Virtual Engineering Summer Camp in the age of COVID-19 Pandemic

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George Nnanna is the Inaugural Dean of the College of Engineering at the University of Texas Permian Basin. The College has 503 students and four departments - chemical, electrical, mechanical, and petroleum engineering. The new state-of-the-art $55M, 105, 000 sq. ft. engineering building located at the Midland campus houses all the departments including the new Water-Energy Nexus Institute.

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He has generated $8.9M in external research funding, over 70 technical publications that has been cited over 1000+ times. He received "Best Paper Award" in the ASME conference, 1st Place Award in 2012/13 ASHRAE project, 14 research awards from Purdue Northwest, and 4 US Patents.

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Abstract

COVID-19 pandemic greatly affected the learning experience of students. Prior to the COVID-19 pandemic, many engineering programs worldwide organized engineering summer camps for K-12 students in the summer of every year. These camps benefit K-12 students by providing a good insight into the introduction to engineering and also inducing intellectual curiosity in them through hands-on projects. Most of these sessions usually take place in a face to face setting versus the virtual mode of instruction. In summer 2020, the majority of the engineering summer camps were canceled due to the COVID-19 pandemic. The College of Engineering at the University of Texas Permian Basin organized the virtual engineering summer camp after shipping the required project kits to the students, thereby providing step-by-step instruction of performing the project virtually while also proving hands-on experience for better learning. To our knowledge, this mode of virtual summer camp that provided a hands-on experience to K-12 students was uniquely implemented in the nation by UTPB College of Engineering. This paper provides the ideas implemented to overcome several challenges, the techniques that rightly helped in conducting the virtual summer camp with hands-on experience, and methods to assess student learning.

1. Introduction

Engineering summer camps for K-12 students are widely implemented in the nation during summer months every year, typically between June and August. These camps provide a hands-on experience to visualize and correlate fundamental engineering concepts, thereby providing students a fundamental grasp and arise curious questions about several working principles in nature. These camps also help in creating an interest and awareness about various engineering disciplines and assist them in decision making related to a pathway for an engineering career. Engineering summer camps are generally held by the College of Engineering that include hands-on projects and sometimes visualizations projects related to several engineering disciplines such as Mechanical, Chemical, Electrical, Computers, Civil, Industrial, Petroleum and more.

Prior to COVID-19 pandemic, all engineering summer camps were held face-to-face with an exception for projects involving computer coding or projects that focus on introducing theoretical concepts, which irrespective of pandemic were conducted virtually. Due to the COVID-19 pandemic that hit United states towards the end of the year 2019, most of the engineering summer camps which used to take place in a face-to-face setting were cancelled in the summer 2020 while a few Colleges held the summer camps virtually. To the authors' knowledge, those virtual camps that were held in summer 2020, mostly included computer coding concepts or introducing theoretical concepts. There were almost no camps that were able to conduct projects using a hybrid model that imparted hands-on-experience through virtual instruction.

Virtual sessions have a drawback of lacking hands-on experience which are critical to improve student's grasp on fundamental concepts. To overcome this drawback of virtual sessions, the college of engineering at UTPB designed a project kit that contained the required project materials and shipped those kits to the students, followed by virtual instruction related to assembly, execution, analysis, critical thinking, interaction with other students, and writing report. Thus, students were able to perform hands-on engineering projects at home with the virtual instruction and supervision from faculty and undergraduate student assistants. The implementation, assessment, outcomes, challenges and results of this virtual and hands-on hybrid experience of engineering summer camp is presented in this paper.

2. Planning and Implementation

The purpose of the summer camp was to introduce some fundamental background related to various engineering disciplines to middle and high school students and inspire them to become next generation engineers.

2.1 Objectives of the 2020 Engineering summer camp

Following objectives align well with the mission of the university,

1) Utilize the resources of the College of Engineering to impart knowledge through hands-on projects to K-12 students,
2) Design projects to middle school and high school students with apt levels of intricacy to challenge and arise intellectual curiosity in them,
3) Engage students and faculty effectively and efficiently and
4) Generate measurable outcomes that assist in measuring student learning and engagement.

2.2 Project planning

The projects chosen for the 2020 engineering summer camp were the following: working of wind turbines with a focus on drag, lift and gear ratios; demonstration of working principle of stirling engine; demonstration of moment of inertia; and assembly and operation of a robot.

In order to provide hands-on experience, a team of undergraduate student assistants were carefully chosen on the basis of their academic performance and recommendation from the faculty. Every faculty mentor was assigned an undergraduate student assistant by matching the student assistant skills and interests with the projects. A two-week time period was assigned to the mentor to train and guide the undergraduate student assistant to perform the project that provides an insight into the possible time taken by a high school student to perform the same project.

A welcome video was made and uploaded to YouTube that provides an overview of the summer camp, details of the projects and list of materials in the kits. The YouTube link is as given below.

https://www.youtube.com/watch?v=a2t6bJHvqv4

A trial run of each of the projects was conducted with student assistants from other project teams in the virtual meeting. As each project is time bound, this demonstration assisted in finding the apt time distribution to perform the project effectively and solve any possible technical issues that may arise while performing the actual project. During this demonstration, a list of steps required to perform the project were developed. Typically, each project consisted of at least 30 steps. These steps included assembly, operation and testing. A clear differentiation of the outcomes was identified and prepared separately for middle school and high school students.

A week before the camp commencement, all experiment kits and needed material items were organized and placed in square cardboard boxes in order to ship, as well to allow easy transition for parents to pick up. The project kits were mailed to the parents that lived far away from the campus, typically in another state, while parents of some local students were able to physically collect the kits directly from the College of Engineering. A total of 23 students attended the 2020 summer camp. Attendees consisted of 11 High school students, and 12 Middle school students. Most project materials were ordered from Amazon and Walmart and delivered to the UTPB Engineering building for arranging and placing the individual project materials into project kits that contained the required materials for all projects. Table-1 shows the list of materials and the kit names that were ordered from Amazon. For moment of inertia demonstration project, raw materials were purchased from Home Depot and machined to form the required dimensions along with 3-D printing some parts.

Table 1: List of equipment ordered

Project materials	Quantity ordered	Merchant
Wind turbine Thames & Kpsmos Wind Power 2.0 science experiment kit	25	Amazon
Robot -mBot Makeblock mBot Build Robot kit	25	Amazon
Moment of Inertia	30	Custom fabricated using 3-D printing and post processing
Stirling Engine Low Temperature Stirling Engine	25	Amazon
Batteries, rulers, multimeters	40 each	Amazon, Walmart

The process to check out experiment packages to students, involved primarily student's parents to arrive to the UTPB College of Engineering building and pick up the packages in person. Parents followed all the guidelines instructed by the university in order to prevent the spread of COVID -19 and used face masks and 6 feet apart between each person. The other method used was to send packages through mail with the help of the universities mail room if the first method was not available for the student's parents.

Microsoft Office Teams was used as a virtual platform to connect with the students. Through this platform the organizer can send the meeting link using which students can access the meeting at the specified time. Apart from the organizers, Microsoft subscription is not necessarily required for students and can be accessible through a browser extension. It is recommended to use google chrome browser. The meeting was recorded when the camp was in session and was made available to students to watch later for further help if needed to prepare the report.

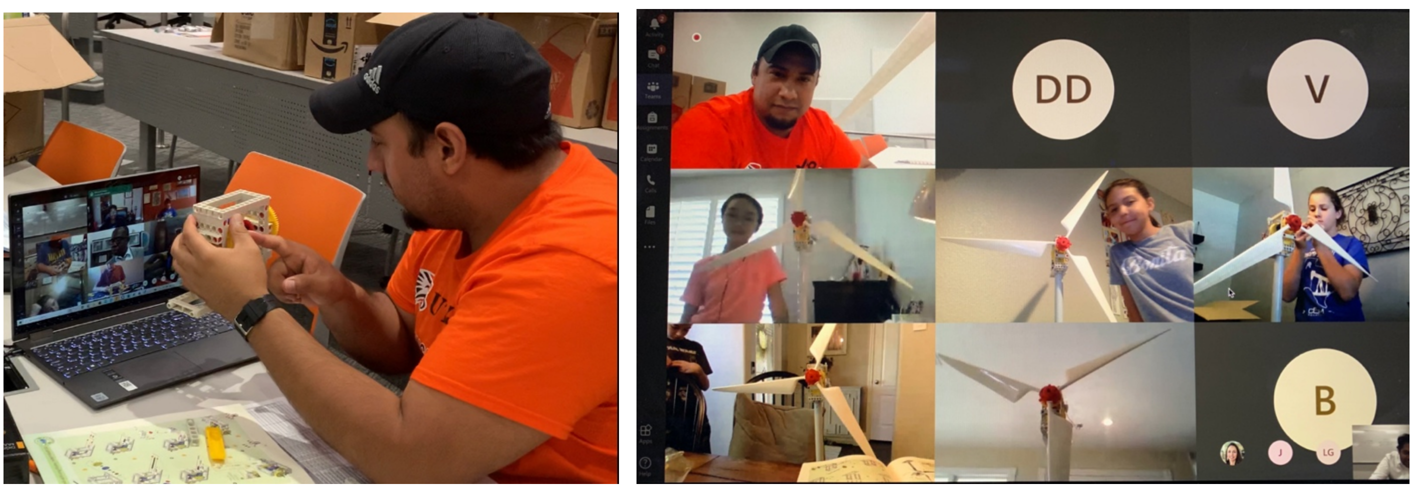
2.3 Description of projects

Four projects were developed. Each of the four projects in the 2020 summer camp incorporated hands-on assembly and testing to enable correlation between theory presented and practical knowledge. Each of these projects partly involved assembly followed by testing and analysis. The following are the list of projects executed in the 2020 summer camp.

Working of wind turbines

In the wind turbine project, students were initially given an introduction to the operational principle of wind turbines, history of windmills and evolution of modern wind turbines. A portion of the material covers an introduction to the size and efficiency of wind turbines. This was followed by a guided step-by-step process to build a prototype model of wind turbines using the kits provided to them. Each step was simultaneously performed on the instructor's end and at each student's end. The progress was virtually monitored and any questions through the process was immediately addressed so as to ensure that no student is left behind. As shown in Figure 1 A, the undergraduate student assistant builds the prototype starting from scratch in a step-by-step approach and at each step, he shows the students how the assembly looks like so that the students confirm that their assembly is in correct track. This enabled students a hands-on experience in understanding the assembly and operational principle of a wind turbine. During the process, the instructor answered any questions from students and ensured each student was following the project path and none was left behind. As shown in Figure 1 B, students display the completed wind turbine assembly that was ready for testing.

After building the prototype, students were asked to place it opposing the direction of wind and test the performance by connecting the two leads to multimeter (present in the project kit and given instruction on how to use multimeters) and calculate voltage generated by the prototype. At this juncture, students were presented with the concepts related to gear ratio, swept area, drag, lift and the effect of blade angle on the performance turbine. At the end of the project, students were assigned a task on exploring ways to improve the wind energy conversion efficiency. Students were asked to interact with one another and generate some ideas thereby imparting an experience of working as a group. Towards the end of the project, a sample report was given to them that has some missing details which needed to be filled by the students and submitted to the professor for remarks and comments. High school students received questions that needed higher critical thinking in order to answer. Once students completed the report, they were tasked to begin disassembly of the turbine and provided them required instructions on how to submit the completed report.



A B

Figure 1: A) Student assistant building the model and virtually presenting each step clearly to students to ensure each student is building the prototype. B) Student Assistant on the top left asking the students to display their prototype ensuring smooth transition to later test this prototype for its performance.

Assembly and operation of a robot: Robotics mbot experiment

Robotics project involved assembly of a robot, operation of the robot with the remote control and programming to make robot move. This project started with an introduction on robots, purpose, and an overview of robot design. This presentation was important as the students had to complete an assignment with different questions related to robotics and the understanding of the mbot which they were going to be experimenting with. When assembly of the mBot began, students followed the instructions of the assembly manual along with the direction of each step with the help of student assistant assigned to the robotics faculty. Figure 2 shows students displaying their assembled mBots after following instructions from the robotics faculty. After completing the assembly of the mBot, students received a detailed explanation on how to make the mBot move using a remote control and a smart phone. With the use of a remote control, students were able to make the mBot move left, right, forward, backwards, and set the mBot in automatic mode in order to allow the mBot to use its sensors. With the help of a smart phone, students were able to make the mBot move using a virtual joystick thanks to an app called 'Makeblock'. Students also learned how to make the mBot move using programing codes in an app called 'mBlock Blockly'. Students from Middle school and High School experimented with the mBot and recorded the coding experiment in a report on how to use the remote control, how to use the two apps previously mentioned, and students recorded every step they made when assembling the mBot. Their report had four different modules, each module had different tasks that included assembly, controlling the mBot using the remote control, using a smart phone, and the last module was a coding assignment. After the completion of this experiment students gained knowledge on how a robot works using a remote control and the use of programing. The programing section of the experiment gave the students basic knowledge on how to program a device.

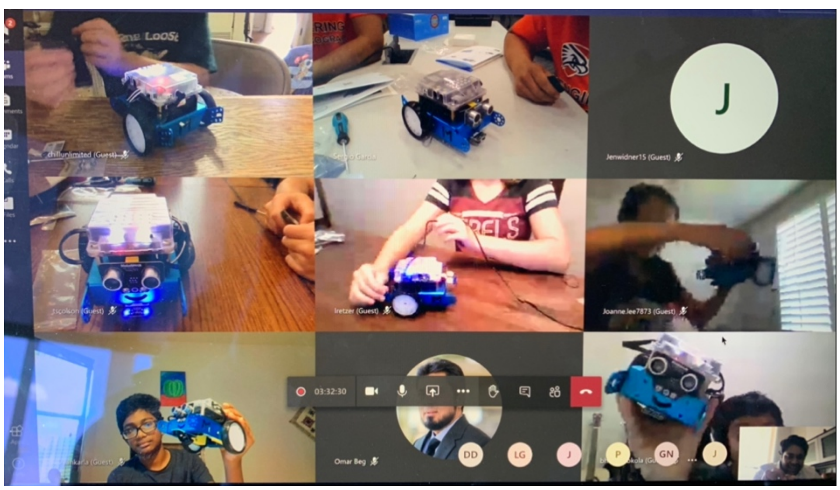


Figure 2: Students displaying their assembled robot model to the instructor. All students were able to successfully complete assembly of the robot and perform initial test runs.

Moment of inertia experiment: Demonstration of moment of inertia

Moment of inertia project involves the effect of mass distribution for rotating solids around an axis. The materials used in this project were, wood block, hollow cylinder, solid cylinder, 2 nails and a timer. An introduction to mechanical engineering was first provided to the students. After the presentation, the faculty posed questions from the presentation to analyze the level of student involvement. Later, the hollow and solid cylinders were pinned to the wood block using nails. The cylinders were tilted and then left to freely oscillate 3 times. The time it took each cylinder to complete 3 oscillations was recorded and then divided by the number of oscillations to get the time for each oscillation. This value of time (T) was plugged into the equation $I_0=T^2mgr/4(pi)^2$. The density of the cylinder was given, and the volume was calculated using $4(pi)r^3/3$, where r was easily found by using a ruler to measure the radius of the disk. After plugging the values into the equation, the moment of inertia was calculated for each disk. All final reports were later emailed to the faculty for feedback.

Stirling Engine experiment: Demonstration of working principle of Stirling engine

Stirling engine works on the principle of expansion and contraction of gases due to heat. This project was demonstrated using a cup of hot water, and Stirling engine. The project description involved measurements, energy in nature and various energy conversion technologies. To demonstrate the heat energy, water was heated in a kettle or in a microwave oven and then the hot water was placed in a mug or cup which was then placed beneath the Stirling engine. After a couple of seconds, the wheel on the Stirling engine began to rotate due to the temperature difference. For those whose wheels did not rotate they were told to give the wheel a slight push for it to gain a little momentum and if the wheel still did not rotate, students were asked to place ice block on top of the wheel to increase the temperature difference. Figure 3 shows students operating using Stirling engine by haven a hot cup of water beneath it. In top center, faculty member shows the students the operation procedure.

Figure 3: Students displaying their working Stirling engine models to the instructor. All students were able to successfully demonstrate working principle of Stirling engine.

3. Strategy for Assessment: Measuring outcomes

Effectiveness was measured by monitoring the progress of each student during assembly and during the project testing. If a student is lagging behind, the undergraduate student assistant identified that student and immediately assisted the student by finding out the specifics. During the 30-minute recess in between the session, the students that were lagging behind the class by few steps were given the required guidance by the faculty and student assistant to catch up with the rest of the session. Completion of project assembly successfully was measured by a distinguishing factor such as an LED being turned ON upon rotation of the turbine blades or movement of the robot using a remote control. After every 5 steps into the project the students were asked to turn on their cameras to help faculty to monitor the status of the assembly or execution. Thereby, providing an opportunity to identify if all students are at the same level and ensuring that no one is left behind.

At the end of each project, students were given a sample report with some missing data, which the students were required to fill and email to the concerned faculty. The faculty reviewed the reports and provided feedback to the students. The reports provided information pertaining to the level of participation, involvement and completion of the project. The class average for middle school and high school students were 85% and 87% respectively proving that the projects were successfully implemented in the virtual instruction based hands-on project hybrid model.

Interaction: As future engineers, it is an important skill to communicate and collaborate. During project sessions, at every possible situation, students were posed some questions as to how they would solve a hurdle if they were handling that problem. This gave them an opportunity to express and the faculty mentors made 3 student teams to interact in the chat option to discuss and come up with a solution as a team. In most situations, the answer as a team was more effective than individual effort. This was duly highlighted and encouraged that in real world, students must not shy away from asking questions or having effective collaborations to solve problems in a better way.

It was interesting to notice that students in the session started to interact with one another after some time into the project and started helping each another if a student is noticed to have a problem at one juncture. High school students were more proactive and almost all students had the capability to navigate through the MS Teams meeting video and chat options.

4. Challenges faced

Lack of time to reach out to wider community. COVID-19 pandemic caused great concern and confusion in academic circles and required quick changes in the mode of instruction shifting to online, making it hard to effectively implement and properly measure student learning. In addition to regular classroom instruction converting to virtual mode of instruction, it did not give us enough time to prepare and incorporate hands-on projects in virtual instruction-based summer camp. Hence, lack of time bought confusion in the approach to the summer camp. By the time a plan was formed, there was barely enough time to reach out to wider community. This camp had a total of 23 students. Had there been more time, the enrollment would have been at least thrice the turnout.

No existing models or available framework in literature: The organizers of the summer camp tried to search for existing models and past experiences in organizing virtually instructed hands-on projects-based summer camp, but the authors could not find any detailed literature or past implementations as proposed in this paper. With the available funding from industry-university partnership, authors in this paper came up with this idea and were able to effectively implement at a highly subsidized rate to the students. Hence, authors took interest to present and record the experience and execution framework for future use.

Technical issues on students' end are beyond control: Any internet connection issues or personal equipment issues at the students' end are beyond control. Hence, each session was recorded and made available to students for them to watch later and perform the project. The email addresses of parents/students using which the students will login to the meeting must be added a week before the camp commencement. At least a couple of trial runs with students in the meeting session to check feedback, connection and audio/video issues a couple of days prior to the camp commencement is recommended in order to ensure proper functionality and remove any discrepancies during the actual session.

Issues with project kits: Due to human error, there can be a chance to misplace a specific piece in the project kits, or there can be instances where students may operate improperly and damage a part, resulting in halting the entire project for that student's project. In that case, that student's only option is to observe how the rest of the other students are performing. This happened once in the project session, where a student forcefully tried to fit a part in a wrong manner, thereby damaging the chance to complete his project. Hence, there is always a risk of damaging the project materials if improperly handled. Hence, it is advised to repeatedly specify and enforce extra caution during assembly.

It is hard to keep students motivated through the entire virtual session: Middle school and high school students need to be constantly challenged and rewarded with good remarks to keep them motivated through the entire session. Too much introduction to theoretical concepts will make them easily lose focus. It is highly encouraged to use as many graphics in the presentation or asking enough question to engage all students in the session.

5. Results

Each student was given a survey and the feedback was duly noted. The following is the recorded feedback.

- *"The camp was very interesting and lots of fun learning. The step by step guidance greatly helped me to stay on track".*
- *"The camp is wonderful. The professors are very helpful in answering questions".*
- *"Engineering is very interesting. I want to learn more".*

Aspects you would like to improve

- *" I prefer face to face sessions instead of virtual".*
- *"I wish there were more team projects".*
- *"Everything would have been even better if this was face to face. Other than that, I had a good time".*

Acknowledgements

XTO Energy and College of Engineering at University of Texas Permian Basin funded this summer camp.

Conclusion

Total student attendees for the 2020 Summer Camp was 23 students. Attendees consisted of 11 High school students, and 12 Middle school students. Most project kits and material items were ordered from amazon and delivered to the UTPB Engineering building. For one project, raw materials were purchased and machined at the Engineering building. All experiment kits and needed material items were organized and placed in square cardboard boxes in order to ship, as well as allow easy transition for parents to pick up physically from the campus. A total of 4 faculty members and 4 student assistants actively involved in designing project steps. A thorough step-by-step instruction was developed for each project and made it available to the camp coordinator for successful implementation. It is advisable to have at least one faculty member assigned to each project for a session comprising of 50 students. Overall, this was the first time that a hybrid model was implemented at our university to perform hands-on projects through virtual mode of instruction. This model was effectively incorporated and outperformed our expectations. The challenges faced by the authors in this type of execution were clearly written in this paper. The designed projects were completed within the stipulated time, thereby giving students ample time to make reports.

It is highly recommended to perform trial runs to ensure the experiments do not exceed beyond the time limit.