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An Online STEM Summer Education Program: Helping Students Develop Interest in STEM

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Abstract

The top challenge of managing a competitive workforce in today's environment is finding people with the right skills. Part of the problem is the gap between the skills new graduates have and what the industry needs. We need to improve how students are prepared during or after school to close the skills gap. The after-school summer education outreach program was initialized in 2017 with a primary focus on teaching data analysis, statistics, and mathematics to students, thereby equipping them with the needed STEM skills to be college and career-ready. The program is offered yearly in the summer, and students enrolled in the program are from middle and high school in southeast Michigan. The program's goal is to expose and engage students (with particular emphasis on minority and female groups) to the process of mathematical/statistical inquiry, from learning how to develop a testable research question through data analysis, interpretation, and presentation of findings. The program utilizes a project-based learning curriculum to teach students. Teamwork amongst students is highly encouraged as well as parents' participation. The program demonstrated both the feasibility of the curriculum and its promotion of positive student experiences within the context of data analysis and the use of technology. For example, the exit survey analysis reveals that students rated their experience as rewarding, and the vast majority (81.2%) felt that the program helped increase their interest and motivation in STEM, especially with the project activities. Also, parents, in their feedback, acknowledge the increased interest in STEM from their children.

Keywords
STEM Education, K-12 students, Online Learning, Student Engagement, Project-based Learning

1 Introduction
The year 2020 began as a blur, with numerous uncertainties since the inception of the Coronavirus, ranging from Americans filing for unemployment and workers getting furloughed, to school shutting down any form of physical interaction between students and their teachers. Through it all, the education system still thrives on keeping things running, with the aid of technology, proving to be more of a blessing rather than a curse in these times. With the halt of in-person classes during the winter, parents were concerned about how they would keep their kids busy during the summer holidays. Concerns grew as the pandemic situation kept plaguing the world and the safety of its population. The STEM Summer Outreach Program (SOP) was initialized in 2017 to provide education for a more intelligent workforce. With the current situation of the pandemic, the program was virtual for everyone's safety. The program's focus was on Mathematics, Data Analytics, Statistics, and the role of technology in society alongside career advising. Our target population for this program was middle and high school students from southeast Michigan, with the primary purpose of exposing them to different career opportunities. In terms of enrollments, we had middle and high school students, with the program divided into two sessions each week. Parents received daily camp materials and instructions regarding each session.

Regarding the sessions' scheduling, the first half stems from an introductory view in which a general presentation informs the students about the days' activity. The second half of the session entails a full practical activity to keep the students engaged. Finally, we end the session with an assessment activity (using Kahoot) to evaluate students' abilities and determine how they progress in their learning. We encouraged an atmosphere of teamwork amongst students as

well as parents' participation. The inclusion of parents' participation/involvement in their ward's education gained appraisal in Finland as it positively influences the parent-student relationship and increases students' focus in their education (Hakyemez-Paula *et al.* 2018).

Furthermore, students had to identify a camp project, work on them, and make a presentation on the last day of camp. The camp project will enable the students to build and apply the new skills learned, stimulate their mental acuity, and engage them physically to solve problems. For the current year, the program was funded by Verizon Foundation to help foster our mission and spread STEM awareness to the underserved population of southeast Michigan. Women and minorities are our key focus, although this program is accessible to everyone. The program's duration spanned three hours on Saturdays from 9 am to 12 noon for four weeks (June 18th to July 20th, 2020). The participant involved in the camp were both middle and high school students from southeast Michigan. Students came from the following communities Belleville, Novi, Redford, Southfield, Troy, and West Bloomfield within Southeast Michigan as shown in the map (see Figure 1 & 2).

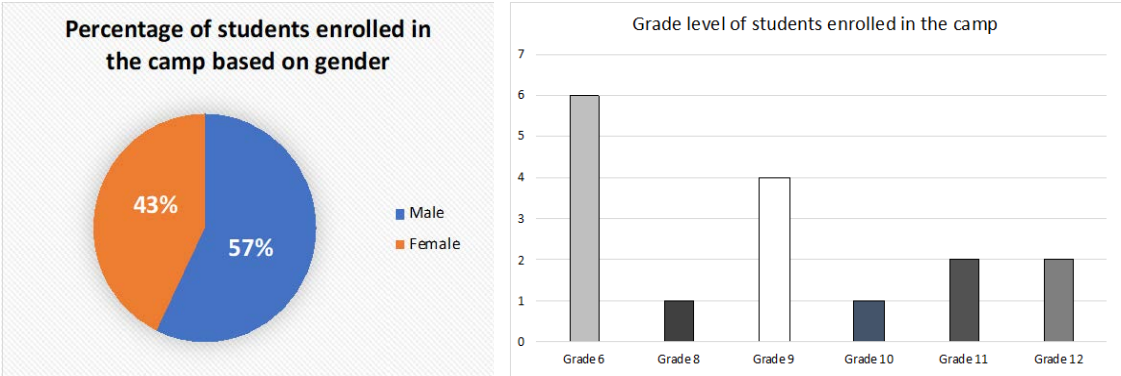

Figure 1. 2020 student demographics based on gender and grade level

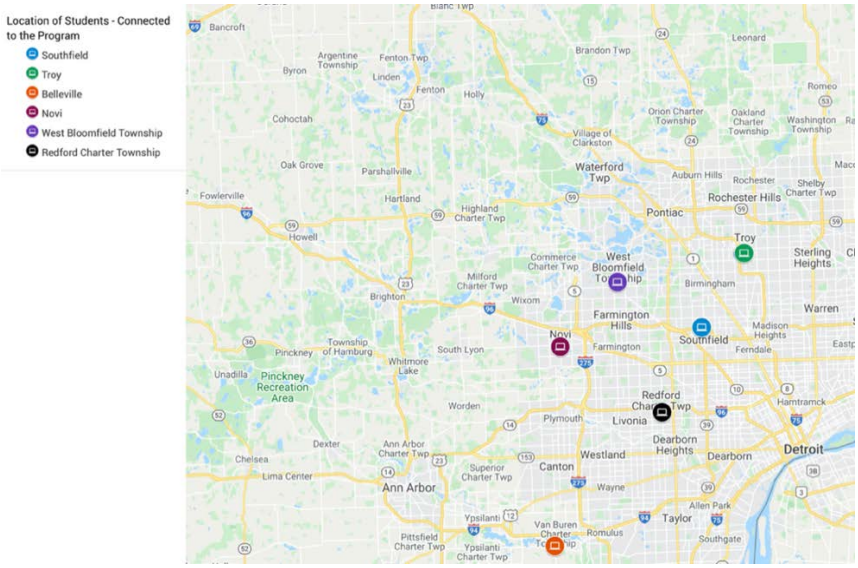

Figure 2. Location of students on the Southeast Michigan's map

2 Activities Performed

During the four (4) weeks program, the students were engaged in different activities encompassing STEM's significant areas, with more emphasis on Mathematics, Statistics, and Data Analytics using specialized software (see Table 1 for weekly schedule). The subsequent sections below illustrate each task performed.

Table 1. Camp Weekly Schedule with Topics

1st Week	2nd Week	3rd Week	4th Week
• Camp Introduction & Logistics • Middle School: Descriptive Statistics/CODAP • High School: Regression Analysis/CODAP • Practical session with CODAP • Virtual Tour: *Sustainable energy & Smart Cities* • Class assessment: Kahoot	• Artificial Intelligence and Automated Vehicles • Practical session: Teachable Machine with Google • Virtual tour: *Toyota Research Institute, MI* • Class assessment: Kahoot	• Industry speaker: Internet/Network Communication • Mobile app development: MIT App Inventor • Practical session: Designing a mobile app • How to present information/findings • Class assessment: Kahoot	• Keynote Presentation • Project Presentation & Judging • Awards & Certificates

2.1 Week 1: *Statistical Data Analysis and Application of CODAP*

The first week brought us up to a great start, with the camp director moderating the program, and a general introduction of the camp instructors, students, and parents. The essence of the program was communicated to instill a better understanding of STEM to the students. For this week, the middle school students learned about the *Measures of Central Tendency* (i.e., mean, median, mode, and range) while the high school students learned about *Regression Analysis*. The respective topics were explained using a problem-based learning approach, and students learned how to use specialized software – Common Online Data Analysis Platform (CODAP) ("Common Online Data Analysis Platform " 2014) to conduct analysis as well as result interpretation. Students need to be grounded on how to interpret statistical results and make informed decisions with it. Students in the camp were presented with real-world problems and data for investigation during the practical activity.

Challenging Exercises: *Middle School Section* – A newly formed sports and entertainment management company is looking at managing players in the National Football League (NFL). To be successful in player management, they must understand the salary trends of the 1,800 players in the league and know how much each player is being paid. Knowledge of the salaries, player skills, and other factors will enable the company to bargain appropriately for its players. The company has employed a data analyst to conduct an exploratory analysis and provide insights into the player payroll in the NFL 2018/19 season (in millions of U.S. dollars). Students were expected to report on the following: create a graph to show what is the most popular team and position; create graphs of each of the salary attributes and plot the mean, median, and standard deviation on each graph; describe the data as skewed right, left or symmetrical; and create box plots of the salaries for each team and determine if there are any outliers? Figure 3 shows the resulting output of the student's analysis. The students performed data pre-processing, conducted the analysis using CODAP, and result interpretation, as displayed in Figure 3.

High School Section – According to a newly published study in the Educational Researcher Journal, students' high school grade point averages (GPA) are five times stronger than their ACT scores at predicting college graduation. As a final year high school student, you would like to predict your ACT scores based on your high school GPA. The findings will help you determine if you are college-ready. High school data of various students with ACT and GPA scores are provided to students for analysis. Students were asked to construct a scatter plot: describe the direction, form, strength, identify outliers, build a regression model, and interpret their findings. Figure 4 shows the resulting output of the student's analysis. The students loaded the data on CODAP, conduct data analysis, and interpret their findings. During the four (4) weeks program, the students were engaged in different activities encompassing STEM's significant areas, with more emphasis on Mathematics, Statistics, and Data Analytics using specialized software (see Table 1 for weekly schedule). The subsequent sections below illustrate each task performed.

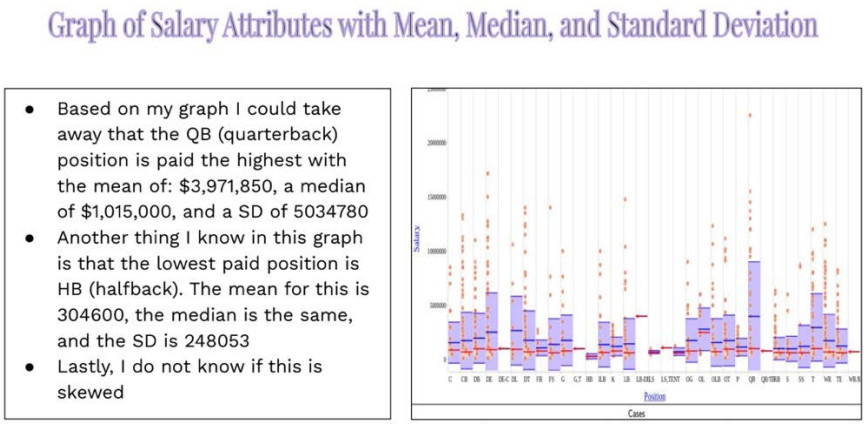

Figure 3. Middle school students: Descriptive statistics CODAP output

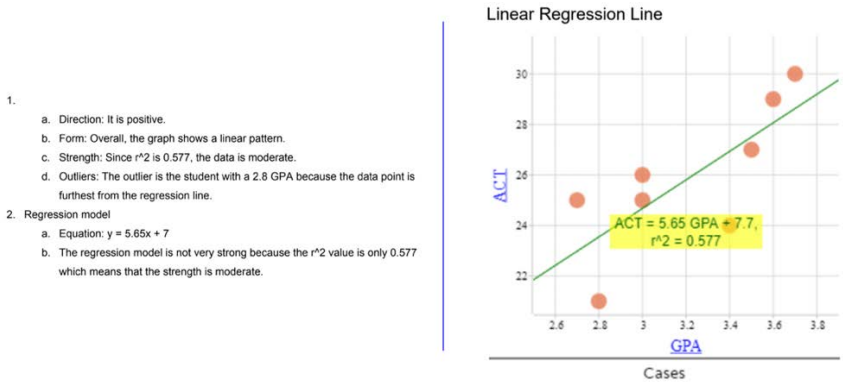

Figure 4. High school students: Regression analysis CODAP output

2.2 Week 2: *Artificial Intelligence and Automated Vehicles*

In the second week of the program, the students were introduced to Artificial intelligence (AI) and Automated Vehicles (AV). The students and parents alike were exceptionally excited to know more about this particular topic, as it reflects the current advancement of technology in our everyday life. Artificial intelligence makes it possible for machines to learn from historical data, adjust to new inputs, and perform human-like tasks (Lu *et al.* 2018). AI is everywhere in our daily lives – computers, phones, search engines, social media, intelligent personal assistants such as Alexa, Siri – and today's students are a generation who will grow up with these AI technologies. We need to teach them about AI. During the first session, the instructors gave a presentation on AI and explained the three steps used in AI – datasets, learning algorithms, and prediction. For the practical session, the instructors utilized Teachable Machine ("Teachable Machine" 2009), a web-based tool that makes creating machine learning models fast, easy, and accessible to everyone.

The instructors explained the tool's uses, and then the students were left to try it out on their own. To better help the students understand the concept of AI, a practical exercise was given to them. A virtual tour of the Toyota Research Institute in Ann-Arbor, MI, was conducted during the second session to show students the different research advancements in self-driving autonomous vehicles. Also, students had a clear understanding of how AI is employed for self-driving vehicles, how the AI learns from historical data and uses that data to find patterns in a real-life scenario. This series of presentations and practice sessions provided the kids with sufficient information about AI and AV. Likewise, to wrap up the camp, a Kahoot session was administered to test the students on the days' activity.

Challenging Exercise: In this exercise, students were tasked with building a simple program to perform object recognition using the Teachable Machine platform provided by Google. Students were employed to be creative in using the tool. One example was to use a half-full and a full bottle of water to carry out this experiment. Students were

expected to report on the following: train the AI to identify a half-full and full bottle water you have at home (or pictures from the internet); train the AI to identify your voice or a clapping sound. See Figure 5 for the results.

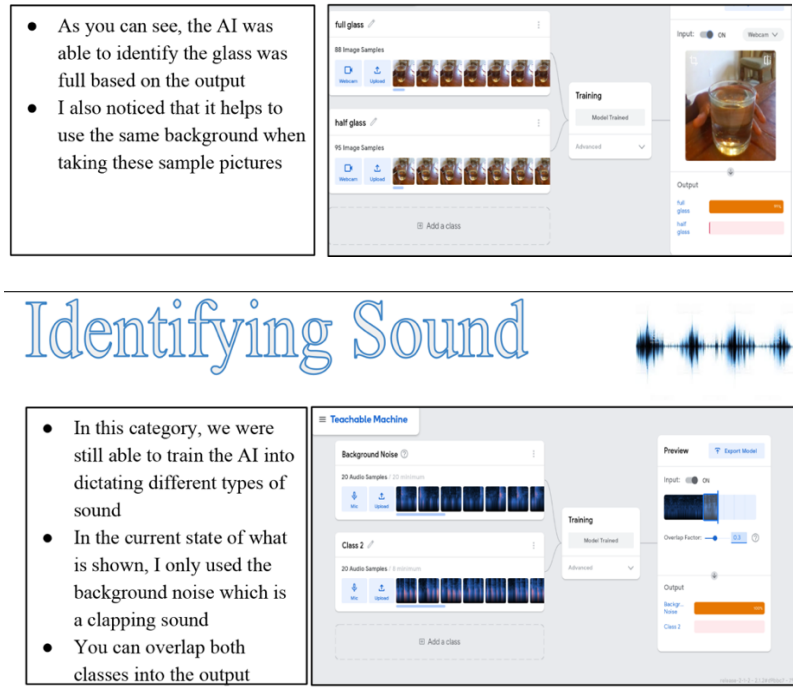

Figure 5. Student's AI results using Teachable Machine Platform

2.3 Week 3: *Internet/Network Communications*

Network communication, or internetworking, defines a set of rules and standards that allow application programs to communicate with each other without regard to the hardware and operating systems being used. Internetworking allows application programs to communicate independently of their physical network connections. The field of networking and communication includes the analysis, design, implementation, and use of local, wide-area, and mobile networks that link computers together. The Internet itself is a network that makes it feasible for nearly all computers in the world to communicate. The industry guest speaker (Mr. Michael Davis – Solutions Architect with Verizon) provided insights into telecommunications, internet networking, 5G network, and its benefits.

The students were introduced to mobile application development. Mobile application development is the set of processes and procedures involved in creating software that runs on a mobile device (Joorabchi *et al.* 2013). The students learned about the mobile app development cycle and the reasons behind software updates. The mobile app creation was made possible through the MIT app inventor ("MIT App Inventor" 2012). The *App Inventor* lets students develop Android phone applications using a web browser and either a connected phone or emulator. Students were able to run the software and follow through with the instructors on different exercises, showing them how to use it. Students were challenged to be creative and use the App Inventor to create a mobile game, as presented in Figure 6.

2.4 Week 4: *Keynote and Project Presentation*

In the last week of the camp, students listened to a keynote presentation from another industry guest speaker (Brianna Ellison, Community Engagement Manager with Verizon). The presentation centered on increasing digital literacy amongst today's youth, benefits of STEM education, and some of her industry's plans to improve the social environment. Students asked thoughtful questions about what the industry is doing to help address disparity issues in the country. Students presented their individual or team project that was assigned to them throughout the STEM program. These projects range from designing a one-story building using ARCKIT, a soda fountain machine, and a hydraulic robot arm. Some teams worked on a regression analysis project using CODAP (see Figure 7).

Figure 6. Output from mobile app inventor

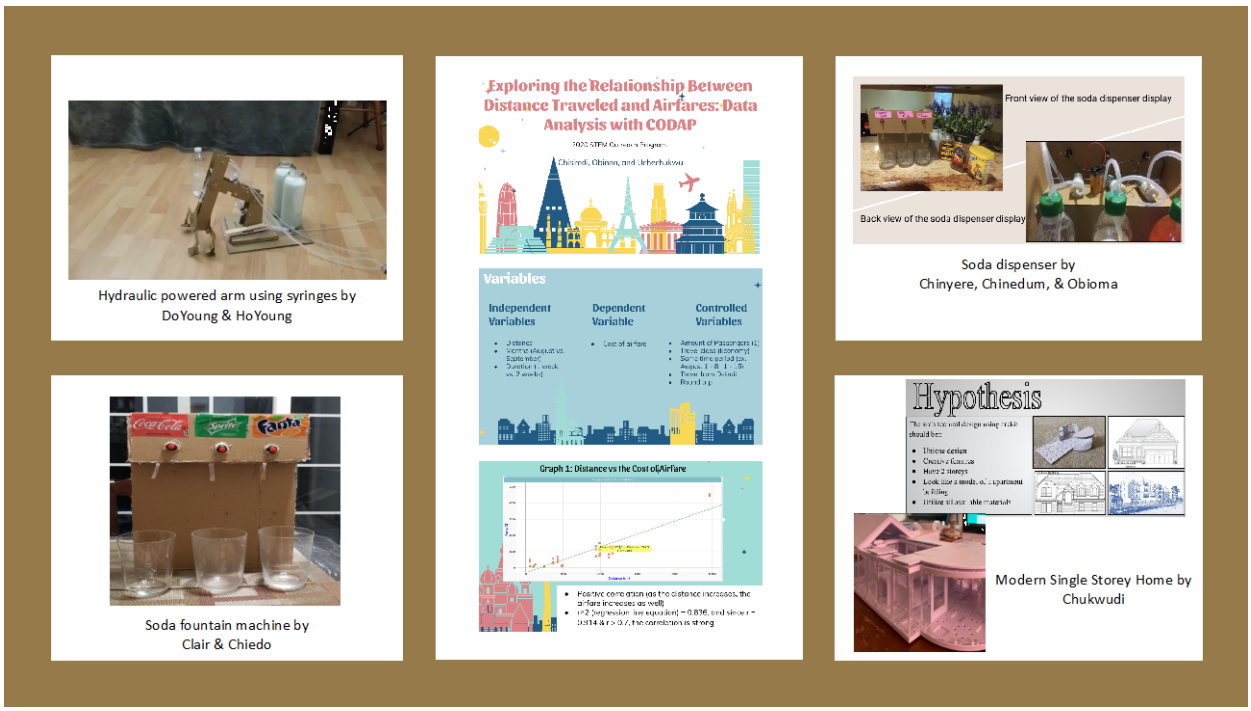

Figure 7. Excerpts from student project presentations

3 Conclusion

The period of mentoring students virtually on the importance of STEM was an impactful one. The program aided in exposing and engaging students (with special emphasis on minority and female groups) to the processes involved in mathematical/statistical inquiry, from learning how to develop a testable research question through data analysis (via specialized software like CODAP), interpretation, and presentation of findings. Students actively engaged in technological activities by using the *MIT App Inventor* and *Google Teachable Machine* to solve real-world problems. The students learned and developed skills that will make them better persons in the nearest future and give them an advantage above their peers. The program was designed so that parents could also get an equal chance of having a hands-on experience alongside their wards.

With the primary goal of providing education towards a better workforce, the program made it possible to engage students in activities that would keep them focused mentally, even though it was the summer holidays. The program

also gave them an added advantage over their peers, as the topics introduced were specifically tailored to address real-world scenarios. In the traditional K-12 education setting, most students do not have the opportunity to participate in problem-based learning, which exposes them to statistical analysis and technological tools. As stated earlier, the global pandemic has disrupted numerous activities. Nonetheless, with the aid of technology, we ensured that students and parents could learn and become fully equipped with the necessary tools required for the future workforce.

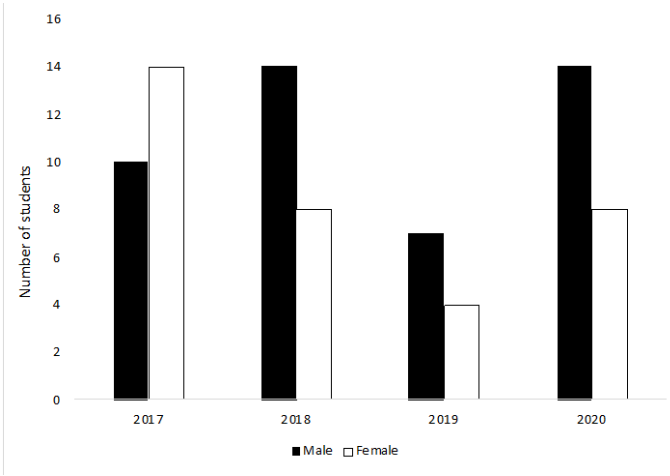

Figure 8. 3-years summer program student enrollment data

4 Lessons learned and challenges

The authors learned a lot from having an online summer program. The online presence allowed for more families and students to actively participate in the program. The camp experienced a 100% increase in student enrollment compared to the 2019 data presented in Figure 8. The following are some of the lessons learned:

1. We discovered that students had full confidence in themselves to answer questions and present their ideas in a meaningful way.
2. We observed an improvement in student engagement when activities are done in breakout rooms compared to a full-size class.
3. Keeping the parents informed about the camp's activities ensures that students complete all their tasks on time.
4. Having the parents/guardians participate in the program ensured good cooperation between students and instructors. All the students were well-behaved throughout the program.
5. After each session, we noticed that students were captivated and eager to learn more after sharing their individual learning experiences.
6. Less theoretical content, more interaction with technological tools ensured that students remained engaged and focused throughout the camp.

Some challenges encountered include:

1. Regular issues with internet connectivity, resulting in disruption for most students and instructors.
2. Time management was an initial challenge with activities, questions, and assessments to be accomplished.
3. The instructors' inability to hold numerous office hours after each camp to ensure that all of the students' questions were answered.
4. Getting project materials across to students was challenging due to unforeseen shipping delays.

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Biographies

Celestine Aguwa is currently at WSU as an Associate Professor Research involved with research and teaching graduate courses in Industrial and Systems Engineering. His background includes engineering education, lean and value methodology in product development and advanced manufacturing, and customer voice analysis. He is currently working on several funded research projects in data analytics. He has a cross-functional industrial experience at Ford Motor Company and extensive professional experience as an Architect. Dr. Aguwa has a Ph.D. and MSIE in Industrial and Manufacturing Engineering from the University of Pittsburgh and Massachusetts, Amherst, respectively. He also has a B.Arch. Degree in Architecture from the University of Nigeria. Dr. Aguwa has several awards, including a patent, and has written several published papers. He is a member of the Institute of Industrial & Systems Engineering (IISE), SAVE International, and Institute of Operation Research and Management Sciences (INFORMS).

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Lezlie Bueno is an Industrial & Systems Engineering graduate from Wayne State University. She holds a master's and bachelor's degree in industrial engineering. Her research interest lies in engineering education and healthcare resource allocation.

Leslie Monplaisir is a Professor in the Department of Industrial and Systems Engineering at WSU. He is the Lead Researcher and Director of the Product Development and Systems Engineering Consortium (PDSEC) at WSU. His research interests include Lean Product Development, Design for lean Systems and Services and Design reuse, New Product Technology Decision modeling, Product Architecture Optimization, and Healthcare Technology System Design. He has authored over 100 publications in these areas with funded research from NSF, Veterans Administration, and Ford Motor Company. Dr. Monplaisir joined the College of Engineering at WSU in the Department of Industrial and Manufacturing Engineering in 1996 from Florida A & M University, where he was a visiting assistant professor. He earned his Ph.D. in Engineering Management from the Missouri University of Science and Technology (MUST), a Master's in Computer Integrated Manufacturing from the University of Birmingham in Great Britain.