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Teaching Community College Students Programming without Programming using Arduino Spark Fun Inventors' Kit

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***Abstract* – This paper presents the concept of teaching programming to non-computer-science students without programming, a concept referred to as visual or conversational programming. Virtual programming is different from programming generated by Generative AI Chatbots such as ChatGPT and Google Bard that can write code in any language. However, users must have programming knowledge to use and modify the generated code. The virtual programming uses the concept of building block to assemble some logic while coding is generated in the background. While the concept in itself is not new, implementing it using the Arduino SparkFrun Innovator's Kit is truly innovative. The use of the kit has been part of grant activities for REU-PATHWAYS participants, from local community colleges (CCs), of a funded REU site by a grant form NSF. The goal of the activity is to expose CC students to 4-year college environment via a fun hands-on activity in the hope to prepare them to consider transferring to higher education as a pathway to improve their future education and employment. The method we used is to have CC students work on programming assignments weekly using the SparkFunk kit lessons and get them to build circuits for hands-on experience. CC students spend 10 weeks during summer in the REU program. They present a project at the end of the program. The project gets them to design and build their own circuits. The results of this activities have been positive. It improved students skills in programming and engineering design. The students feedback is positive, confirming the observation that visual/conversational programming is a viable concept to teach programming without programming.**

***Keywords* – REU, Community Colleges, STEM, AI, Smart Engineering, Pathways, Transfer, Programming, SpakFun Kit.**

I. Introduction

Northeastern University (NU) received an NSF grant recently titled "REU-Site: REU-PATHWAYS: Pathways for community college students to enrich their education and careers". The grant provides funding to establish an REU (Research Experience for Undergraduates) site that provides Community College (CC) students with research experience at 4-year institution, NU. The goal of the grant is to expose CC students to research environment in the hope they become motivated to either transfer to 4-year colleges or persist in STEM to graduate and join the STEM workforce. By transferring to 4-year colleges, they advance their education, their careers, and getting better paying jobs.

Research shows that transferring to 4-year colleges is important and beneficial to CC students [1-4], especially for the underrepresented. 42% of all undergraduates in 4-year colleges were enrolled in CCs [5]. That is not surprising knowing the many benefits of attending CCs [6]. Open access to admission is a big factor where high school graduates do not face the tougher admission standards of 4-year colleges. Also, the tuition cost and fees are much lower for CCs when compared to public and private universities. In addition to financial benefits, CCs offer very flexible schedules to minimize taking student loans and lower debt burden.

More recent research has shown that transferring from a community college to a 4-year college is a viable op-

-tion for students who want to pursue higher education [7-9]. The benefits of transferring include lower tuition costs, more flexible schedules, and the opportunity to adjust to the college lifestyle [10]. A recent article from the U.S. Department of Education titled "New Measures of Postsecondary Education Transfer Performance: Transfer-out rates for community colleges, transfer student graduation rates at four-year colleges, and the institutional dyads contributing to transfer student success" [7] provides insights into the performance of the U.S. postsecondary education system in providing a pathway for students who start at community colleges to eventually graduate with bachelor's degrees. Another article from the Conversation titled "Doing this one thing helps community college students transfer to a 4-year university" [8] discusses how researchers tracked over 1,600 community college students over five years to learn what helped them get into a four-year college once they completed their two-year degrees. A report from the Community College Research Center (CCRC) titled "3 Challenges Community College Students Face Transferring to Four-Year Colleges" [10] found that about 86% of students in community college do not go on to earn a bachelor's degree. The report highlights some of the challenges faced by transfer students, including lack of information and guidance on the next best steps when it comes to getting credit at a new school.

Also, many CC students work full time and have to care for families during the day, thus attending classes at night. A major concern for all college students, especially CC students, that they are absolutely sure about what they want to study. CCs provides students the opportunity to test interest at low cost. CCs also typically offer smaller class sizes and offer more personalized attention to their students as compares to 4-year colleges.

Transferring from a CC to a 4-year college is much easier for students than being denied admission if applying from high schools. Finally, the transfer makes getting a higher degree more affordable because students spend half of their education journey paying less money at CCs.

II. Teaching Programming

The REU-PATHWARS research experience for CC students has been designed to maximize their learning experience. The program runs over 10 weeks during, for example from May 23, 2022-July 29, 2022, supported directly by a graduate student and faculty mentor. REU-PATHWAYS will run for three years. Research projects, faculty mentors, and mentoring research graduate students may change from year to year as needed based on the results of the yearly formative evaluation conducted by the site external evaluator. Participants will learn basic research, writing and communication skills.

In addition to working on research labs, REU participants develop competencies in open-ended design projects, and makerspace skills including 3D printing and laser cutting. Each student selects a problem to solve during the 10 weeks in parallel to conducting their research. We seek to challenge the students to solve a problem of their choice and present a viable solution. While students conduct research in research labs under the supervision of a research faculty member and a graduate student, students also use NU makerspace lab to implement and test their project design.

We model the design projects after our experience of teaching our college of engineering first-year students. These projects require the use of sensors and programming them to achieve a certain task. The students build a circuit board and program it with the sensors to accomplish the design task. Students would typically need resistors, capacitors, wires, soldering tools, and other hardware such as pliers and hammers.

When we designed this concept of design projects, we knew it will require students to gain basic skills in programming to program microcontrollers. Thus we set to investigate the question of teaching CC students programming skills, really without teaching them specific programming syntax and logic. There are two drawbacks to this approach of teaching syntax and logic. First, we would not have enough time to teach syntax and logic to students. Second, students will not like the abstract content of programming. Third, we could risk loosing them and drop out of the REU summer program as they may view the capstone design project as a secondary activity to their research projects they conduct in research labs.

There have been many attempts to teach programming by hiding syntax and logic and replace them by other less abstract concepts, known as graphical or visual programming. The famous example of that concept is MIT Scratch Programming created by the Lifelong Kindergarten group at MIT Media Lab [11-14]. These types of programming languages are suitable for what is known as "conversational programmers" [15].

While our thoughts agree with the concept of visual programming to hide abstract syntax and logic from the learning process of students, the Scratch language or other similar concepts would work for CC students. In addition to being visual, these students are also hands-on, especially if they are currently working in the STEM workforce. Thus, we looked for other solutions and came up with the Arduino SparkFun Inventor's kit [16] (SparkFun kit for short).

III. Programming without Programming

The first week of REU-PATHWAYS serves as an orientation as well as a warm-up week to ease the transition of students to the 4-year college atmosphere and culture. REU-PATHWAYS provides students with basic design skills: programming, sensors, data collection, data sampling, data analysis, makerspace skills, and prototype fabrication. Students may work in pairs on their design projects.

We utilize the commercially-available Arduino SparkFun Inventors Kit [16, 17] utilized in our Cornerstone course for our First Year Engineering curriculum. As part of REU training, we conduct a workshop to train REU students on how to use the kit. The SparkFun kit introduces students to programming without programming. The SparkFun Kit uses the Arduino programming language which is a free open source platform for building microcontroller programmable projects without any programming syntax. The kit consists of hardware which is the SparkFun RedBoard and software which is Arduino IDE (Integrated Development Environment).

The use of the SparkFun kit enables CC students to gain basic skills in common every day electronics and programmable microcontrollers without having to learn complex operating systems (OS) or programming languages. CC students program their own RedBoards to create various circuits using simple electronics components such as resistors, motors and light sensors. Each CC student is provided with a SpakFun kit (for them to keep) and a laptop to carry out the projects as part of the REU grant. The SparkFun board requires a USB port on a laptop, either a PC or Mac, to be able to download the Arduino program from the lpatop to the SparkFun RedBoard microcontroller. Sample circuit projects may be: (1) an LED night light that illuminates in response to the absence of ambient light using an RGB (red, green, blue) LED and a light sensor; (2) An autonomous robot (using DC motors, an ultrasonic distance sensor, an LCD, push buttons, piezoelectric speaker, and LEDs).

The use of SparkFun kit proved effective for retaining NU freshmen (92% retention rate of first year to secon-

-d year engineering students per Northeastern University College of Engineering data). The kit introduces students to the engineering design process and algorithmic thinking using a combination of in-class activities, hands-on project-based learning, and makerspace lab experiences [18] for prototyping and fabrication to promote and practice creative problem-solving, collaborative teamwork, effective written and oral communication, critical thinking, and engineering ethics with global, cultural, social, environmental and economic considerations [19].

One of the many recommendations that was published in the "Educating the Engineer of 2020" report states "Whatever other creative approaches are taken in the four-year engineering curriculum, the essence of engineering- the iterative process of designing, predicting performance, building, and testing- should be taught from the earliest stages of the curriculum, including the first year." [20]. Also, the use of SparkFun kit in teaching freshmen students supports ABET students outcomes #2 and #7 [21]. Thus, we can infer that using SparFun kit with CC students should prove effective as CC students, like many other students, prefer learning by doing.

Introducing CC students in the first week of REU-PATHWAYS to a 4-year college First Year experience through programming SparkFun kit serves multiple purposes. First, it helps build skills for the creative and digital economy - critical thinking, collaboration, communication, curiosity, problem-solving and invention. Second, it eases the transitions of CC students to their REU experience. Third, it provides students with a first-hand experience and alignment regarding 4-year college learning so they can gauge their interest in transferring in the future. Fourth, it demonstrates to them that becoming part of the STEM work force after graduation is fun, exciting, and rewarding. When they work on open-ended projects and see the finished product, they will build a sense of pride, accomplishment and positive self-efficacy [22].

IV. Overview of SparkFun Kit

The sparkFun kits is designed and sold by SparkFun Electronics, Inc. [23]. The kit overall design is shown in Figure 1. The kit consists of hardware and software. The kit hardware consists mainly of the RedBoard Platform (Figure 2) he breadboard (Figure 3) and the Baseplate Assembly (Figure 4). The RedBoard is the brain of the kit that can be programmed to achieve certain tasks. It can be thought of as a small computer, known as microcontroller. It can take input such as a push of a button, and produce output such as blinking of an LED. This enables applying programming to the physical world, so REU students become visual programmers.

The breadboard (Figure 3) is a circuit building platform to allow connecting multiple components without using soldering iron. The board has a self-adhesive back for easy mounting on the kit baseplate as shown in Figure 1.

The baseplate (Figure 4) makes circuit building easier by keeping the RedBoard microcontroller and the bread Baord connected together without the possibility of disconnecting or damaging the circuit the user builds. It is the housing where the user mounts the RedBoard and the breadboard as shown in Figure 1.

The SparkFun kit contains an extensive array or electronic elements to enable building elaborate circuits for various applications. These elements include LCD display, LEDs, Poteniometer, sensors, buzzers, different types of motors servo, gear), push buttons, resistors, and wires.

Fig. 1. SparkFun Inventor’s Kit – v4.1 (Courtesy: https://www.sparkfun.com/products/15267).

Fig. 2. SparkFun Inventor’s Kit Red Board Platform (Courtesy: https://www.sparkfun.com/products/15267).

Fig. 3. SparkFun Inventor’s Kit Bread Board (Courtes: https://www.sparkfun.com/products/12002).

Fig. 4. SparkFun Inventor's Kit Baseplate (Courtesy: https://www.sparkfun.com/products/11235).

V. SparkFun Kit Training

Our REU-PATHWAYS team designed a training program for RUE students. The training program has 3 foci: understanding the engineering design process (EDP) and design briefs, teaching the use of the SparkFun Kit, and the use of the makerspace lab at NU. The EDP is the center of organizing design activities. Figure 5 shows the process. The design brief is an important part of the EDP [24]. The design brief is an tool that provides students with the directions they need on how to proceed with to solve a design problem. The brief can help guide the students through Steps 1 and 2 of the EDP (see Figure 5), i.e. scoping the design problem. Figure 6 shows how we apply the design brief concept to our REU-PATHWAYS program and tailor to the needs of our REU students. The figure shows the 6 steps that REU students go through to help them solve their design problems. The idea behind step 2, Picture of the Problem, is to help students set the problem context with a picture. While the image provides a visual, it should not imply a design solution or uncover the details about the design problem. Figure 7 shows an example of applying design brief to a specific problem: solving remote learning fatigue in a young learner.

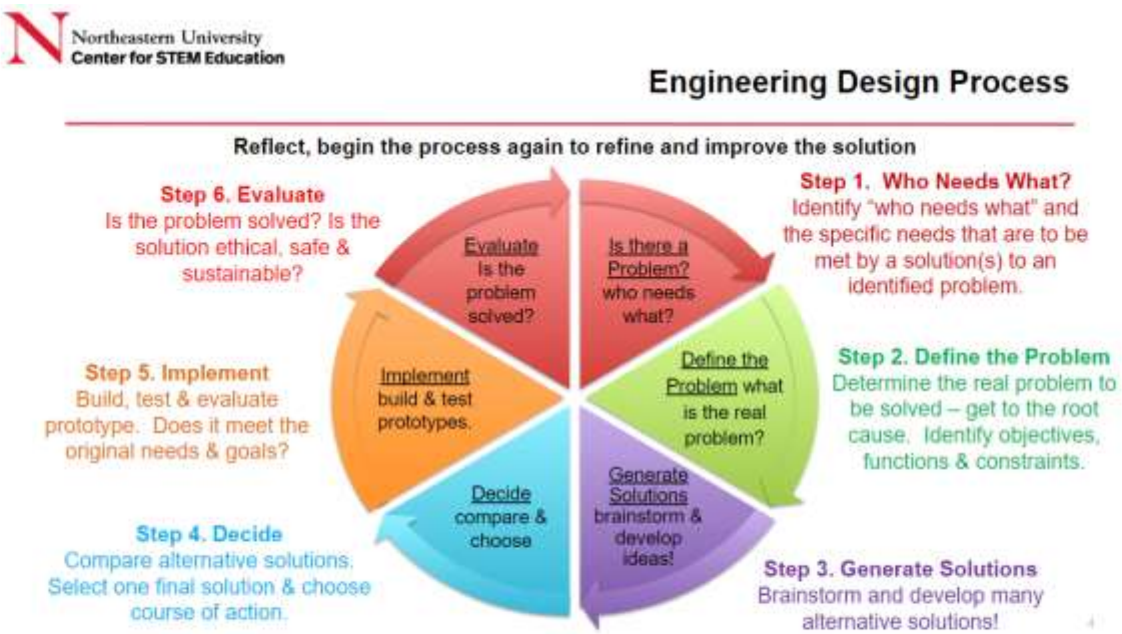

Fig. 5. The Engineering Design Process (EDP).

Northeastern University
Center for STEM Education

Design Brief for SMART Project

1. **Identify the Problem** - look for inspiration in your own life.
2. **Picture of the Problem** - ***who*** is affected?
3. **Functions** - what do you want your project ***to do***?
4. **Objectives** - what **features/behaviors** should the design have?
5. **Constraints** - limitations (cost, time, size…) *quantified metrics!*
6. **Problem Statement - "The problem is that ______. …"**

SMART technology is an umbrella term used to describe ***interconnected*** devices that ***perform relatively normal functions*** with a greater degree of ***autonomy*** than their non-smart equivalents.

Fig. 6. Deign brief of REU-PATHWAYS design projects.

SparkFun Design Brief
Guild Member Names (alphabetical by last name)
GE1501 CRN # (18985, 19002 or 19003) & Class Section (8am, 9:15am or 1:35pm)
Submission Date (Month Day, 2020)

Guild Name or Crest / Logo (optional)

Title (Name of Problem)
Use your literature review summary to explain who is experiencing what problem, in 2 – 3 sentences. Who needs what? In other words, condense your 2 – 3 paragraphs from your Literature Review Summary (Guild Quest #2) into a few brief sentences here. Add in-text citation(s) from your journal article(s) that provide evidence of this problem directly.

Picture of the Problem
Include a labelled and cited picture of the problem that clearly shows who is experiencing what problem, with a proper MLA 8th edition in-text citation under the picture (for example: Figure 1. Students learning (author, page #)).

Figure 1. Remote learning fatigue in a young learner (@karajmcdowell).

Functions (list at least 2 here)
The primary action that a designed device or system is supposed to do. Use active verbs in phrases. For example:
1. Allows remote game playing
2. Authentically engages
3. Motivates young learners
4. Uses at least 1 SparkFun input component and at least 1 SparkFun output component

Objectives (list at least 3 here)
A feature or behavior that the design should have or exhibit. Use adjectives. For example:
1. Inexpensive
2. Accessible
3. Intuitive

Constraints (list at least 2 here)
A limit or restriction on the design's behaviors or attributes. Use phrases & quantified metrics (something that can be measured). For example:
1. Costs less than $10, not including the SparkFun Inventor's Kit
2. Only 1 SparkFun game setup per player
3. Less than 12 inches × 12 inches × 18 inches in volume

Fig. 7. Applying design brief to solving remote learning fatigue in a young learner.

The second aspect of the SparkFun training (first being the EDP and design brief) is the focus on the use of the actual SparkFun kit. Students participated in 15 hours of hands-on learning and Arduino instruction, then spent the rest of their weekly workshop-allocated time on a final project (working in pairs): designing a SMART device using the engineering design process and any SparkFun kit components. Despite students varying levels of familiarity with arduino/SparkFun at the start of the program, all students' projects came together and were formally presented the final week of the program. Our first REU cohort has 7 students. Their final projects are (subtends worked in groups of 2): a plant soil monitoring system, a personal belongings lock box, a pill medication reminder/dispensing system, smart watering system, GPS location tracking.

The last part of the SparkFun Kit training program is the use of makerspace at NU. This part focuses on the rules of using the lab, safety measures REU students must follow. The students receive an orientation of the lab on the first day of using it. Some of the safety rules included wearing toe-closed shoes and using goggles while in the lab.

VI. Evaluating Students Experience

As part of evaluating the REU-PATHWARS program by an external evaluator, we evaluated the SparkFun experience and its related workshops. On a Likert scale of 0 (No interest) and 4 (Very interesting/valuable), the mean was 3.3. One student wrote "I really enjoyed the Arduino project this summer. I came into the program only having a vague understanding of programming, and am now leaving with a good foundation of fundamentals. Keeping the Sparkfun kit is incredibly valuable to be able to continue practicing and learning more through the projects and am very grateful to receive it."

VII. Discussion

An independent external evaluator evaluates the REU program each year via survey that REU participants fill. One survey focuses on the Sparkfun Arduino activity. Students rated the Arduino workshops in two ways: during their tri-weekly evaluation and in a stand-alone end-of-program survey. In the first year of REU-PATHWAYS, the Arduino workshops were a required component and students were tasked with completing a final project. Feedback from that year was that this was too much of an additional commitment on top of all their other research work, so this second year the work was scaled down and students were encouraged to try their best and complete things to the best of their abilities and interests.

The feedback and results reflects this - those students who found enjoyment in the work continued till the end of the program and committed to working on their projects, whilst those who didn't - simply didn't do the work. In the tri-weekly survey, results showed that 100% of respondents found the Arduino workshops "very interesting and valuable", but only 8 and eventually 5 students were committed to the projects by the end of the program. From the weekly surveys:

"I thought it [arduino] was very fun because we actually did hands-on activities. Also a plus was learning some coding while actually being able to implement them and seeing real change."

"I loved the arduino workshop! I really enjoyed getting to work hands-on with the technology. For me, where I have worked with circuits, this workshop made sense to me and I felt comfortable to explore and try a few variations with the software and the breadboard. I think for me the most challenging part will be in the coding rather than the circuitry because I feel very comfortable with the circuits and components within them. I played with this all weekend!"

VIII. Future Research

Based on our students' survey responses from the program evaluation by the external evaluator, the REU students indicated that the Arduino project was challenging to them although they enjoyed it as indicated by the evaluation scores shown here in section 6. The REU students' feedback was mixed: some wanted more time to work on projects whilst others wanted less time. Some preferred partners whilst others would have preferred working alone. However, everyone would have preferred a more informal experience with more student choice, i.e. how much time to commit to projects, what final presentations look like, how strict final project requirements are. These issues will be addressed in the second offering of the REU-PATHWAYS program.

IX. Conclusions

This paper presents the concept of teaching programming to non-computer-science students without programming, a concept referred to as visual or conversational programming. While the concept in itself is not new, implementing it using the Arduino SparkFrun Innovator's Kit is truly innovative. It is applied as an activity for REU-PATHWAYS participants, from local community colleges, of a funded REU site by a grant form NSF. It improved students skills in programming and engineering design. The students feedback is positive, confirming the observation that visual/conversational programming is a viable concept to teach programming without programming.

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References

[1] Elizabeth M. Kopko, E.M. & Crosta, P.M. (2016). Should community college students earn an associate degree before transferring to a 4-Year Institution?, Research Higher Education, Volume 57, pp. 190-222.
[2] Townsend, B.K. (2001). Redefining the community college transfer mission. Community college review, 29(2), 29–42. https://doi.org/10.1177/009155210102900203
[3] Nora, A., Rendon, L.I. Determinants of predisposition to transfer among community college students: A structural model. Res High Educ 31, 235–255 (1990). https://doi.org/10.1007/BF00992310
[4] Alicia C. Dowd, John J. Cheslock, and Tatiana Melguizo, Transfer access from community colleges and the distribution of Elite Higher Education, Journal of Higher Education, Pages 442-472, 2016, https://doi.org/10.1080/00221546.2008.11772110
[5] Gary Hoachlander, Anna C. Sikora, and Laura Horn, Community College Students: Goals, Academic preparation, and Outcomes, Education Statistics Quarterly, Vo. 5, Issue 2, pp. 121-133, 2003.
[6] https://plexuss.com/news/article/benefits-of-going-to-community-college-then-transferring
[7] Casey Maliszewski Lukszo1 and Shannon Hayes, Facilitating transfer student success: Exploring sources of transfer student capital, munity College Review 2020, Vol. 48(1) 31–54.
[8] Hans Johnson and Marisol Cuellar Mejia, Increasing community college transfers: Progress and Barriers, Public Policy Institute of California, September 2020.
[9] The Conversation, Doing this one thing helps community college students transfer to a 4-year university, https://theconversation.com/doing-this-one-thing-helps-community-college-students-transfer-to-a-4-year-university-146526, October 14, 2020
[10] Jennifer Glynn, Persistence: The success of students who transfer from community colleges to selective four-year institutions, Jack Kent cooke foundation, https://www.jkcf.org/wp-content/uploads/2019/01/Persistance-Jack-Kent-Cooke-Foundation.pdf, January 2019
[11] S. Nikiforos, C. Kontomaris, K. Chorianopoulos, MIT Scratch: A powerful tool for improving teaching of programming, Conference on Informatics in Education 2013, pp. 1-10.
[12] Mitchel Resnick, John Maloney, Andrés Monroy-Hernandez, Natalie Rusk, Evelyn Eastmond, Scratch: programming for all, Commu--nications of the ACMVolume 52Issue 11November 2009 pp 60–67https://doi.org/10.1145/1592761.1592779

[13] Stavros A. Nikou; Anastasios A. Economides, Transition in student motivation during a scratch and an app inventor course, 2014 IEEE Global Engineering Education Conference (EDUCON), IEE Xplore, DOI: 10.1109/EDUCON.2014.6826234.
[14] Kyungwon Koh, Adolescents' information-creating behavior embedded in digital media practice using scratch, Journal of the Americ--an Society for Information Science and Technology, 2013, https://doi.org/10.1002/asi.22878
[15] April Y. Wang, Ryan Mitts, Philip J. Guo, Parmit K. Chilana, Mismatch of expectations: How modern learning resources fail conversational programmers, Proceedings of the 2018 CHI conference on human factors in computing systems, April 2018 Paper No.: 511, Pages 1-13 https://doi.org/10.1145/3173574.3174085
[16] Northeastern University First-year makerspace lab, https://www.sparkfun.com/northeastern
[17] Kurniawan, Agus, SparkFun ESP8266 Thing Development Workshop, Aug 2015, PE Press, available at books.google.com
[18] Love, J.O., & Freeman, S.F., & Jaeger-Helton, K., & Whalen, R. (2015, June), No Lab? No Shop? No Problem: Intentional Design of a First-year Engineering learning center with enlightening outcomes paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24526
[19] Whalen, R., & Freeman, S.F., & Love, J.O., & Schulte Grahame, K., & Hertz, J.L. (2018, June), Evolution of cornerstone: Creating a first-year culture with a multifaceted approach paper presented at 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah. 10.18260/1-2-30459
[20] Committee on the Engineer of 2020, National academy of engineering & committee on engineering education. (2005). Educating the Engineer of 2020: Adapting Engineering Education to the New Century. Washington, D.C: National Academies Press.
[21] ABET. (2020). Criteria for Accrediting Engineering Programs, 2020-2021. Retrieved from: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/
[22] Bandura, Albert, W. H. Freeman, and Richard Lightsey. "Self-efficacy: The exercise of control." (1999): 158-166.
[23] SparkFun Electronics, Inc., https://www.sparkfun.com/
[24] Todd R. Kelley, the anatomy of a design brief, Technology and Engineering Teacher, 2020, pp. 8-12.

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