC Vive [19]. The lab includes a VR treadmill with high processing computational resources enabling students to get fully immersive experiences and begin to create their own VR experiences. The space is used both for classroom exercises as well as a space for students to explore technologies on their own. Multiple tutorials introduce students to available resources and operating processes. The Digital Lounge's role in the project is to provide the students with an environment where they can put together the hardware and develop the software for the competition.

2.4. Isley Innovation Hub

The Isley Innovation Hub [20] is a facility created and managed by the College of Business. It provides a space for ECU students to develop ideas, create early-stage prototypes, build project teams and access entrepreneurial resources. The Isley Innovation Hub provides an ideation space, video and audio recording facilities and a technology lab providing the resources to support high-level design and 3D printing. The Isley Innovation Hub also hosts the Miller School of Entrepreneurship [21] providing access to expertise and guidance in pursuit of entrepreneurial projects.

The Isley Innovation Hub's role in the project is to provide students with a space where they get to build the teams participating in the competition, acquire the knowledge necessary to complete the tasks and flesh out each team's plan for execution. At the end of the competition students return to the hub to discuss their experience.

3. Results

The first phase of The Amazing Race competition was conducted on November 16, 2022 and focused primarily on raising awareness about the three participating facilities and encouraging students to use technology to solve real world problems.

3.1. Planning the Competition

The CIEI team developed a set of sensing hardware/software projects for the competing teams to choose from. All these projects have already been implemented in various use cases within ESDN. The goal is for the students to develop technical confidence through the process of re-building them under the supervision of the CIEI staff. Examples of projects are:

- Physical Environmental Features
    - Temperature
    - Humidity
    - Atmospheric Pressure
- Soil Moisture
- Visible/Invisible Light
    - Ultraviolet A

    - Ultraviolet B
    - Visible
- GPS
    - Longitude
    - Latitude
    - GPS Satellites within range
- Distance Detection
    - Ultrasonic
    - Optical (LiDAR)
- Time of Flight
- Open/Close Break Beam

The competition is set up as a race taking teams through several stages covering the three participating facilities, stages where each team must complete a set of tasks. Figure 2 depicts the roadmap for the race.

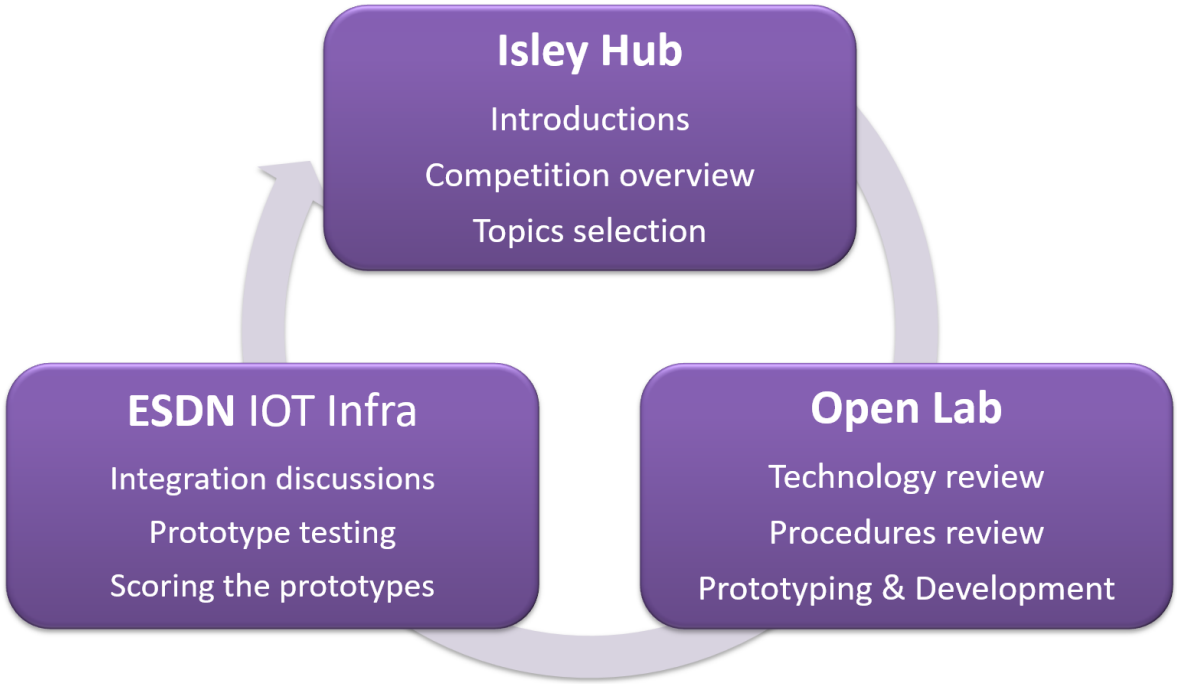

Figure 2. The Amazing Techno Race roadmap

Communication was viewed from day one as a critical component of planning the competition. We wanted to communicate broadly and consistently. The following mechanisms were used to communicate with the students:

- Physical posters displayed on campus with a dedicated QR code
- Messages sent through the Canvas [22] shell used by the Isley Innovation Hub and by CET Safety Training respectively. These messages reached the communities already built around these facilities
- Announcements in the Canvas shells of various running courses in CET. We benefited from the support of many faculty who shared information about the race with their students.

Students were engaged multiple times in the weeks leading to the event to avoid loss of interest and to encourage referral. Each communication channel is independently tracked to evaluate its efficacy.

3.2. Lessons Learned and Results

The event was successful beyond the expectations of the organizers. It was successful with respect to participation, the diversity of participants, student involvement and competition outcomes. Student feedback was very positive with requests to organize the follow-up event.

The effectiveness of communication channels with respect to engaging and recruiting students for the event is summarized in Table 1. Each channel lists the data when communication was sent ahead of the competition on November 16, 2022.

Channel	Audience	Opened	Page Views	Registered
CET training page – emailed 2 weeks prior event	3600	123	140	9
CET training page – emailed 1 week prior event	3600	130	146	11
Isley Innovation Hub – emailed 2 weeks prior event	412	38	40	6
Isley Innovation Hub – emailed 1 week prior event	412	18	19	9
Campus poster (20 printed)				10

Table 1. Effectiveness of communication channels

Several courses in the Information technology department posted announcements about the competition, however, the impact of these announcements could not be evaluated. Of the 49 registered students, 41% learned about the event from CET communications, 31% from Isley Hub communications, 20% from the physical posters and 8% were walk-ins who likely learned about the event from friends.

The original goal of the competition to involve a diverse group of students in terms of majors and experience with coding and hardware was achieved. Figure 2 summarizes the educational background of the participants which included expected technology and computer science as well as biology, nursing, neuroscience, and business majors.

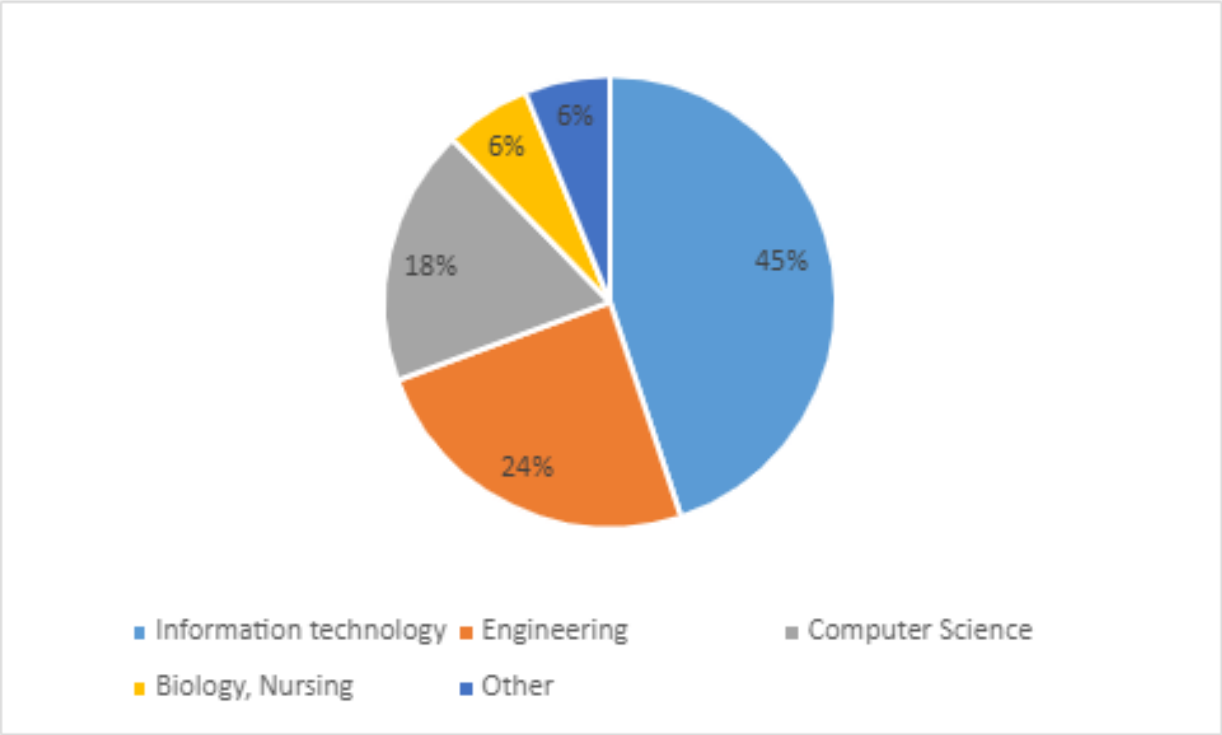

Figure 3. Majors of participating students

As expected, most students had a technology, engineering or computer science background. However, 12% of participants were from fields where IOT is a research, productivity enabling solution. The level of expertise of the participants with the two major elements of the scope of work, coding and computing hardware, is listed in Table 2.

Proficiency Domain/Level	Zero	Beginner	Intermediate	Expert	No Response
Coding	19	17	9	0	4
Computer Hardware	17	19	8	1	4

Table 2. Level of proficiency of the participating students

One of the goals of the competition was to expose un-experienced students to the technologies involved in IOT. As reflected in Table 2, this goal was achieved, with most participants having zero or limited experience with embedded platforms (Raspberry PI) and coding for them.

The event was organized on November 16, 2022, and the participants were grouped into 8 teams combining students with various levels of expertise and experience. Each team was provided with the kit needed to assemble the communications shim and sensor, the guide to assembly and the necessary code. The first team who managed to have their communication shim connected to the LoRaWAN infrastructure and transmit data from their sensor was declared the winner of the competition. Of the 8 teams, 2 completed the task within the allotted time while a third team completed the task after staying an extra 10 minutes because they wanted to see their project through. The remaining teams did not manage to complete the task.

Students were surveyed at the end of the competition to assess their experience and their interest in future competitions. Table 3 summarizes the survey responses based on a scale of 1 to 5 where 5 is the most positive response and 1 is the most negative response.

Question	Average (1-5)	Std Deviation
How was the pre-event communication?	4.25	1.15
How was the event?	4.38	0.78
If we have a second, more challenging event, a hackathon, how likely are you to participate?	3.31	1.36
How likely are you to use the Isley Innovation Hub in the future?	4.5	0.71
How likely are you to engage with the Center for IOT Engineering and Innovation in the future?	4.19	0.88
How likely are you to use the CET Digital Lounge in Rawl 107/108 in the future?	3.94	1.09

Table 3. Level of proficiency of the participating students

The event did achieve its goals of exposing students to IOT, demonstrating the opportunities available to innovate around IOT and exposing students to existing resources such as CIEI, the Isley Innovation Hub and the CET Student Success Lounge.

The evaluation of the overall event experience was very positive as reflected in the response distribution (Figure 4).

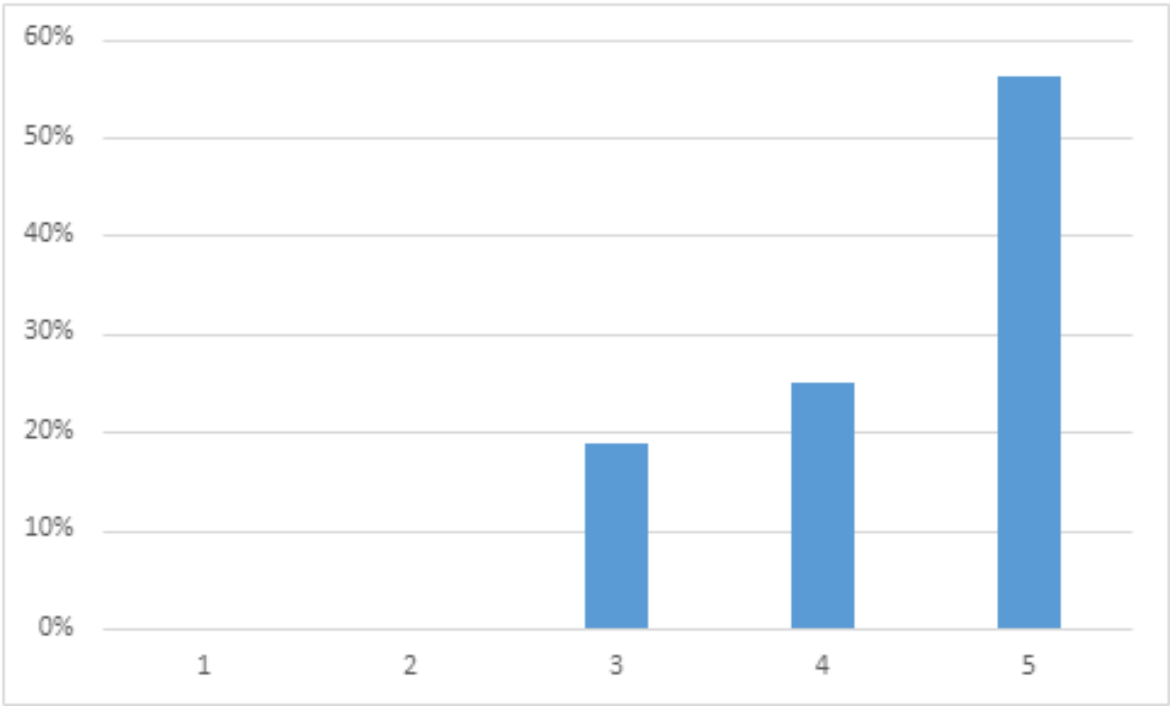

Figure 4. Student evaluation of the overall event (5 = Very Good, 1 = Very Poor).

The qualitative feedback on the event was also very positive as exemplified by the student comments:

- “I liked the process of learning on your own. It allowed me to act on previous experiences I’ve had”
- I liked the “overall atmosphere and ease of starting the race” and the “difficulty and challenge”

- “It was challenging and brought the team together”
- “I enjoyed the challenge and working in a team”
- “Good teamwork and competition atmosphere”
- “I like the competitiveness and the ability to meet more people in that area”

Student comments underlined some of the positive aspects of such a competition: opportunity to learn, being challenged, working in teams.

Several areas of improvement were identified by the organizers and suggested by the students:

- Better expectation setting: “It was a bit more complicated than anticipated even for those with coding backgrounds had a very hard time.”
- Improving the kit: "Some of the sensor specific issues were troubling.”
- Improved instruction document: “The instructions were sort of confusing I feel like a lot of groups got lost in the middle when we had to figure out the coding.”
- Have additional resources to answer questions faster: “Event holders staying too long in one group and not floating more often.”
- Time management was challenging and could be structured better in future events.

These lessons learned will be incorporated in the next event planned for Spring 2023.

4. Conclusions and Future Work

This paper presents the results of the author’s attempt to leverage the internally developed ESDN platform as an environment to facilitate student innovation in IOT and to expose students in a consistent manner to the various resources available on campus to support innovation activities. We describe the approach and methodology used to advertise and run an event where student teams were provided with a hardware kit and coding guidelines to put together a sensor communication shim and connect to the ESDN infrastructure. The intent was to enable students of all majors and technical expertise to learn how to develop key elements of an IOT solution thus enabling them to prototype new ideas.

The results of the competition and the student feedback have shown that the original goals have been achieved. Students had a good learning experience and an enjoyable competition; they expressed interest in similar activities in the future and they expressed interest in taking advantage of the innovation related resources they experienced during the event. There were several important lessons learned regarding the organization of such an event, particularly with respect to communication and resources allocation. The feedback will be used to optimize future events.

In the context of expanding the value of the ESDN platform towards supporting student innovation, the authors plan to organize a follow-up event structured as a hackathon where participants in the covered competition will be able to apply the skills they developed to solve new problems from a list of requests received by the Center for IOT Engineering and Innovation from researchers and communities. The organization of this second event and the results will be subject of a follow-up paper.

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