# Removing barriers and preparing students for STEM majors through partnerships with local public schools

**Don Wittrock, University of Cincinnati CEAS Office of Inclusive Excellence and Community Engagement**

Don has over 25 years in working with science and community based youth programs. His education background is in Human Development and Family Studies at Colorado State University and a Master's from Miami University. My focus has been synthesizing research to put into practice for programs which focus on increasing the diversity in STEM for young people.

**Dr. Whitney Gaskins, University of Cincinnati**

Dr. Gaskins is the Assistant Dean of Inclusive Excellence and Community Engagement in the University of Cincinnati College of Engineering and Applied Science, the only African-American female currently teaching in the faculty of the College of Engineering. Whitney earned her Bachelor of Science in Biomedical Engineering, her Masters of Business Administration in Quantitative Analysis and her Doctorate of Philosophy in Biomedical Engineering/Engineering Education. In her role as Assistant Dean, Dr. Gaskins has revamped the summer bridge program to increase student support and retention as well as developed and strengthened partnerships in with local area school districts to aid in the high school to college pathway. In 2009, she founded The Gaskins Foundation, a non-profit organization, whose mission is to educate and empower the African American community. Her foundation recently launched the Cincinnati STEM-ulates year round K-12 program, which is a free of charge program that will introduce more students to Math and Science. She was named the 2017 K12 Champion by the National Association of Multicultural Engineering Program Advocates (NAMEPA).

**Ms. Jutshi Agarwal, University of Cincinnati**

I am a PhD candidate in Aerospace Engineering with research objectives focussed on Engineering Education. Currently, I am the Lead Graduate Teaching Assistant for the first year engineering design course with an enrollment of 1300 students across all engineering majors.

**Mr. Gibin Raju, University of Cincinnati**

Gibin Raju is an Adjunct Faculty with the Transition and Access Program at the University of Cincinnati. He is also a graduate student in Educational Studies with the College of Education, Criminal Justice, and Human Services at the University of Cincinnati. His research interests are focused on ID/ODD, stem accessibility issues, workforce development, STEM education, and education practices.

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## Abstract

Middle school years are always a critical time frame for cultivating students' interest and preparedness for Science, Technology, Engineering, and Mathematics (STEM) careers. However, not every student is provided with opportunities to engage, learn and achieve in STEM subject areas. Engineering topics are further excluded from curricula when the focus is on Science and Mathematics. The Public-School District involved in this study has 35,000 students and 75% of them are from under-represented minority communities. Over the years, the schools offering a high school Algebra-based Physics course decreased as a larger number of schools faced staffing, scheduling, or other issues. The College of Engineering and Applied Science requires applicants to have completed high school Physics and Chemistry courses for admission into college level engineering degrees. One of the reasons for a low number of local students entering STEM majors at the university was found to be the lack of access to these courses among students in high schools. This study presents a partnership between a college of engineering and the local school district faced with low numbers of students enrolling in STEM majors, who sought to change the trend. Our partnership began planning in 2019 and started our first cohort the summer of 2020. The Office of Inclusive Excellence and Community Engagement offered a physics course online during the summer of 2020. Results from the feedback survey were collected to evaluate the effectiveness of lessons offered in the course and may potentially help increase students' STEM-related content knowledge and skills.


## Introduction

Many students are underprepared for college and a career, lacking postsecondary degrees or the required skills to enter the STEM workforce [1]. Students from historically underrepresented groups are least likely to have key transition knowledge and skills to go on to college and careers [2]. In some regions of the U.S., a postsecondary degree will be required for more than half of future jobs [1]. If current trends continue, by 2025, there will be a 16 million college-educated worker shortage in the U.S. [3]. Several studies [4], [5], [6] have focused on college and career readiness among underrepresented populations which include minority, low-income, and first-generation students who attend urban schools. To prepare secondary students for college and careers, students in urban schools must receive adequate training. It is imperative to narrow the disparity in STEM degree attainment for underrepresented students in order to produce a ***21st century workforce*** to address the needs of a rapidly evolving population. Educational tools and policies can help ensure more high school graduates are college and career ready, especially members of historically underrepresented groups.

When reviewing reasons why local high school students, even those from STEM high schools, do not matriculate into STEM programs. It was revealed that many applicants lack the prerequisite courses to gain admission. For a student to meet the admission standards, they must have passed Chemistry and Physics courses, respectively. Unfortunately, due to a shortage of teachers certified to teach both subjects high schools do not have an option to offer the courses. Understanding this disparity, the Office of Inclusive Excellence and Community Engagement developed a program to allow students to obtain the necessary credit by attending a summer program. This initiative was in line with the goal of the Office of Inclusive Excellence and Community Engagement to increase the number of Under-Represented Minorities (URM) in the College of Engineering and Applied Science at the University of Cincinnati. Intentionally working with our diverse school district to provide this physics course will begin to develop a pipeline for the school and STEM Fields. Typically, students who applied to engineering or other STEM departments were rejected or directed to a secondary or exploratory program, due to missing physics or chemistry courses. This would lengthen the time and financial burden of students for their college career. It was believed many would then choose another major entirely as a result. Taking this course instead can begin to open a new pathway for students to consider and be eligible for admission while providing greater career exploration. Students can now foresee a career in STEM fields if they so choose.

**University Initiative**

The University of Cincinnati has a new strategic direction, which it seeks to create an impact on the community and the future through inclusive excellence. This strategic direction highlights the power in diversity and people of different backgrounds sparking innovation [7]. But to strengthen the pipeline of future college graduates and professionals, access must begin much early on. So, the University of Cincinnati seeks to strengthen the access, preparation, and pathway programs for local K-12 students through the "CPS Strong" initiative. Multiple undertakings were part of this initiative like collaboration of the Honors program and college graduates teaching in Cincinnati Public Schools (CPS) to increase the number of University of Cincinnati graduates from CPS. Under this initiative, the College of Engineering and Applied Science, in collaboration with local companies, and after much research on the barriers, decided to offer an Algebra based Physics course for local students.

**Credit Flexibility**

During the planning process, a large amount of focus was given to creating a college credit plus course where students would receive college credit while in high school. In order for this to happen, however, the students would need to meet college level math requirements and the course would have to be a college level course. For college application purposes, students needed an algebra-based physics course, where they could get a background, develop interest, and build confidence with the material versus a college level course which may or may not count for credit at the college they choose. It was imperative we focused on providing the access and opportunity for the local students to have equal educational resources including, the science courses, so they can be considered on a more equal basis for admission to STEM majors in colleges, and the University of Cincinnati.

Utilizing the Ohio Department of Education Credit Flexibility [8] option where students can engage in outside courses for mastery, our two organizations were able to begin to remove the barrier. This course took place over the summer, interfering with many plans' students may have such as work and family obligations. With Credit Flexibility, students are not held to a specific hour total or seat time. Instead, students are assessed on demonstrated skill and level of performance. We designed our course to cover the Ohio Department of Education's Physics standards and created an interactive, project-based learning course to enable students to experience and master the use of physics in everyday life. Learning was assessed by a pre/post evaluation of content knowledge, testing on topics, daily assignments, and a final presentation on "application of physics in real life."

**Community Partnerships**

Local companies have also expressed the dearth of professionals in STEM fields and seek to diversify their workforce [9, 10]. Schaefer, a structural engineering firm that has assisted in several building projects at the University of Cincinnati, cites how the supply of structural engineers is not meeting their demand [9]. Another local firm, Messer Construction Co. that has taken several construction-management contracts with the university also partnered with Schaefer to assist in the CPS Strong Initiative. They both agreed that change must start at the beginning and were interested in investing in the STEM pipeline from K-12. Once aware of the barriers K-12 students face in applying to colleges of engineering, they were more than willing to partner with the University and the course was able to secure funding from these local companies for 5 years 2020-2025. The companies not only fund the course but also help in developing industry-relevant projects and give access to their successful professionals. Students are able to talk to current STEM professionals and learn the importance of STEM courses in future careers.

**Participants**

Participants for the course were recruited from the Cincinnati Public School (CPS) district. The district college readiness personnel and science curriculum head connected staff from both organizations. Recruitment began in February 2020 by sending information to science teachers, counselors, and community resource coordinators. In this school district it was identified that these 3 roles would have the best insight and contact with the target population, rising 10$^{th}$ - 12$^{th}$ graders who have completed Algebra. As the COVID-19 pandemic began, all recruitment and contact were strictly over phone, email, and online methods. This did prove to be a challenge and we had several "School Champions" emerge. These "School Champions" believed in the program and wanted their students to have access to this course. Participants then completed basic information for registration purposes and were contacted by program staff. For Cohort 1 the program enrolled 11 participants from 3 schools. Of these 11 participants, 6 are women, and 7 are under-represented minorities (3 Hispanic or Latino, 5 Black or African American), and comprised of 6 Sophomores, 4 Juniors, and 1 Senior. Upon application 7 listed career interests in STEM and self-reported grade point averages of 2.75-3.6.

**Course Delivery**

As details were being finalized, the course was modified to accommodate for circumstances arising due to the COVID -19 pandemic. A new virtual format was developed to engage high school students instead of the original in person design. This new virtual format presented a unique set of challenges to overcome such as the interactive labs which then had to be adapted for simple household items all students would find while in quarantine. Our research plan will include evaluation of student knowledge, effectiveness of content delivery, and interest in Science, Math, Engineering, and Technology. Upon enrollment, participants initially took an assessment of basic understanding of physics principals such as kinematics, forces, and waves which will be compared to a similar post-test as a measure of improvement. Students' end of course presentations, which are a collection of examples of the course topics represented in real life, will also be analyzed for understanding and application of course material. Interest in STEM fields will be assessed through a questionnaire about how the course may have impacted their choice of potential career fields. These items will guide us in future iterations of the course and expansion of our efforts into Chemistry and a combined Physics/Calculus course in the future.

To implement the online physics course we utilized several platforms, databases, and online tools. Utilizing the below tools our online environment resembled that which we all experience today with Individual picture tiles, shared screens, videos and more. The following tools allowed us to effectively organize, engage, and allow for interactive instruction:

*a) Canvas* – Canvas is a widely used learning community platform. We setup each student an affiliate account and enrolled them in the community. This was utilized for assignments, test grades, syllabus and more.

*b) WebEx* – Our University supports WebEx and the meeting function was utilized for synchronous instruction and the parent orientation. During this time, we learned WebEx is difficult to use for Chromebook, phones, and tablets. Not all families and students had access to a laptop or desk top PC where WebEx can be fully utilized. WebEx also utilizes significant bandwidth and students were often unable to view the course without stoppages

*c) Google Meet* - Google platform was significantly better as many students have district assigned Chromebooks which works well with all Google applications. One difficulty is we could only generate the session link each morning and email it to the students. Chat feature and captioning worked very well, and bandwidth usage was much less

*d) Jamboard* – To teach and demonstrate the math and formulas it was difficult without a whiteboard feature. Jamboard enables the entire class or group to collectively add and workout diagrams, solutions and more as if it were paper or a smart board.

- https://edu.google.com/products/jamboard/?modal_active=none

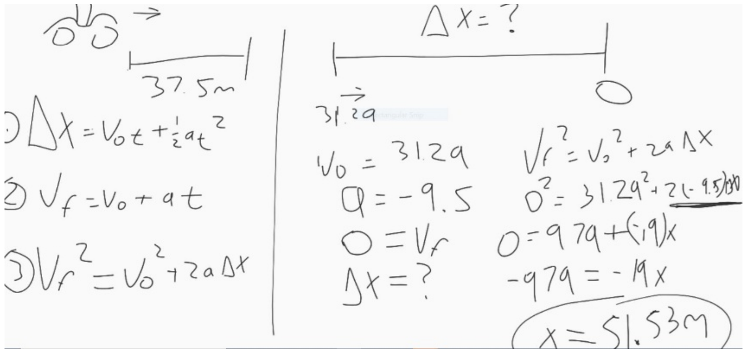



*Figure 1: Jamboard example from our class*

NOTE: For Group work, we created individual Google Meet rooms, and assigned specific jamboards which we could view once the group was back together.

*e) FlipGrid* – Flipgrid is a short educational video making platform. Flipgrid was used for getting to know your videos, and for students to demonstrate physics experiments and demonstrations. Flipgird integrates with canvas and participants could submit an assignment through the platform. Students created videos about newton's laws of motion, getting to know you, and more. This program works on any device and moderators can assign specific video lengths.

- https://info.flipgrid.com/

*f) Physics Simulations* – We used two online physics simulations programs where students could change parameters and test ideas since we could not meet in person.

- https://www.myphysicslab.com/
- https://phet.colorado.edu/en/simulations/filter?subjects=physics&sort=alpha&view=grid

*g) Presentations* – For the final project students provided examples of physics in real life and presented on a chosen unit(s) using Thinglink. This allowed students to choose videos and other examples and integrate them into a presentation with calculations and more.

- https://www.thinglink.com/

**Other Essential elements to our successful course**

Many factors came into play for our success that we will continue to build upon. Beyond our platforms and tools above there were other significant and intentional aspects to this course which made it a success.

- Focus on Mastery versus high stakes test: From the start we focused on our intention for students to Master the concepts. All efforts, projects etc. Would be around the students learning the material and acquiring knowledge of physics. If students struggled staff worked with them to learn the information and students were required to go back to the notes and information to learn from the mistakes. "If you watch the nickels and dimes the dollars will take care of themselves." As we had the students focus on the material the test scores took care of themselves. This difference from other environments encouraged the students to seek mastery and knowledge versus fact memorization

- Engaging Staff: Our staff were screened for their express interest in connecting with students. When students and instructors connect, amazing transformation can happen. We scheduled time for intentional friendship building among students, and staff also participated in the various games or challenges. Appropriate humor was also encouraged. Students found it extremely fun to "Rick Roll" the staff by providing a break video that started as calming beach waves and morphed into "Never Gonna Give you Up" By Rick Astley. Staff also managed to Rick Roll the students back and they were amazed and delighted we did so. This had minimal distraction but allowed everyone to have connection, laughter, and normalcy during that time.

  Also, we had a focus on attendance. Many young people struggle with timeliness and attendance when working/learning from home. If a student was not logged in within 10 minutes of start time, parents and the student were notified via text. Shortly thereafter the student would log in. The text was focused on their wellness and safety, making sure they were okay, and instructing them to reach out to let us know. We learned through the duration of the course that some of the students would be late as they were watching and caring for siblings as well as taking our course and this meant a delay at times. Near the end students started to be pro-active in letting us know if there was any delay.

- Hands on and Project based focus: Each lesson we did our best to make things hands on, interactive, inquiry based, and project based. While difficult in an online environment, we just had to creatively think of ways students could utilize their world in the activities. After all, Physics is life, and most incidents can be described through physics. Below is a list of in home and online experiment examples.
  - Kinematic equations – students would cross the distance of their learning location and time it and measure the displacement to make calculations.
  - Projectile motion – staff setup catapult and horizontal and vertical measuring tools in an open garage. With the students watching the staff would launch the catapult. Students would mark the location on the monitor of the impact, and staff would take measurements. This was used to improve accuracy and more through the calculations
  - Similar experiments had staff launch water rockets and students would time the flight with descriptions of start and stop by the staff members.
  - Students would also create pendulums with shoelaces, mobiles with hangers and more to see physics in real life
  - Electricity: Staff member placed "Snap Circuits" in front of the camera and utilizing inquiry techniques the class instructed him on how to build the circuit for various challenges and wiring methods.

Our constant focus was to engage the learner. Even in a virtual environment, students can time, measure and explore how everyday acts can be represented in physics. This made the material relevant and our focus was on the materials and activities that everyone had a home.

## Results

The following figures (Fig 2,3,4) indicates that the overwhelming majority of participants agreed the information was presented in an engaging format with Labs and Interactives helping followed by videos and simulations. This feedback also indicate that materials were engaging and helped students to understand the course.

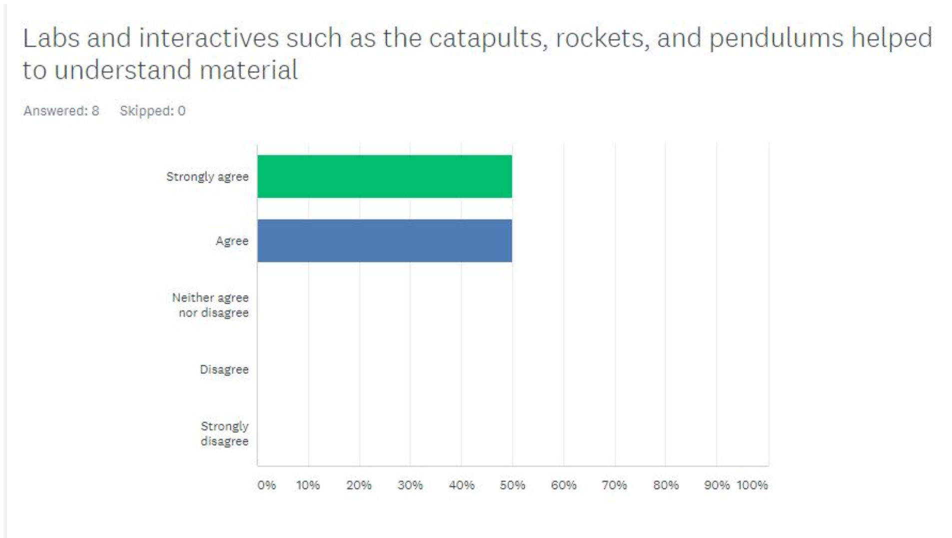



*Figure 2:Feedback Survey Results on Labs and Interactives*

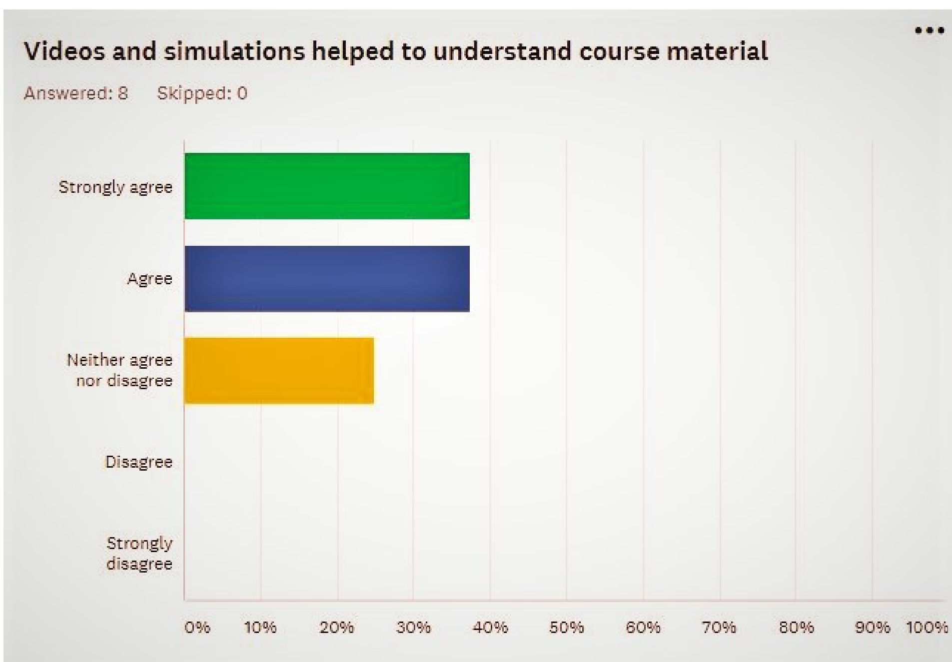



*Figure 3: Feedback Survey Results on understanding the course material using videos and simulation*

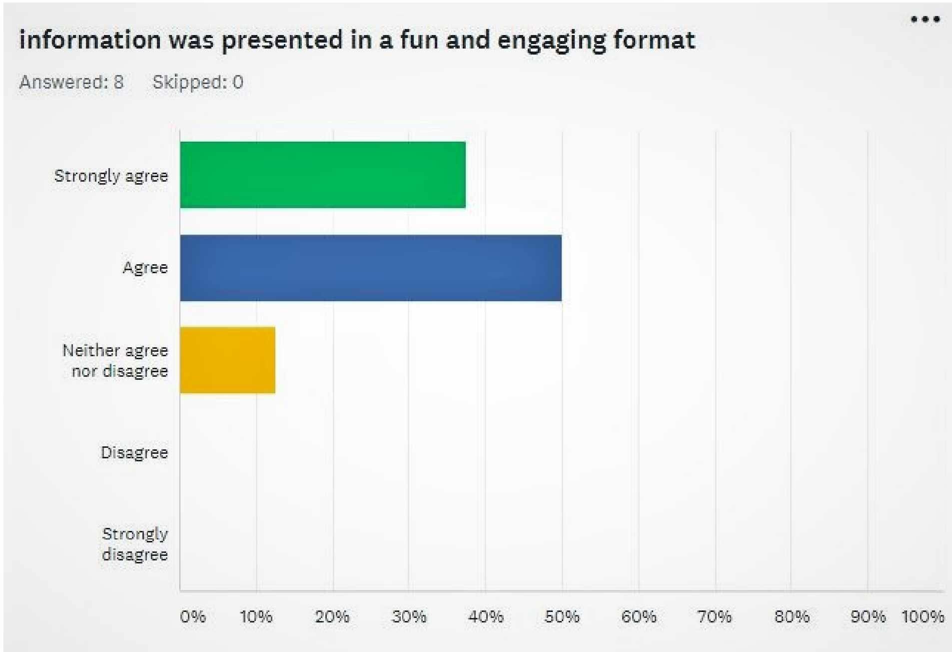
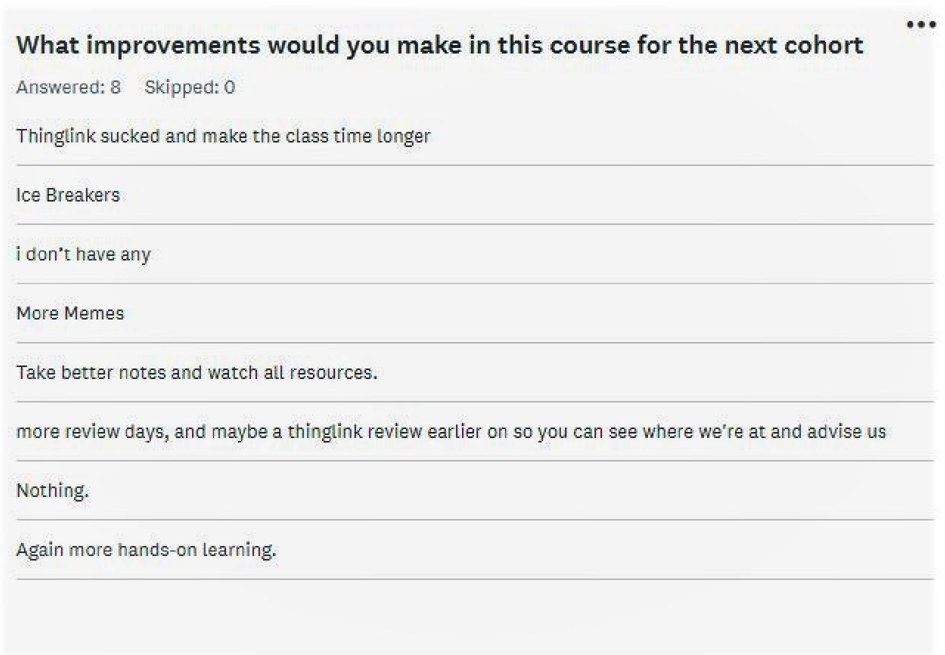



*Figure 4: Feedback Survey Results on engaging student using presented information*

Under the improvement section of the feedback survey, students reported that they wanted more hands-on learning which was a theme from course implementation. The recommendations on the Thinglink had mixed reviews as a presentation platform. During the course planning, we did not schedule review days and it was indicated in student feedback.



**What improvements would you make in this course for the next cohort**

Answered: 8 Skipped: 0

Thinglink sucked and make the class time longer

Ice Breakers

i don't have any

More Memes

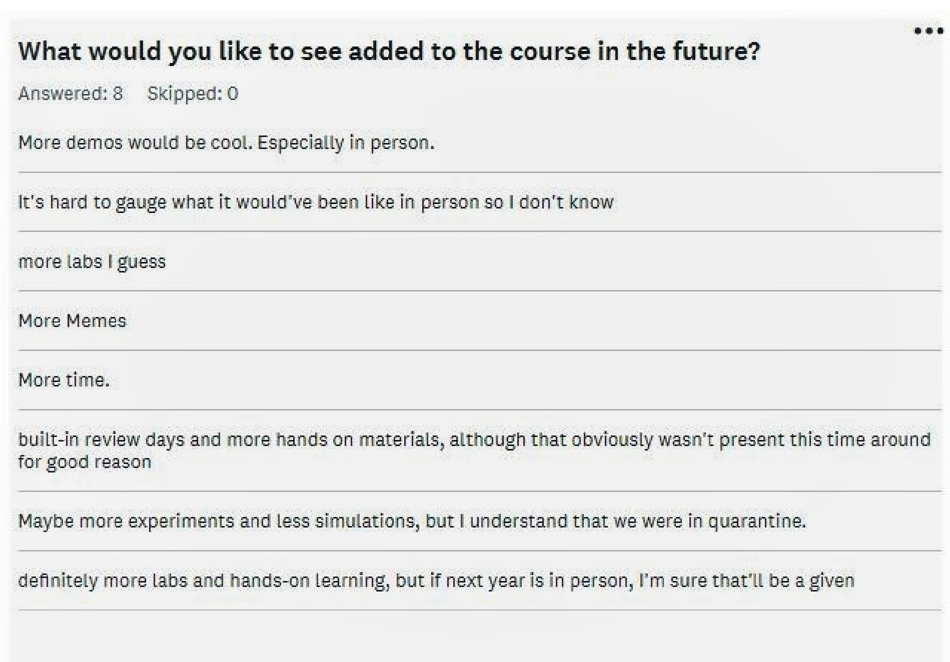
Take better notes and watch all resources.

more review days, and maybe a thinglink review earlier on so you can see where we're at and advise us

Nothing.

Again more hands-on learning.

*Figure 5: Feedback Survey Results on improvements for the course*



**What would you like to see added to the course in the future?**

Answered: 8 Skipped: 0

More demos would be cool. Especially in person.

It's hard to gauge what it would've been like in person so I don't know

more labs I guess

More Memes

More time.

built-in review days and more hands on materials, although that obviously wasn't present this time around for good reason

Maybe more experiments and less simulations, but I understand that we were in quarantine.

definitely more labs and hands-on learning, but if next year is in person, I'm sure that'll be a given

*Figure 6: Feedback Survey Results on what additional information needs to be added*

During the course, students asked if they could meet for demonstrations or labs. However, due to COVID-19 as restrictions, this was not feasible. Feedback surveys reflected the desire to meet in person with hands-on learning using labs and interactives. This will be integrated into future courses.

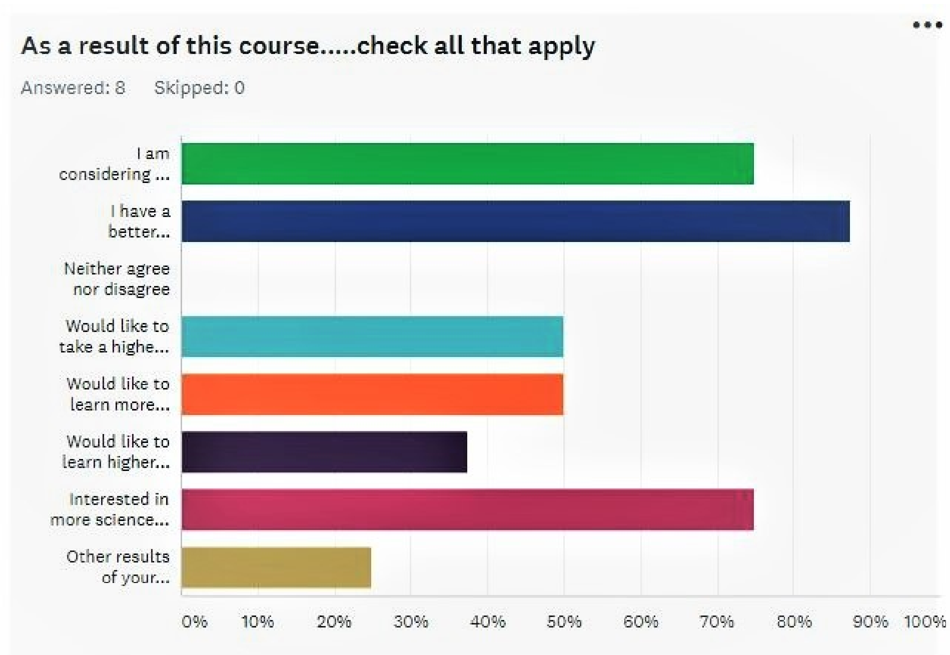



*Figure 7: Feedback Survey Results on the course success*

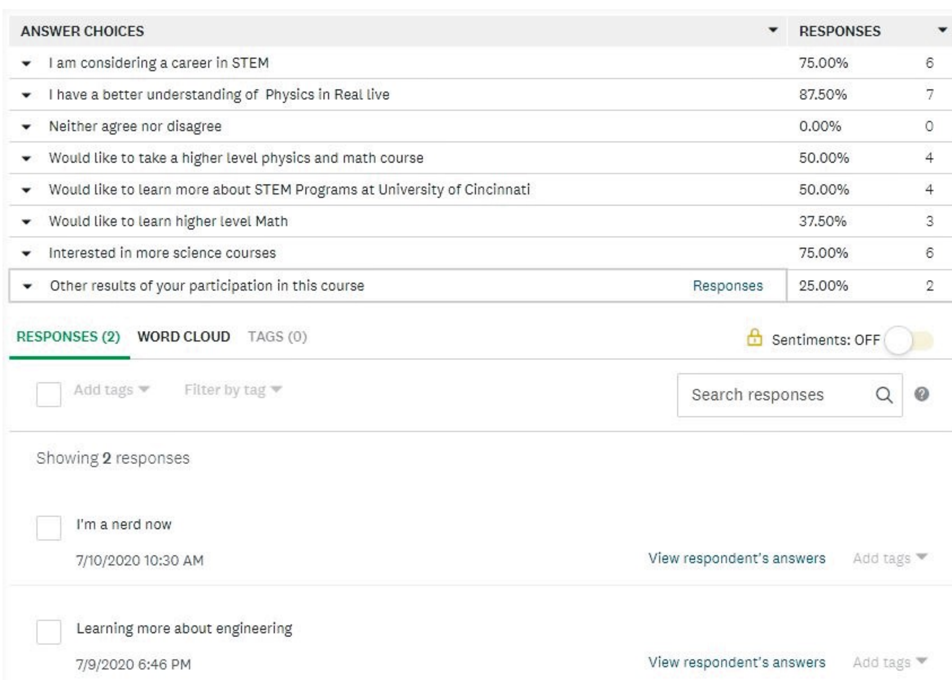



*Figure 8: Feedback Survey Results - Answer choices from "As the results of this course "*

As a result of this course, students reflected that they have had a better understanding of physics in real life, followed by consideration of a career in STEM. They also expressed increased interest in taking higher-level Physics and Math courses as well as learning more about the University of Cincinnati. We received two write in responses which consisted of "I'm a nerd now" and "Learning more about engineering."

## Discussion and Future Work

The abovementioned Physics course was intended to meet a foremost need of providing access to high-quality integrated STEM experiences to students who might have otherwise lost interest and opportunity to pursue a STEM career. Pre- and post-test results suggest that participating students' content knowledge showed improvement, and their applicable skills were evidently better, based on their project submissions. This is particularly important given the vulnerability of the underrepresented minority student representation in the STEM workforce. By providing access to this course, we were able to prepare students with engineering-integrated STEM activities to which students normally would not be exposed. This curriculum was aimed to increase content knowledge that would help students succeed academically as well as enhance student interest in STEM careers by including application-level tasks. These findings can provide a template for effective outreach programs in terms of balancing student engagement and learning.

While the students appreciated all the efforts in demonstrations and interactives, many responded they would like to have more and even in person time (Pandemic permitting). During the course in June/July students were still adjusting to the changing conditions and quarantine guidelines and frequently expressed an interest to hold class in person or discussed about what things would be like for the next cohort. Some expressed interest in an enrolling in a second in-person class sequence. Overall, the students also indicated interest in are more labs, more interactive activities, and built-in review days. Over the summer and considering the age of our target population, it is imperative to continue making this physics course a hands-on experience where students use projects to relate course content to real life. Key lessons from our initial cohort are as follows:

- Hands-on activities are a must, even if it is the instructor doing them at their home
- Have video cameras and other aids besides a regular computer camera
- Developing a Physics Course Concept inventory will help us determine the accurate set of concepts and understand misconceptions among students. The implemented inventory would accommodate all the components yet still be manageable for student's time
- Staff who can connect with students, and develop a professional relationship around the content is of upmost importance
- Providing students enough time in the online environment to motivate them to attend each day
- Track and outline techniques and activities which allow connection so these can be replicated.

Future plans include increasing the size of the class to 20-25 students and adding a math component where the students would learn and practice the corresponding math concepts needed for the physics course. We also plan to expand our programming other schools that have indicated an inability to offer Chemistry or other Math courses, especially during the COVID-19 pandemic. We are creating options to alleviate these course deficits as they arise and our discussions with the school districts continue.

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