2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34049

Global Impact of Experiment-centric Pedagogy and Home-based, Hands-on Learning Workshop at a Historically Black University

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Dr. Oludare Owolabi, a professional engineer in Maryland, joined the Morgan State University faculty in 2010. He is the assistant director of the Center for Advanced Transportation and Infrastructure Engineering Research (CATIER) at Morgan State University and the director of the Civil Engineering Undergraduate Laboratory. He has over eighteen years of experience in practicing, teaching and research in civil engineering. His academic background and professional skills allows him to teach a range of courses across three different departments in the school of engineering. This is a rare and uncommon achievement. Within his short time at Morgan, he has made contributions in teaching both undergraduate and graduate courses. He has been uniquely credited for his inspirational mentoring activities and educating underrepresented minority students. Through his teaching and mentoring at Morgan State University he plays a critical role in educating the next generation of underrepresented minority students, especially African-American civil engineering students. He is also considered to be a paradigm of a modern engineer. He combines practical experience with advanced numerical analysis tools and knowledge of material constitutive relations. This is essential to address the challenges of advanced geotechnical and transportation research and development. He is an expert in advanced modeling and computational mechanics. His major areas of research interest centers on pavement engineering, sustainable infrastructure development, soil mechanics, physical and numerical modeling of soil structures, computational geo-mechanics, constitutive modeling, pavement design, characterization and prediction of behavior of pavement materials, linear and non-linear finite element applications in geotechnical engineering, geo-structural systems analysis, structural mechanics, sustainable infrastructure development, and material model development. He had been actively involved in planning, designing, supervising, and constructing many civil engineering projects, such as roads, storm drain systems, a $70 million water supply scheme which is comprised of treatment works, hydraulic mains, access roads, and auxiliary civil works. He had developed and optimized many highway design schemes and models. For example, his portfolio includes a cost-effective pavement design procedure based on a mechanistic approach, in contrast to popular empirical procedures. In addition, he had been equally engaged in the study of capacity loss and maintenance implications of local and state roads (a World Bank-sponsored project). He was the project manager of the design team that carried out numerical analyses to assess the impact of the new shaft and tunnel stub construction on existing London Underground Limited (LUL) structures as per the proposed alternative 3 design of the Green park Station Step access (SFA) Project in U. K. He was also the project manager of Category III design check for the Tottenham Court Road Tunnel Underground Station upgrade Project in UK.

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Al Ferri received his BS degree in Mechanical Engineering from Lehigh University in 1981 and his PhD degree in Mechanical and Aerospace Engineering from Princeton University in 1985. Since 1985, he has been a faculty member in the School of Mechanical Engineering at Georgia Tech, where he now serves as Professor and Associate Chair for Undergraduate Studies. His research areas are in the fields of dynamics, controls, vibrations, and acoustics. He is also active in educational research as well as course and curriculum development. He is a Fellow of the ASME.

Dr. Kathy Ann Gullie, Gullie Consultant Services LLC

Gullie Consultants Services LLC, Owner, Dr. Kathy A. Gullie Ph.D. Dr. Kathy Gullie and her associates at Gullie Consultant Services LLC have been in education, assessment, program development and evaluation in New York State for over 30 years. A former New York State teacher for 36 years, Dr. Gullie is committed to the improvement of education for students in all areas and education levels. Collectively, along with members of the team, Gullie Consultant Services LLC. has served as external evaluators for school districts, federal and state agencies, not-for-profit organizations, and institutions of higher education in New York State, as well as from around the country. Some of our past clients include: The National Science Foundation, the U.S. Department of Education, The New York State Department of Education, New York State VESID, State University of New York at Albany/SUNY, the State University of New York at Binghamton/SUNY, New York Institute of Technology (NYIT), Howard University, Morgan University and New York City Board of Education.

More specifically, Dr. Gullie has served the principal investigator/evaluator on several educational grants including: an NSF engineering grant supporting Historically Black University and Colleges through Howard University, the Syracuse City School District Title II B Mathematics and Science Partnership grants, Building Learning Communities to Improve Student Achievement: Albany City School District, Educational Leadership Program Enhancement Project at Syracuse University and the University at Albany through the Teacher Leadership Quality Program. She holds an advance degree in Educational Theory and Practice from the University of New York/SUNY Albany, with experience in teaching educational methods at the master's level as well as an introduction to education courses designed to develop new interest in teaching careers. She has worked as an elementary classroom teacher developing specific curricula for gifted and talented students as well as inclusion classrooms in a school district eligible for rural and low-income programs. Dr. Gullie's experience and past projects qualify her for the position of evaluator to examine the impact of the Alliance: Pathways to Success in Engineering (PASE). Her experience and qualifications working with data from multiple educational projects and personal work with students give her an in-depth understanding of the developmental nature of students participating

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Dr. Spaulding is a program evaluator serving as an external evaluator on this NSF project.

Dr. James William Brown Ph.D., School of Professional Studies, City University of New York

Dr. James Brown is a pioneer in online course development in science. He has been dubbed the ”Godfather of Online Science” and recently has been designated One of the Top 40 Innovators in Education by the Center for Digital Education. He received his M.S. and Ph.D. in microbiology from the Waksman Institute of Microbiology at Rutgers University and an additional M.S. in Health Sciences from New Jersey City University. He is a former director of microbiology for Roche and an Assistant Commissioner of Health for New Jersey overseeing the Division of Public Health and Environmental Laboratories. He is a former dean of Science, Engineering, Health Sciences and Human Performance for Ocean County College that became an East-coast powerhouse for online science course development with over 14 unique online science courses. He is president of James W. Brown Associates LLC which develops online science courses for colleges and universities with a special focus science courses for Medical Schools, Dental Schools, Nursing and other health care related colleges and universities. Courses such as Anatomy and Physiology, Microbiology and Chemistry which are all designed using Hands-On Labs LabPaqs as the foundation for the laboratory experience. He developed the Online Science Laboratory Series for the Sloan Consortium (now named the Online Learning Consortium) in the Spring of 2014 which helps train science faculty and instructional designers in how to develop online courses in science. Dr. Brown teaches science totally online at California State University at San Marcos, Colorado Christian University, City University of New York, the University of New England, and Gwynedd Mercy University. Dr. Brown presented ”Opening Online Laboratory Science Courses to the World Community 2017 International Higher Education Teaching and Learning Conference at the University of the West of Scotland held in Paisley Scotland, June 28 – 30, 2017.

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Global Impact of Experiment-Centric Pedagogy and Home-Based Hands-on Learning Workshop at a Historically Black University

Abstract

With support from the National Science Foundation, an evidence-based experimental centric pedagogy (ECP) is being implemented across STEM disciplines at a historically black university. This is the first of its kind, where the ECP is being extended to several STEM disciplines after its successful implementation in electrical engineering to promote motivation and enhance academic achievement of minority students. One of the project objectives is to organize workshops whereby STEM faculty in biology, chemistry, physics, civil engineering, computer science, industrial engineering and transportation systems will learn how to develop and implement ECP as an active learning pedagogy. This paper highlights the strategies used for planning, publicity, implementation, and assessment of the workshop conducted in Summer 2020. Due to the ongoing pandemic, the workshop was held virtually with 360 participants registering globally. The workshop's focus was developing and implementing inexpensive home-based hands-on learning activities. Workshop assessment revealed that participants expressed positive outcomes; 84% reported that they believe the workshop was a good use of their time and 83% said they plan to implement what they had learned at the workshop in their own practice, affording the participants more opportunities to include home-based hands-on learning in their curriculum. This project seeks not only to increase public scientific literacy, but to also contribute to the development of a diverse, globally competitive STEM workforce.

Introduction

The experimental centric pedagogy (ECP) is a hands-on pedagogy that utilizes inexpensive, safe, and portable electronic instrumentation systems at various learning settings (classroom or student laboratories) to effectively engage students. The current project (NSF DUE 1915614) that is being implemented at Morgan State University is the only and first ECP project, where ECP is being utilized across seven STEM disciplines. The term ECP originates from the Mobile Studio Project (NSF CCLI #0717832) which was originally developed by Rensselaer Polytechnic Institute to increase students' motivation and achievement in electrical engineering. The ECP, through generous NSF funding, has been successfully implemented and assessed in the electrical engineering departments at 13 HBCUs [1]. Faculty (95%) stated that students were more motivated and had higher engagement with course content [1]. One of the current ECP project objectives is to organize workshops whereby STEM faculty in biology, chemistry, physics, civil engineering, computer science, industrial engineering and transportation systems will learn how to develop and implement ECP as an active learning pedagogy.

The objective of this paper is to present the execution and impact of the summer 2020 workshop conducted virtually at a historical black university with more than 360 participants in attendance across the globe. The purpose of the workshop was to create awareness among STEM faculty on the use of ECP in their respective disciplines, thus facilitating the widespread use and adaptation of the ECP. The workshop introduces the mobile board and parts kit to the participants, pedagogical materials developed for mobile hands-on learning, including videos that can be used

in a “flipped classroom” environment, and an assessment methodology for the effectiveness of ECP. This paper seeks to address the following high-level research question:

1. How does the workshop impact the implementation interest of the active learning pedagogy across all STEM disciplines?

The Intellectual Merit of the Project

The project contributes to understanding of the impact of hands-on learning activities that allow faculty to integrate ECP and new sensors into the curriculum. The multidisciplinary nature of the project team also allows an understanding on how to undertake authentic learning activities that span across the curriculum. The project equally provides valuable insight into learning innovation for minority students by the adoption of ECP beyond the field of electrical engineering. The project also focuses on advancing knowledge and understanding of the deployment of high impact pedagogical techniques across STEM fields at HBCUs. The inexpensive, safe, and portable electronic systems utilized in the project are Analog Devices Active Learning Modules 1000 (ADALM 1000 aka M1K) and Analog Devices Active Learning Modules 2000 (ADALM 2000 aka M2K). When these systems are paired with appropriate software and sensors they are used to measure a wide range of properties, from vibration to oxygen levels.

Background and Motivation

The ECP has been implemented in several institutions in electrical engineering and computer engineering [2]. The implementation of ECP in 13 HBCU electrical and computer engineering (ECE) programs resulted in the creation of a sustainable “HBCU Network” that was focused on the development, implementation, and expansion of an ECP in engineering curricula used in these HBCUs [3]. At these 13 HBCUs there were 135 faculty members and 2,950 students that were impacted by ECP [4]. Forty-five faculty members developed and implanted course modules, while attending both online and in-person meetings [4]. Workshops usually predated the successful implementation of ECP as evidenced by the SWOT analysis performed by Kelly et al [4], where it was observed that experienced faculty trained instructors at schools new to personal instrumentation at both face-to-face workshops and regular online meetings. To successfully diffuse ECP at five engineering schools in Puerto Rico, one of the authors (KC) was one of the facilitators of two-NSF-funded faculty workshops [5]. The workshops focused on the hands-on use of the Analog Discovery Board in circuits and instrumentation courses. The two workshops trained Electrical Engineering (EE) faculty on the use of the Analog Discovery board in the classroom and related active learning pedagogies as well as on the assessment of ECP implementation in an underrepresented Hispanic student setting. [5]. The first workshop was rated as “excellent” with an average score of 4.9 on a scale of 1 to 5, and each faculty was ready to implement ECP in their classrooms [6]. The second workshop provided a forum, where faculty shared and discussed initial impressions of the ECP implementation.

Thirteen HBCU and two Hispanic Serving Institution (HIS) ECE programs that had been working on implementing ECP in their curriculum created a new organization [4]. The purpose of the organization which comprises of a core group of collaborators and other affiliated members from other universities, industry, and professional societies, is to address the full learning and working experience of students, faculty, and staff. In July 2019, the organization held a stakeholder’s

workshop in order to realize its grand vision of becoming a virtual super department with broadly based strengths in education, scholarship and service [4].

Workshop Description

A two-day workshop focusing on developing ECP and home-based learning in STEM programs during the pandemic was held virtually from Wednesday June 3rd to Thursday June 4th, 2020. This was a timely workshop that was pioneered by a HBCU. It was a virtual workshop with 360 registered participants across three continents. In responding to the ongoing pandemic (COVID-19) which has swept off every activity from its normalcy since March 2020, the virtual workshop was organized to prepare the global educational communities on developing home-based hands-on experimental activities to support the concepts being taught in several STEM disciplines. A series of polls was conducted to determine the participants' locations, job title/role, institutional type on the first day of the workshop. As shown in Figure 1, the participants' geographic location indicated a larger number representation from North America, Africa and Asia. Each symbol in Figure 1 represents the clusters of the demographic location of the participants. Table 1 shows participants' discipline distribution, while Table 2 shows workshop attendees by title and location.

Figure 1. Geographic location of the workshop participants

Table 1: Participants content focus

Participants by General Content Focus	**Percent**
Engineering	26
Biological Sciences	17
Chemical Sciences	13
Mathematics	12
Computer Sciences	9
Physical Sciences, Physics	6
Education	6
Business	4
Architecture	4
Others	8

(*n = 105)

Table 2: Workshop attendees title and location*

Title	**Percent**	**Home Country**	**Percent**
Assistant Professor	29	United States	75
Instructor	20	Nepal	10
Associate Professor	18	Nigeria	5
Professor	14	Other Countries	10
GA/TA/RA	12	HBCU	39
Other	6	Non-HBCU	64

Topics covered at the conference include the following:

- Introduction to Experimental Centric Pedagogy (ECP)
- How to Introduce ECP into Teaching and Laboratory Exercises
- Home-based hands-on learning in science
- Hands-on learning in mechanical engineering and aerospace engineering using portable devices.

Table 3 shows the schedule during the two-day workshop. The workshop schedule was strategically developed to cater to the needs of STEM faculty during the pandemic, focusing on the best practices for the implementation of home-based hands on activities across multiple STEM fields. One of the authors gave a warm welcome address to the global audience on the first day of the workshop. She introduced the university as a foremost premiere public urban research university in Maryland, known for its excellence in teaching, intensive research, effective public service, and community engagement. A global HBCU with nearly 8,000

students, and a home of international students from over 40 countries, where students' success is the focal point. She further presented the background of the ETA-STEM project, its objectives and the seven participating STEM disciplines; biology, physics, chemistry, computer science, civil engineering, industrial engineering and transportation engineering. The project was pioneered by four (4) departments in the university.

Table 3: Workshop topics and presenters

Topic	**Day 1: June 3, 2020 Objective**	**Presenter (s)**
Introduction	Project overview & goals for workshop	JL
Spring 2020 Implementation & Fall 2020 Plan	Each Discipline will present their experience and challenges with the Implementation of ADALM 1000 and ADALM 2000 in Spring 2020 as well as the proposed Fall 2020 projects on design of inexpensive hands-on homebased lab exercises	Discipline Faculty (Biology, Physics, IE, CE, Chemistry, Transportation)
Experiment Centric Pedagogy	Intro to ECP, details about ECP and how to Incorporate ECP in teaching and laboratory exercises	KC
ECP	Discussion and training on inexpensive homebased hands-on laboratory exercises without M2k and M1k, in multiple ETA-STEM disciplines	KC
ECP	Breakout by Discipline	KC
Wrap Up	Discussion and closing	JL
Topic	**Day 2: June 4, 2020 Objectives**	**Presenter(s)**
Hands on Learning in Science	Home-based hands-on learning in science	JB
ECP Survey Results	Results of ETA-STEM MSLQ survey and Hands-on Lab survey (EE&CE)	KB &UG
ECP in Mechanical and Aerospace Engineering	Hands-On Learning (HOL) in Mechanical Engineering and Aerospace Engineering using portable devices	AF
ECP Evaluation	A quick overview of the ETA-STEM NSF Improving Undergraduate Stem Education (IUSE) grant evaluation process	KG & DS
Wrap up	Discussion and Evaluation	JL

A representative from each discipline presented his/her/their experience and challenges with the implementation of the analog devices (M1K and M2k) during the Spring 2020 and also presented the proposed Fall 2020 projects with focus on designing inexpensive hands-on home-based experimental exercises. There was a successful pilot implementation of the ECP in four STEM disciplines during the Spring semester, with appreciative educational gains. With the number of participating STEM disciplines, it was observed that ECP enhances student learning, retention,

and interest in several fields of study beyond electrical engineering. Table 4 shows the disciplines and topics that ECP was implemented in Spring 2020.

Table 4: Course involvement in ETA-STEM project

Course	**Topic**	**Sections/Date**
Biology	Photoplethymography (heart rate)	3 Sections/February
Industrial Engineering	Heat Transfer by Conduction	1 Section/February
Civil Engineering	Beam deflection	Multi-day lab - 1 section/March
Physics	Electric circuits	Multiple modules – 1 section February/March

Workshop Plenary Session

The first plenary speaker (KC) introduced the global audience to what Experiment Centric Pedagogy entails, and how it could be incorporated in teaching and laboratory exercises across several STEM fields. He presented the analog sensors (Figure 2) with all its features and connectivity. ECP uses an inexpensive analog device (about 100 times cheaper than benchtop instruments) which can be easily carried anywhere by the users at any point in time. With the use of sensors connected to the analog devices, students/users can conduct an experiment and record and interpret data to better understand physical phenomenon with surrounding concepts. The sensor, and other special purpose hardware are connected to the circuit board, while the results are displayed on the computer via the graphical user interface (GUI).

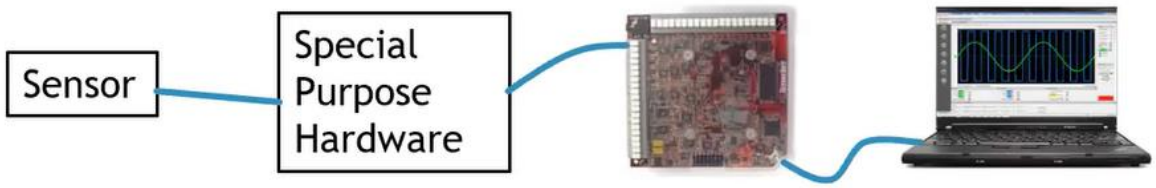

Figure 2. Use of Sensors in Hands-On Learning

The second plenary speaker (JB) who has been designated as one of the top 40 innovators in Education by the Center for Digital Education, spoke about his collaborations with four universities in New Jersey and New York - CUNY, CCU, GMercy and UNE. He presented the 5E Instructional model – Engage, Explore, Explain, Extend and Evaluate, as a means to actively teach science concepts effectively through online sources. Furthermore, he shared the results of calls made to 78 college and University Deans of science to study the wide acceptance rate of adopting Hands-On labs in their respective teaching curriculum. The result shows that 91% would accept ‘Hands On’ labs (Figure 3) in transfer, 21% would accept ‘virtual labs’ and 6% would not accept any online labs in transfer.

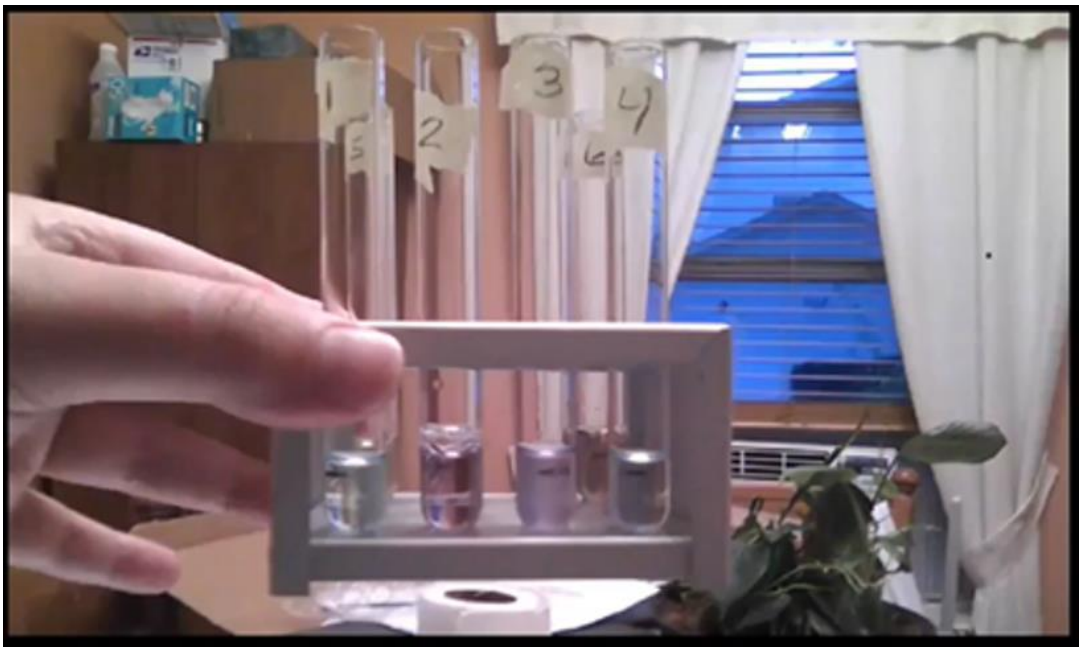

Figure 3. Hands-on active learning approach at home

In another session, the third plenary speaker (AF) presented the implementation of Hands-On Learning (HOL) in mechanical and aerospace engineering using portable devices, as was done in electrical engineering (Figure 4). The experimental set up on the left side of figure 4 are utilized in the electrical and computer engineering disciplines, while the systems on the right are utilized to effectively engage students in the mechanical and aerospace engineering discipline. He gave the HOL pedagogical objectives as a form of active learning which: (1) increase student understanding of basic concepts (2) increase student exposure to real phenomena (3) increase student confidence in subject matter, and (4) increase student teaming skills in the presence of team diversity. From his presentation, he gave a list of a few experiments that student teams have worked on in the Mechanical Engineering and Aerospace Engineering department among which are: the 2DoF vibration platform, 4Bar Mechanism, beam deflection among others. According to him physical experiments to study mechanics of materials usually fall into two categories: (1) simple, portable hand-held demos or teaching aids (2) dedicated laboratory setups that are fully instrumented and not very portable. In his concluding remarks, he said that hands-on learning impacts students on many levels and through many senses, enabling deeper learning.

Evaluation

After each day, workshop participants were asked to complete a short post workshop survey. The purpose of the survey was to gather information from participants about their overall perception of the workshop, the usefulness of the materials and information shared, and how this new information may potentially impact their pedagogy and professional practice moving forward. Typically, these workshops are held in a traditional face-to-face setting; however, due to COVID they were conducted virtually.

Table 8 shows participants' perception of the Summer 2020 workshop. About 93% of the participants reported that the presenters for the workshops were knowledgeable, while 84% agreed that they enjoyed the workshop being presented virtually. In addition, 84% of the

participants purported that they believe the workshop was a good use of their time, while 83% said they plan to implement what they had learned at the workshop in their own practice. Table 9 shows the project outcome of implementing the home-based labs. As revealed in the table, eighty-one percent (81%) of participants found the workshops to have increased their awareness of home-based lab opportunities, with 35% stating that before the workshop the idea of home-based lab experiences for students made them uncomfortable, while 64% of participants indicated that the workshops increased their overall comfort level with designing and using home-based labs.

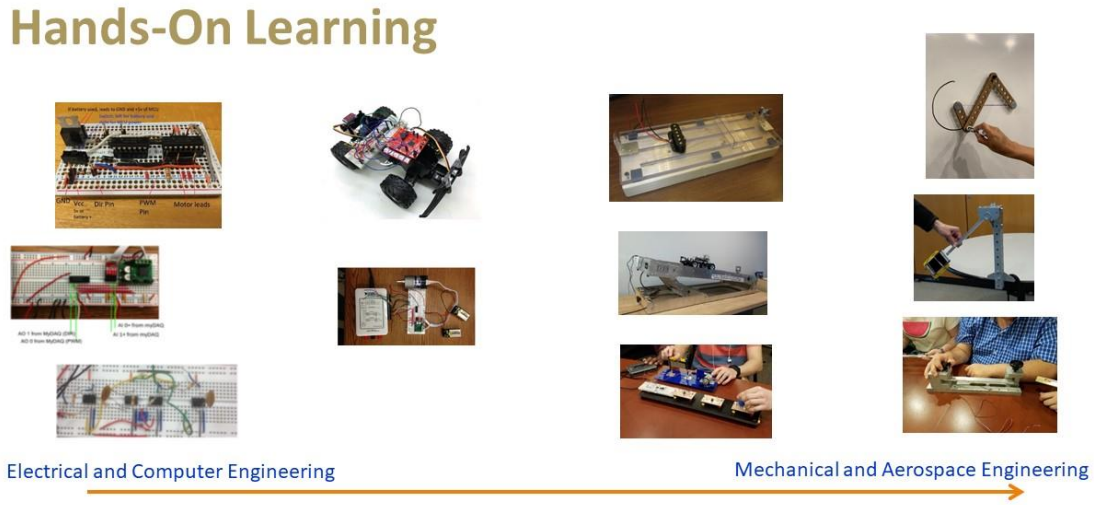

Figure 4. ECP Hands-On learning from electrical to mechanical and aerospace engineering

Table 8: Participants Perception of the Workshop

Statement	**Percent Agree ***
The presenters for the workshop were knowledgeable	93
Materials provided at the workshop were appropriate and useful	84
I enjoyed the workshop being done virtually	84
Overall, I believe the workshop was a good use of my time	84
The presenter(s) made topics interesting	83
I plan to take what I learned at the workshop and apply it to my practice	83
All participants' questions were answered	81
I would recommend this workshop to other colleagues	81
The topics for the workshop were appropriate and of interest	78
The pace of workshop was appropriate for the level of material that was being covered	77

**Percent Agree and Strongly Agree n=92*

Table 9: Outcomes associated with implementing home-based labs

Statement	***Percent Agree**
I found the workshops to have increased my awareness about using hands-on, home-based labs in general	81
I found the workshop to have increased my overall comfort level when designing and using home-based labs	64
As a result of participating in the workshops I am much more comfortable integrating a home-based lab into my course (s)	59
Before the workshop, the idea of setting up a home-based lab experience for students used to be uncomfortable	35

**Percent Agree and Strongly Agree n=92*

Most of the qualitative open-ended responses were positive in nature and supportive of the program content and presenter. Following are the positive responses:

1) "Many takeaways from each of the sessions that can be applied to practice."
2) "Topics were of interest and all the speakers were very knowledgeable and expert in their respective fields."
3) "Great conference - Very diverse group. Learned much. Thanks! Architectural Technology courses are STEM and ECP is a way to work with learning. The fact that we all went into remote teaching and the reason why we had to do it does have an impact on the results of this research. The different 'home' settings and resources do also have an impact that is worth tracking."
4) "Great workshop and really good concept... providing examples of what was being explored and what was working, and I really learn a lot from this workshop, and I am longer afraid to do hand on experiment."
5) "I teach at a two-year institution and my students have an enormous range of skill sets and levels of comfort with hands on materials. Several of the ideas presented would be fantastic additions to our current programs. In addition, we are frequently impacted by hurricane season, our division has been looking for contingency plans for any college disruption we may face in the future. This has been very helpful."
6) "The most significant benefit was to hear how the experiments were developed and to see how they were set up for the various disciplines, and about how each dealt with challenges specific to those applications. It makes possible to compare/contrast all, and to reuse and redefine."

There was an effective follow up through emails and telephone conversation from a university abroad that needed assistance in developing ECP activities at their institution.

Conclusion

The impact of the workshop organized at a historical black university in Summer 2020 was presented in this paper. It is of no doubt that the workshop setup had great impacts in developing and implementing ECP module for both teaching and experimental courses at the university. The workshops are set to have lasting impact on the global community (both HBCU and non-HBCU), Eighty-one percent (81%) of participants found the workshops to have increased their

awareness of home-based lab opportunities and 64% of participants indicated that the workshops increased their overall comfort level with designing and using home-based labs. Additionally, 84% reported that they believe the workshop was a good use of their time and 83% said they plan to implement what they had learned at the workshop in their own practice, affording the participants more opportunities to include home-based hands-on learning in their curriculum. The workshop's focus was developing and implementing inexpensive home-based hands-on learning activities. This project seeks not only to increase public scientific literacy, but to also contribute to the development of a diverse, globally competitive STEM workforce. From the survey it was revealed that participants were motivated to implement active learning pedagogy in their STEM disciplines. The workshop supported the successful implementation of ECP at the authors' institution in Summer and Fall 2020, respectively. There are plans to continue to follow up with workshop participants in ensuring successful implementation of ECP in their curriculum. Additionally, in the future, more workshops will be held at appropriate breaks during the academic year (Winter and Summer), where STEM faculty will further learn how to use and refine ECP as an active learning pedagogy.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1915614. The opinions, findings, and conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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