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Empowering Diversity in STEM: A Collaborative Approach between Engineering Technology and High Schools

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Abstract

Increasing diversity among engineering technology programs is a target by most colleges and universities. In an effort to raise STEM awareness and generate interest among underrepresented groups and to enroll more students from high schools, a team from xxxxx campus has designed and conducted a series of hands-on activities at a local urban high school starting in fall 2021. The activities that have been put into practice encompass topics related to mechanical and electrical engineering technology. These include materials, manufacturing, hydraulics, electric circuits, and programming. Students nurture their STEM interest through engaging in hands-on practice in the areas of materials processing, data analysis, and model building. Simultaneously, students are exposed to a college learning environment while actively participating in these activities. This paper will discuss the strategies employed to create these activities using resources from existing college laboratory exercises and projects within the engineering technology programs. Fifty-six students from different grades participated in the program based on their interests. The emphasis on underrepresented minority groups aligns with xxxx University’s commitment to diversity and aims to increase recruitment from schools with a higher proportion of such students.

Background

The project’s goal was to enhance STEM awareness among minority communities and to increase enrollment at the xxxxx campus of XXXXXX University. A team of three faculty members from that campus proposed and conducted different hands-on activities in collaboration with a local high school offering a STEM program. The STEM initiatives created by the team specifically targeted the cultivation of interest among underrepresented groups at the xxxxxx statewide campus. A retrospective analysis of XXXXXX University's statewide locations from 2008 to 2019 revealed a consistent dominant male student population ranging from 78% to 85% (804 to 1078), while females constituted of 15% to 22% (142 to 315) [1]. During the same period, the average percentage of white students across all statewide locations was 87.5%, leaving the remaining percentages dispersed among other categories [1]. These findings emphasize the need for increased marketing and recruitment efforts to attract more underrepresented minorities and female students to the engineering technology programs.

Providing opportunities for students from traditionally underrepresented subpopulations to engage in STEM activities enhances the probability that they will pursue and be adequately prepared for STEM-related majors [2]. Certain STEM high schools, which focus exclusively on science, technology, engineering, and mathematics, have shown a correlation with elevated achievement among underrepresented minorities students in STEM [3], [4]. These features include the incorporation of engineering and technology into science classrooms, the adoption of student-centered teaching methods such as project-based learning, and more [5], [6], [7].

Our team adopted project-based learning techniques to engage a diverse range of students. The initial project encompassed MET and EET activities in statics, hydraulics, electric circuits, programming, and other areas relevant to engineering technology fields. The team met bi-weekly to prepare these activities, each of which spanned two class periods at a local urban high school, resulting in 3-4 activities overall. Each team member took the lead on an activity, resulting in the delivery of two MET activities and one EET activity over six visits in the span of three months. Each activity started with an introduction to the main purpose of the exercise or project, then directions and materials were distributed among the students who were split into teams to complete the activity. Students who participated in one activity did not participate in the other activities, due to space limitation and due to the fact that the activities were scheduled during normal class laboratories times. Following each activity, participating students were asked to complete a post-survey for the program and the activity in a step to collect some feedback to improve any future attempt to repeat such activities or initiatives.

All three team members anticipated that student participation in the activity process would enhance their interests in STEM, critical thinking skills, and teamwork abilities. The team also believes that this project extends beyond underrepresented minorities and females, serving as a recruiting tool for all students within the local community. Furthermore, it has the potential to be implemented at other statewide locations and less diverse county schools. Although the target of this project was to increase underrepresented minorities enrollment, but this paper is limited to presenting the activities that were conducted. Tracking the number of students who gets enrolled due to their participation in the program is beyond the scope of this paper for several reasons: 1) the participating students are coming from grades 9 through 12, thus it would need at least four years after the completion of the program to track such an effect; 2) the number of participating students was limited due to space, time and support: repeating this activity in the future with a different groups of students would provide a larger pool that would make analyzing the track of enrollment more meaningful.

Activities

Three activities were conducted covering major topics in hydraulics, casting, and computer-and-electrical engineering. The project related to hydraulics focused on the fields of mechanical engineering, electrical engineering, and robotics and targeted students interested and enrolled in a physics course at the school. The casting laboratory project/activity provided valuable hands-on experience relevant to mechanical, industrial, and material engineering technology and included students interested in chemistry and physics. Lastly, the electrical activity was specifically designed for students with interests in computer science and electrical engineering.

To accommodate students' schedules, the high school STEM coordinator arranged the three activities, scheduling them during different courses' laboratory sessions. The hydraulics project was slotted into the physics laboratory session, the casting project was aligned with the chemistry laboratory sessions, and the electrical project was integrated into the computer science laboratory sessions. Participation in the projects was limited to students who opted for the respective courses associated with each project.

Activity 1: Hydraulic Arm Lift Project:

This project focused on engaging students with an interest in physics. The project involved hands-on activities where students constructed small hydraulic excavators using syringes as linear actuators, polypropylene tubes, wooden sticks and employed thrust bearings for rotational motion. Additionally, batteries and switches were utilized to activate an electromagnet responsible for carrying and dropping a metallic object, as shown in Figure 1.

Student groups included students with different ethnic backgrounds as shown in Figure 2 and Figure 3. Groups of 5-6 students were randomly formed. Each group built a different design in terms of arm reach, rotational base, and location of the syringes as shown in Figures 2, 4 and 5. Two, 50-minutes sessions were used to complete this project. During the first 50-minutes, the students brainstormed and tested different designs. The groups then completed their designs during the second 50-minute session. The students were given a set of objectives and goals that they needed to achieve including:

- the arm should provide three degrees of freedom: angular, horizontal, and vertical
- the angular rotation should cover a minimum of 90 ° angle
- the horizontal and vertical allowances should be at least 3 inches each way
- the arm should be able to lift a small object using an electromagnet
- caution should be taken to avoid having the tubes pop up from the cylinders (syringes) when in operation carrying the ball from one location to another
- teams should avoid having air bubbles inside the tubes which can limit the performance of the hydraulic arm

Activity 1 Results:

Students constructed several different designs. Two designs (Figures 2 and 4) were similar in scope and function. The design provided in Figure 5 was closer in operation to an excavator with longer reach, but all samples met the main objectives: the arms moved horizontally, back and forth three inches, it lifted a small ball three inches from the base, and rotated 90 °. All of the groups' designs successfully met the requirements, except one group that had conflict on distributing the tasks between the group members.

Figure 1. Hydraulic excavator project (sample # 1)

Figure 3. Student groups participating in the hydraulic excavator activity (sample # 2)

Figure 2. Student groups participating in the hydraulic excavator activity (sample #1)

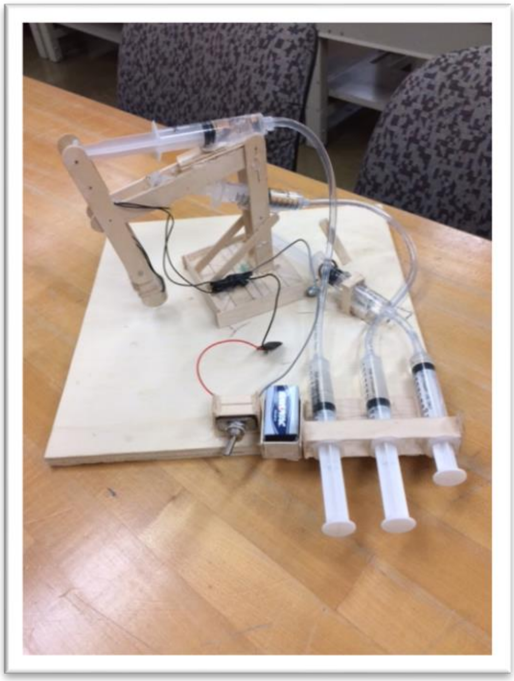 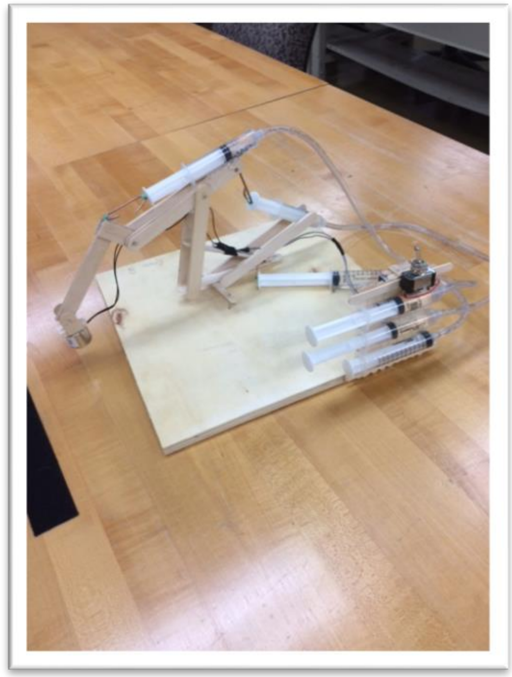

Figure 4. (Left): Hydraulic excavator/lift sample #2; Figure 5. (Right): sample #3

Activity 2: Sand Casting Project:

This hands-on project serves as an introduction for students to the practical aspects of sand casting, aiming to stimulate their interest in materials and manufacturing processes. The instruction manual developed for these two 50-minute laboratory sessions is versatile and can be applied to various STEM-related activities for middle and high school students. Three engineers from a local casting plant actively participated in the project, providing live demonstrations of the casting process. This direct involvement of industry professionals not only enriched the students' learning experiences, but also established a tangible connection between the laboratory work and real-world industrial applications.

The goals of practicing this sand-casting project were:

- gaining hands-on sand-casting experience
- understanding some mechanical properties and processing methods in manufacturing metals
- acquiring information of foundry safety
- understanding molds and mold making
- observing the effect of shrinkage due to change in temperature
- understanding that the mold pattern is reusable while the mold is not
- improving interest in metal casting and mechanical engineering technology

This activity was conducted over two 50-minutes sessions similar to the Hydraulic Arm Lift.

Session One: During the first session, engineers from a local casting plant helped in conducting the procedures. The activity was performed in the school's chemistry laboratory and it included five steps:

1. Safety precautions were taken such as wearing the appropriate safety equipment-safety glasses, long sleeve shirts, and safety gloves.
2. The laboratory activity was introduced to the students by demonstrating the activity (Figure 6 - approximately 15 minutes). Four sets of the laboratory materials and tools were placed on the students' benches.
3. Students were split into four groups (five students per group). Students started the project by following the procedures listed in the provided manual.
4. The students added sand to an 8” $\times$ 6” $\times$ 5” flask and placed a mold pattern in the sand. There were multiple flat aluminum patterns for students to choose from. The surface areas of the patterns were around 2-3 in^2.
5. Using prepared tools to set up a gating system which consists of a pouring cup, sprue, and a runner, the students removed the pattern and cleaned the loose sand in the mold cavity.

Figure 6. Demonstration set for tin sand casting-prepared by yyyyyy casting plant

Figures 7-8. Students participating in the casting activity

Figures 7-8 show students actively working on this project. Despite the demonstration, some students had concerns about how to proceed with the procedure. The engineers from the local casting plant were very helpful in addressing these concerns. To better assist students in the future, it is recommended to share the manual for this activity in advance, providing them with detailed instructions before the activity begins. For safety concern, all the four molds were brought back to the university's laboratory where a technician prepared the liquid metal and filled the molds. Figures 9-10 display aluminum parts cast by the students.

Session Two: The second session consisted of post-casting processes and survey and it included the following:

1. Students were instructed to open the mold and remove the metal casting parts.
2. Upon removal of the casting, the students were instructed to clean any sand off the part and to use a file to smooth rough and sharp edges.
3. The students then were instructed to observe the surface texture and to check if there was any shrinkages on the surface of the part. Possible reasons for shrinkage in casting were shared with the students.
4. The students were then asked to clean their work area and to deposit the used sand into a bucket.

5. Survey. Gender and ethnicity surveys were distributed and each student anonymously completed the surveys. Simultaneously, a photo release form was also collected for students to provide consent for the use of their pictures (this was done for all three activities).


Figures 9-10. Aluminum parts cast by the students

Activity 2 Results:

For session 1 of this activity, one group successfully completed their work in 35 minutes; three other groups finished just before the end of the 50-minute class period. Subsequently, the four flasks used in the project were transported to the university laboratory for the pouring and demolding process, as the chemistry laboratory at the high school lacked the necessary equipment for venting and removing the gating system. Figures 9 and 10 show two metal parts cast by high school students prior to cutting.

Students showed keen interests in this hands-on activity, with the majority of them actively participating throughout the entire process.

The second session required less time, as the cutting process had been completed in the university laboratory. For future sessions, consideration can be given to bringing a small cutting machine into the chemistry laboratory to streamline the process. On the other hand, students had time to talk with the participating faculty members and engineers who gave insightful information about the engineering technology programs, program requirements, and other details that are beyond the scope of this paper.

Activity 3: Computer Science Activity:

The third activity was composed of two, 50-minute periods and was developed for use in the Computer Science course at xxxxxx High School with the intent on offering this in other schools in the future. The Computer Science course uses Java programming where the students develop graphical programs shown on the computer screen.

The goals of this supplemental activity were to expose the students to:

- programming in a different computer language and see similarities between Java and Arduino syntax;
- interfacing with external hardware;
- fundamental electronic circuits building;
- fundamental circuit troubleshooting;
- analog to digital signal conversion;
- binary, decimal and hexadecimal numbering systems;
- integer division in programming;
- and to spark interest in programming and engineering/engineering technology as a career.

Session One - 50-minute activity

The first session activity consisted of four steps where the ultimate goal was to use an optical distance sensor to control the brightness of an LED. Students worked in groups of two or three. These steps consisted of:

1. Using the Arduino Uno platform, a resistor and LED were connected to the onboard 5-volt source to illuminate the LED. This allowed the students to establish that the LED circuit was functioning properly.
2. The circuit was modified so that one of the Arduino output pins was used to apply voltage to the LED/resistor circuit. A program was written which would allow the voltage on the Arduino output pin to be set "HIGH" (5 [V]) or "LOW" (0 [V]). This allowed the students to see that they could turn the LED on or off using the software.
3. The Arduino software was then modified to repeatedly turn the LED on and off for ½ second intervals. After the students observed this, they then changed the timing to 50 [ms] intervals. The students then adjusted the on and off times and observed the brightness of the LED using 90% duty cycle (18 [ms] on and 2 [ms] off) and comparing it to 10% duty cycle (2 [ms] on and 18 [ms] off). Students were allowed to observe the effects of different duty cycles by modifying the software.
4. An optical distance sensor was then connected to one of the analog A/D inputs of the Arduino. The output value from the A/D varied between 0 and 1023 depending the proximity of an object to the sensor. This value was used to vary the LED duty cycle and

in turn vary the LED brightness. The final circuit is shown in Figure 11 and the final program is shown in Figure 12.

Most students completed the first session's activity in the allotted time and were able to experiment with the program and to ask questions about the circuit and program.

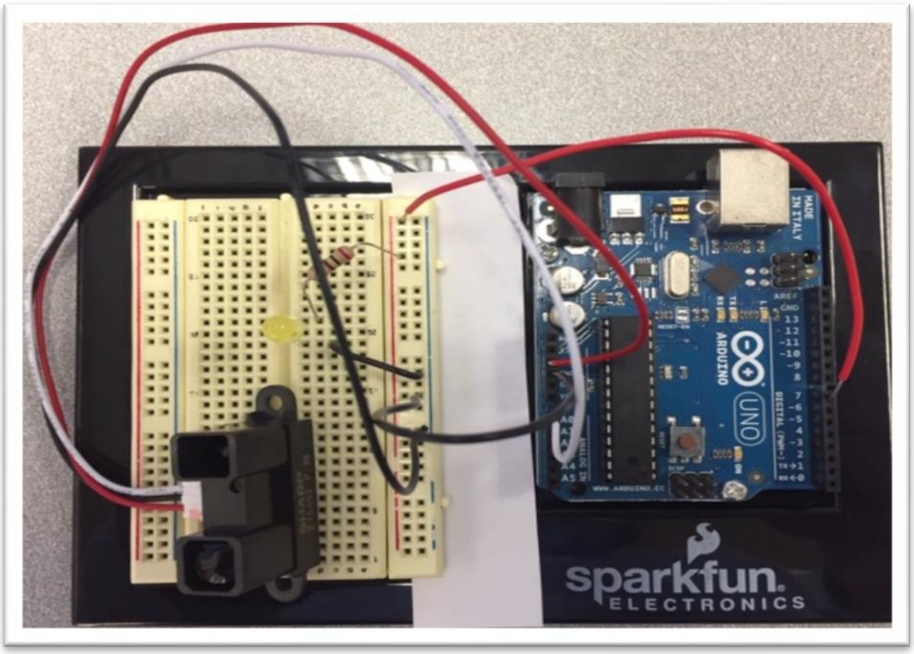

Figure 11. Session one activity final circuit with optical distance sensor

```
void setup()
{ // put your setup code here, to run once:
  pinMode(7, OUTPUT);   //initializes digital pin 7 as an output
}

void loop()
{ // put your main code here, to run repeatedly:
  int on_time;          // declares a variable named "on_time"

  // analogRead(A0) below examines the 0 to 5 [V] voltage applied
  // to pin A0 and produces a value from 0 (@ 0[V]) to 1023 (@ 5[V])
  on_time = analogRead(A0)/100;   // on_time will be an integer from 0 to 10

  digitalWrite(7, LOW);   // turns the LED off (LOW is the voltage level)
  delay(6 - on_time);     // OFF time
  digitalWrite(7, HIGH);  // turns the LED on (HIGH is the voltage level)
  delay(on_time);         // ON time
}
```

Figure 12. Session one activity final program

Session Two - 50-minute activity

The second session activity had three main objectives.

The first objective was to examine why the optical sensor and A/D produced a value between 0 and 1023 and how this affected the program used to control the LED brightness. This led to a discussion of binary numbers and how many combinations were possible with a specific number of bits. Once more than four bits were being used, a discussion of hexadecimal numbers was needed. With this understanding the students examined the 0-1023 values and determined that the A/D used 10-bits in its conversion for 0-5 [V]. The students then looked at the program used to control the LED and observed the effect of integer division.

The second objective involved some basics of structured programming in Arduino software. These structures were similar to what the students already knew from Java (declaration of variables, while loops, if/else statements).

With these tools, pairs of students were tasked with creating a simulated light control system where detection of an object using the optical sensor would turn a light on. After an allotted period of time with no object detected, the light would turn off. Some student pairs completed the activity in the allotted time and were able to experiment with the program and to ask questions about the circuit and program.

Figures 13-14. Students participating the computer science lab

Activity 3 Results:

Most of the students were able to complete the first activity in the allotted time and several had enough time after completion to explore a bit. The second activity needed a bit more time for most of the students and most wanted to complete the task.

Several of the students stated that as a result of the activity that they were interested in studying engineering technology or computer technology. Figures 13 and 14 show students engaged and focused during the electric engineering technology laboratory activity.

The Arduino software is free to download. One of the biggest challenges was getting students access to the Arduino software. xxxxxx High School provides laptops to their students, but they are not permitted to load their own software. They have no computer laboratories with dedicated desktop machines. In Spring 2023, the IT staff were able to load the software to the students' laptops; however, in Fall 2023, they suggested a different method of getting access to the software that didn't work and as a result, the activity could not be performed. The team is working with the school to resolve this issue so this does not happen in future activities.

Summary

A total of 56 students participated in these STEM activities. Twenty students attended the hydraulic sessions held in the physics laboratories, including two female participants. For the electrical sessions in the computer science activity, 15 students attended, with only one female student. The casting activity had the highest attendance, with 21 students, out of which 13 were female. It's worth noting that the STEM activities were pre-scheduled during routine laboratory times for the three different courses, so students' attendance for each project was not based on personal choice.

Table 1. Feedback of Sand Casting Lab

Like the least about Sand Casting Lab	Like the most about Casting Lab
Building the mold	Working with sand
The mess – getting the sand everywhere	Making the mold
Smell of the gloves	Seeing the final products
Hard to work with sand	Get to learn about casting
Packing	Packing the sand
This activity took a while	Working with team mates
Couldn't pour the liquid metal inside the mold	Built the down-sprue
Wearing gloves	Cool and new laboratory experience

The surveys also showed the feedback from the students. Table 1 displays the outcomes of the questions posed to the students participating in the sand-casting activity on the feedback forms. The students' feedback highlighted their enthusiasm for the hands-on experiences and enjoyment of team work, with some expecting future activities. Moreover, Figure 15 shows the feedback received by the three activities. It was noticed, out of those who completed the forms, that 50%

of the students attending the electrical and computer activity, 75% attending the casting activity, and 65% attending the hydraulic activity felt the difficulty level of the laboratory was the just right. In terms of activity duration, students expressed similar opinions with very close ratios, but again this was limited to 50-minutes sessions as it was scheduled during regular class periods.

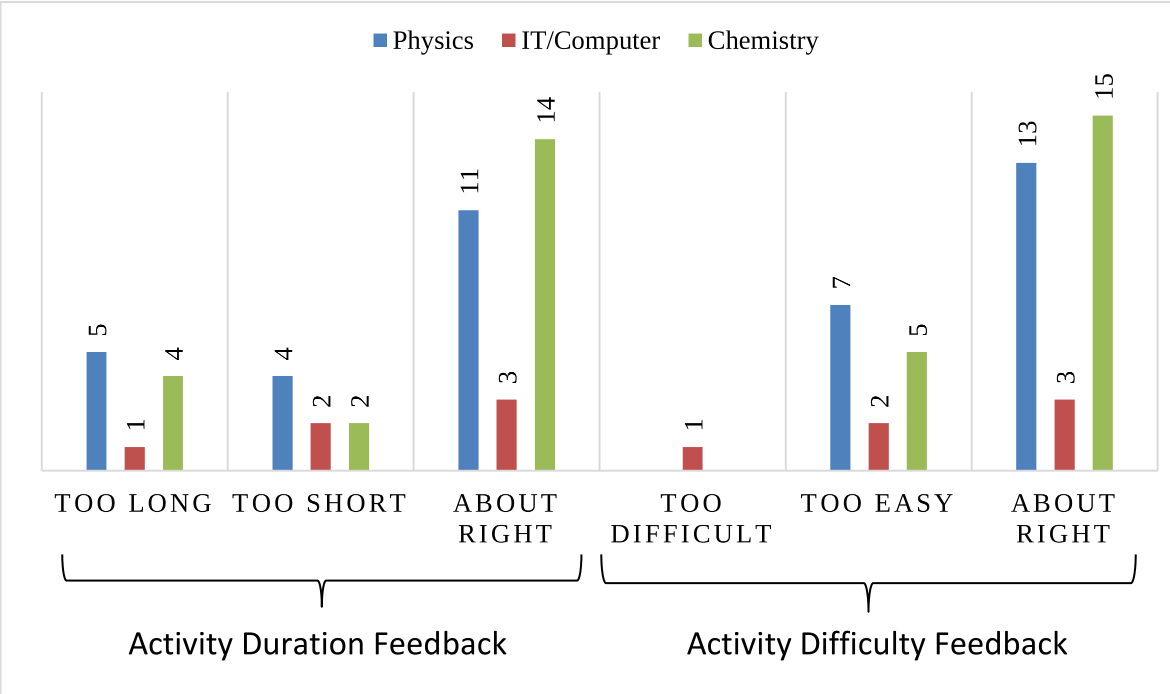

Figure 15: Students' Feedback Survey Results

Table 2 displays the survey results for gender and ethnicity. Among the students who participated in the STEM activities, 14.3% were identified as African-American, whereas the overall school population had a little higher representation of 16.5% African American students. Similarly, 14.3% of the STEM activity attendees were Hispanic, while the school's general population had a much lower percentage of Hispanic students at 6.8%.

Table 2. Gender and Ethnicity Survey

	Hydraulic Lab	**Casting Lab**	**Electrical Lab**
# Students	20	21	15
Male	18	8	14
Female	2	13	1
Grades	10, 11 and 12	9 and 10	10, 11 and 12
Asian	1	1	3
White	12	14	9
Black	5	2	1
Hispanic/Latino	2	4	2

Limitations and Future work

Tracking long-term enrollment outcomes post-participation is a future focus, necessitating longer studies and collaboration with more institutions. Assessment of the program's impact on students' academic and career choices through follow-up surveys or interviews is vital, however, ensuring scalability and replicability across diverse educational settings requires refining the program's materials and implementation strategies. The team is planning to employ a more comprehensive evaluation methods such as pre- and post-program assessments and qualitative interviews which can enhance program effectiveness. Addressing access challenges, like ensuring equitable access to necessary software, remains a priority for future iterations.

Finally, collaboration with community organizations and schools can further enhance the program's reach and inclusivity. Overall, ongoing iteration, evaluation, and collaboration are key to maximizing the program's effectiveness in promoting diversity and inclusion in STEM education.

References

[1] Data Digest. (2021). Student Enrollment. [Online]. Available: https://www.purdue.edu/datadigest/?dashboard=EnrollmentBars_1

[2] V. Young, A. House, H. Wang, C. Singleton, and K. Klopfenstein, "Inclusive STEM schools: Early promise in Texas and unanswered questions," in *National Research Council Workshop on Successful STEM Education in K-12 Schools*, National Academies, 2011.

[3] E. Peters-Burton, S. Lynch, T. Behrend, and B. Means, "Inclusive STEM high school design: 10 critical components," in *Theory into Practice*, vol. 53(1), pp. 64-71, 2014.

[4] R. Capraro and S. Slough, "Why PBL? Why STEM? Why now? An introduction to STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach," in *STEM project-based learning*, pp. 1-5, 2013.

[5] K. Lesseig, J. Firestone, J, Morrison, D, Slavit, and T. Holmlund, "An analysis of cultural influences on STEM schools: Similarities and differences across K-12 contexts," in *International Journal of Science and Mathematics Education*, vol. 17, no. 3, pp. 449-466, 2019.

[6] W. McCorkle, "The Relationship Between Teachers' Grade Level and Views on Immigration and Immigrant Students," in *Journal of Social Studies Education Research*, vol. 11, no. 1, pp. 21-41, 2020.

[7] A. Bicer, Y. Lee, and C. Perihan, "Inclusive STEM High School Factors Influencing Ethnic Minority Students' STEM Preparation," in *Journal of Ethnic and Cultural Studies*, vol. 7, no. 2, pp. 147-172, 2020.