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Bioengineering Experience for High School Science Teachers

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Jennifer Olson is a clinical assistant professor in the College of Education at University of Illinois at Chicago. She coordinates the Secondary Education program and teaches curriculum, instruction, & assessment courses to undergraduate and graduate secondary education students. Jennifer's research focus on urban high school reform is informed by nine years of teaching in Chicago Public Schools, giving her an informed perspective of how policy moves from theory to practice. Dr. Olson's current research interests include urban teacher preparation, teacher professional development and student voice. Her most recent publication in Journal of Urban Learning, Teaching and Research Becoming A Culturally Responsive Teacher: The Impact Of Clinical Experiences In Urban Schools focuses on elementary and secondary teacher candidates' perspectives of how their clinical experiences influence their preparedness in becoming effective culturally responsive educators.

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Bioengineering Experience for High School Science Teachers

Abstract

A meaningful Summer Research Experience in a bioengineering laboratory at a major research university can enhance the knowledge of a high school pre-engineering or science teacher, making it possible to more effectively convey the nature of the scientific process in bioengineering to his or her students. In combination with guided instruction in Common Core State Standards and Next Generation Science Standards-aligned curricula design, the laboratory research is more effectively translated and applied in high school science classrooms. The Bioengineering Department at the University of Illinois at Chicago (UIC) is ideally positioned to implement such a combined experience for local high school teachers, which in turn will have a dramatic impact on one of the most diverse group of young learners in the country, who are the next generation of bioengineers. This program includes a six-week intensive on-campus summer research experience in a bioengineering laboratory under the guidance of one of seven research-active core bioengineering faculty mentors. In partnership with faculty from the UIC College of Education, recognized leaders in curriculum design and teaching in secondary education, and in particular, teaching of secondary science in urban schools, this program also provides guided instruction to help the teacher-participants incorporate their research experience and learning into their classroom. This state adopted the Common Core State Standards (CCSS) in 2010 and the Next Generation Science Standards in 2014, which outline the knowledge and skills students are expected to learn throughout their K-12 education. Because of the rapid introduction, adoption, and implementation of the CCSS, many districts and teachers have found themselves searching for quality curriculum aligned to the CCSS; this presents a golden opportunity to make a major impact. But, as summer research experience programs aim to build long-term collaborative partnerships with STEM teachers by involving them in research and introducing them to the most current developments in engineering and science, it is also critical to provide them guidance on how to translate their experience to their own classrooms. Thus, in addition to bioengineering laboratory research opportunities in diverse areas including biomechanics, rehabilitation engineering, bionanomaterials and biomedical imaging, the first year of the Bioengineering Experience for Science Teachers (BEST) Program provided in-depth participant-tailored curricular mentoring via weekly workshops that focused on principles of effective planning, instruction, and assessment which will be directly connected to teachers' classroom curriculum. In addition to exposure to research in bioengineering labs, City Public High School teachers from diverse schools across the district also translated their experience into curriculum unit lesson plans being implemented the following academic year.

1. Introduction

It has been well established that there is a shortage of STEM professionals [1]. While there are a number of approaches to improving engineering education in the classroom [2], the majority primarily focus on the educating the students. Programs that enhance instructor knowledge of STEM fields translates into greater interest in these fields among their students [3]. As summer research experience programs aim to build long-term collaborative partnerships with STEM teachers, it is also critical to support the translation of their experience to their own classrooms. This summer research experience offers teacher participants the opportunity to be immersed in both content and pedagogy as faculty in the College of Engineering and College of Education collaborate to enhance the skills of Chicago Public School (CPS) science teachers and enable them to more effectively communicate the nature of the scientific process in bioengineering to their students and enhance overall science literacy. With the shift to national standards and accountability in the education policy landscape, teachers have found themselves at the center of education reform efforts as they are charged with implementing new standards, creating curriculum, and assessing students. With these ambitious reform efforts, it has become increasingly important that teachers be immersed not only in their content, but also in the pedagogy of effective classroom planning, instruction, and assessment.

The UIC Colleges of Engineering and Education collaborated to enhance the knowledge base and skillset of CPS science teachers related to teaching bioengineering to their students. The summer research experience provides an opportunity for pre-engineering and science teachers to spend time in bioengineering research labs and use the experience to create a curriculum for use in their own classrooms. The six-week program matches teachers to a laboratory under the guidance of one of thirteen research-active core bioengineering faculty mentors. These lab opportunities are in diverse areas that include 3D printing laboratory equipment, tissue engineering, biomedical imaging, brain activity monitoring, computer simulation of proteins, rehabilitation engineering, bioacoustics, biomaterials, and mechanics of the pulmonary system. In partnership with faculty who are recognized experts in curriculum design for secondary education, participant-tailored curricular mentoring in weekly workshops focus on principles of effective planning, instruction, and assessment to be directly connected to teachers' classroom curriculum.

Recent adoption of Next Generation Science Standards (NGSS) requires complex curriculum planning and is a big shift in thinking from previous standards. While states have adopted the NGSS, it is up to districts, schools, & teachers to develop new curriculum aligned to the new standards. Unfortunately, few teachers have the opportunity to develop their content knowledge and pedagogical skills in ways that translate into classroom practice. This summer research experience delivers both in-depth content and pedagogy to teacher participants so they can make meaningful connections to their classroom professional practice.

Having teachers participate in research programs has been shown to improve student performance in science [4]. One shortcoming in similar existing programs is the lack of formal instruction regarding the enhancement of high school science curricula following participation in the summer experience. This program seeks to address this gap by partnering with faculty in the College of Education who have expertise in curriculum design and teaching in secondary education, and in particular, teaching of secondary science in urban schools.

2. Program Structure

Announcement of the program, descriptions of the available project focus areas, and application material are available online at the UIC Bioengineering Summer Research Experience website in late winter. The BEST program collaborated with Jennifer Sarna, High School Science Specialist for Chicago Public Schools, to communicate this opportunity throughout the school district. As part of the application process, interested teachers rank which laboratories and projects most aligned with their interests and were matched accordingly. These research opportunities include microcontrollers, tissue engineering, MRI measurement, neuroscience, protein modeling, robotics, pulmonary acoustics, nanomedicine, cardiac function, and retinal imaging. Of twenty three applicants, eight were selected based on their experience, diversity, and schools at which they teach. Once accepted, BEST teacher fellows and UIC bioengineering faculty refined the research plan to tailor it to teacher's individual interests and classes they teach.

Before the program began, participants attend an orientation where they are given an overview of the program, are formally assigned to their research labs, and relevant background reading in the research area of choice (book chapters, publications) is provided in preparation for their lab experience. Participants were provided a stipend after successfully completion of the 6 week program and pre/post implementation surveys. (IRB approval was obtained to administer the surveys in advance of the program.) In addition, BEST teacher fellows were provided up to $1,000 of classroom supplies to support implementation of their new curriculum.

The BEST teacher fellows conducted research related to their individual projects from Monday through Thursday of each week in conjunction with their sponsoring faculty and graduate students. Each Friday, participants met together with faculty members from the College of Education, who have expertise in secondary science education and curriculum design, for weekly Curriculum Workshops. These workshops were an opportunity for teacher participants to develop curriculum related to their summer research experience, with guided instruction from faculty who have knowledge in Common Core State Standards, Next Generation Science Standards, and curriculum design. The lesson plans, instructional materials, and assessments were designed to be implemented within their CPS classrooms the following academic year. To facilitate classroom translation, participants were assessed on the development of their curriculum materials by College of Education faculty using rubrics aligned to the CPS Framework for Teaching.

At the conclusion of the summer, an exit survey was administered, soliciting feedback from participants to help identify weaknesses and suggestions for improvements, as well as asking teachers to again answer questions related to current trends in bioengineering. Post curriculum-implementation, teachers were asked to complete a follow-up survey, to report how the curriculum was implemented, what challenges and/or successes were encountered, recommendations for program improvements, and how their participation in the program affected their own classrooms and/or career. In addition, this post-implementation survey polled teachers on their self-reported knowledge in trends in bioengineering research, and solicited feedback to help identify weaknesses and suggestions for program improvements. Self-reported information in a pre-program survey was used as the baseline metric to evaluate changes in knowledge and perception of preparedness before and after program participation.

In addition to the exit surveys, BEST participants also presented their work at the conclusion of the program to each other and representatives of of the CPS central office.

Teacher participants disseminated their curriculum frameworks, instructional materials, and student assessments to science teachers at their schools to increase the number of CPS teachers and students who benefit from the newly designed curriculum materials. They also utilized the BEST Program website to share their prepared curriculum materials.

Faculty Mentor and Laboratory	**Project Description**
Salman Khetani, Ph.D. *Microfabricated Tissue Models (MTM) Laboratory*	Lab and cell culture basics; measure and model the growth of a cell population; micro pattern cells on a tissue culture dish; and assess the effects of drugs on cocultures containing two cell types.
Dieter Klatt, Ph.D. *Motion Sensitive MRI Laboratory*	Manufacture an anisotropic phantom composed of asparagus samples embedded in a tissue mimicking gel and measure using Magnetic Resonance Elastography (MRE) and Diffusion Tensor Imaging (DTI).
Alex Leow, MD, Ph.D.	Examine EEG connectivity as a whole using modern network science (i.e., connectomics).
Jim Patton, Ph.D.	Evaluate effects of robotic force field training on

Rehabilitation Robotics Laboratory	adaptation during motor tasks.
Tom Royston, Ph.D. *Acoustics & Vibrations Laboratory*	Audible Human Project: Investigate pulmonary diseases, with a focus on the airways. Once the medical relevance has been established, create a multiphysics simulation to investigate the acoustic profile of a healthy set of airways versus a diseased set of airways.
Tolou Shokuhfar, Ph.D. *In-Situ Nanomedicine Laboratory*	Observe the Multifunctional Bone Implant fabrication process. Fabricate nanomaterials on an actual dental implant and assist with validating their surfaces using Field Emission Transmission Electron Microscopy (FESEM) and Energy Dispersive Spectroscopy (EDS).
Daniela Valdez-Jasso, Ph.D. *DVJ Laboratory*	Acquire in-vivo blood pressure, volume and flow and take them to the ex-vivo setting to obtain the biomechanical properties at the tissue level of pulmonary arteries.

Table 1. Bioengineering Faculty Mentors and project topics investigated by the BEST participants.

3. Results and Discussion

Participants completed weekly feedback surveys as well as pre-program and post-program surveys. The weekly surveys consisted primarily of open-ended questions that sought to identify specific challenges and successes each participant was experiencing. This enabled the instructors to quickly diagnose obstacles and determine how to rectify the situation. It was also helpful for highlighting positive aspects for the group during the curriculum workshops.

In the weekly surveys, when asked the following question, several common themes emerged.

"*What aspects of the BEST program hindered teacher fellows' opportunity to develop their depth of content knowledge and pedagogical skills?*"

- Difficulty of translating complex research into high school curricula
- Not enough time in the curriculum workshops
- Complexity of the bioengineering research
- Lack of knowledge in computer and software programs

Several of the research laboratories heavily utilize programming for data analysis and these coding languages take time and effort to learn. While the participants were still able to conduct their research, this learning curve was daunting at the early stages of the program.

In the weekly surveys, participants had varied responses to the following question. (Sample responses shown below.)

"*What was the highlight of your lab experience this week?*"

- "Meeting other professors and listening to what they are doing in their labs and actually being able to understand it all."
- "We actually got the robot to work!!!"
- "Seeing the 3D model of the pig lung take shape on the computer screen."
- "Today I 3D designed a part that will help anesthetize the mice. I felt like my CAD skills that I learned at the MSI were valued and were genuinely beneficial to the program."

In addition to the weekly, pre-program, and post-program surveys, participants were given a final opportunity to provide feedback after implementing their new curriculum in their classrooms. From the eight participants that were selected, six participants completed the BEST Program and plan to implement their new curricula in the coming academic year. Of the two who will not implement a bioengineering curriculum, one was unable to participate in the program at all due to unforeseen personal circumstances, and the other took a position in the district's administration prior to the start of the academic year. Of the remaining six BEST teacher fellows, three have implemented their new curricula at the time of writing. This is addressed in detail in the Program Challenges and Modifications section.

In the post-implementation survey, multiple themes emerged. All respondents strongly agreed that their ability to explain the nature of the scientific process had improved. Additionally, all either agreed or strongly agreed that they have been able to transfer their learning in the bioengineering lab into my classroom, their students have a better understanding of bioengineering after participating in their curriculum, their curriculum was an improvement in how concepts of bioengineering were previously taught, their ability to explain bioengineering concepts to students had improved, and and their curriculum planning has improved as a result of their participation in BEST. Where they reported challenges was in the ease and effectiveness of their implementation. Figures 1-4 provide quantitative results on teacher improvement in various skill sets after completing the program.

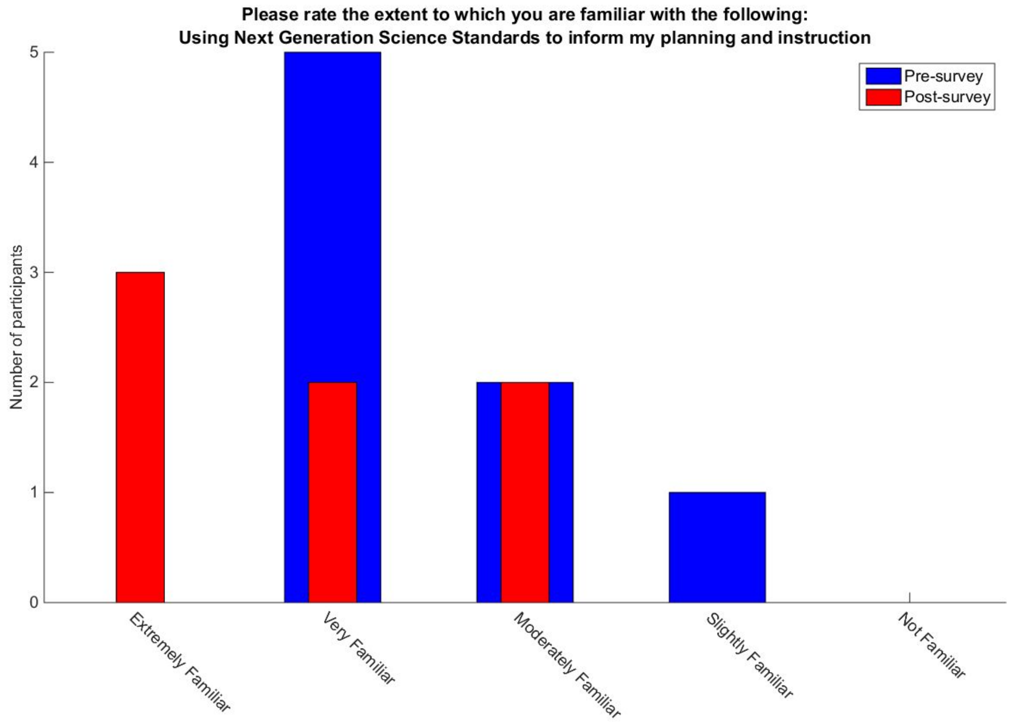

Figure 1. BEST teacher fellow familiarity of NGSS for their lesson plans increased after completing the program.

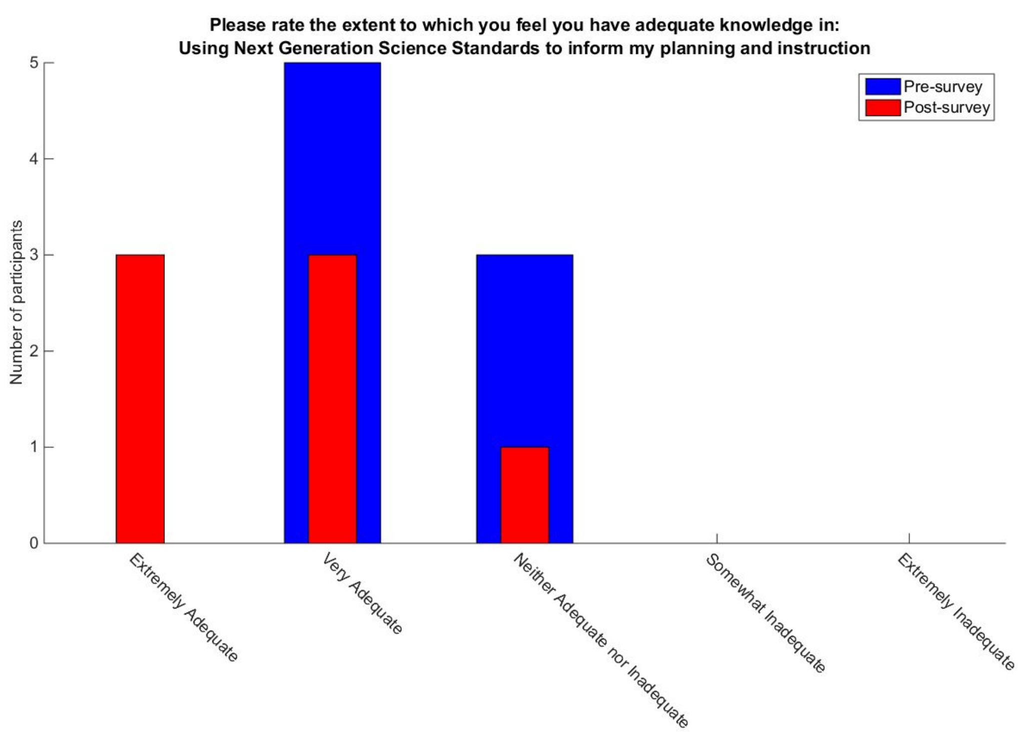

Figure 2. BEST teacher fellow reported that their knowledge in using NGSS for their lesson plans increased after completing the program.

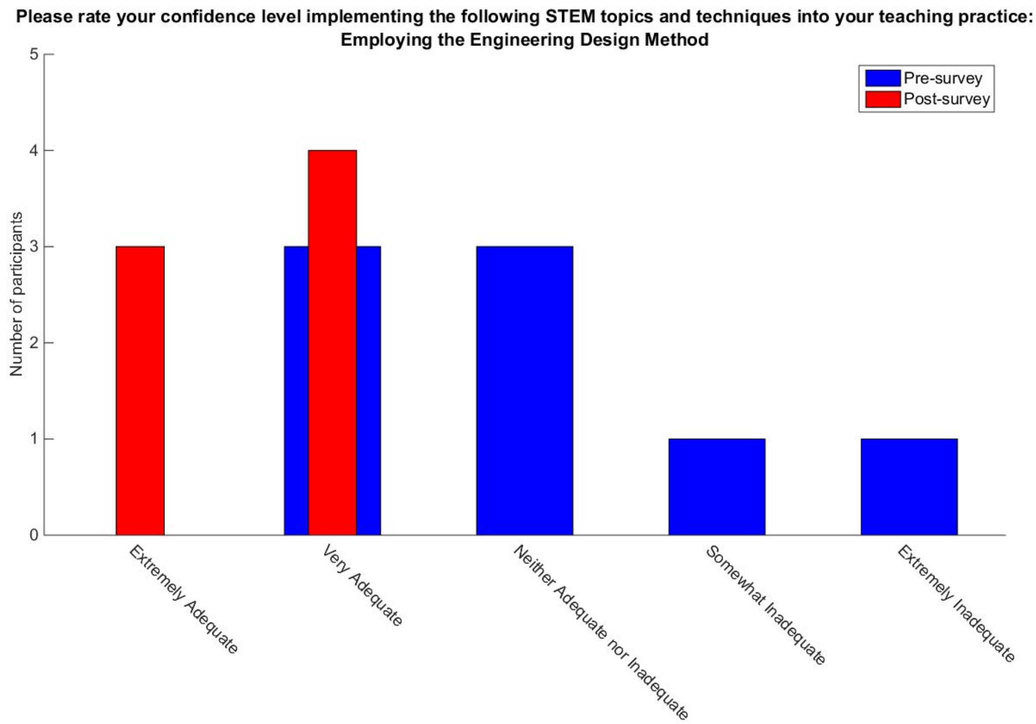

Figure 3. BEST teacher fellows confidence in employing the engineering design method increased after completing the program.

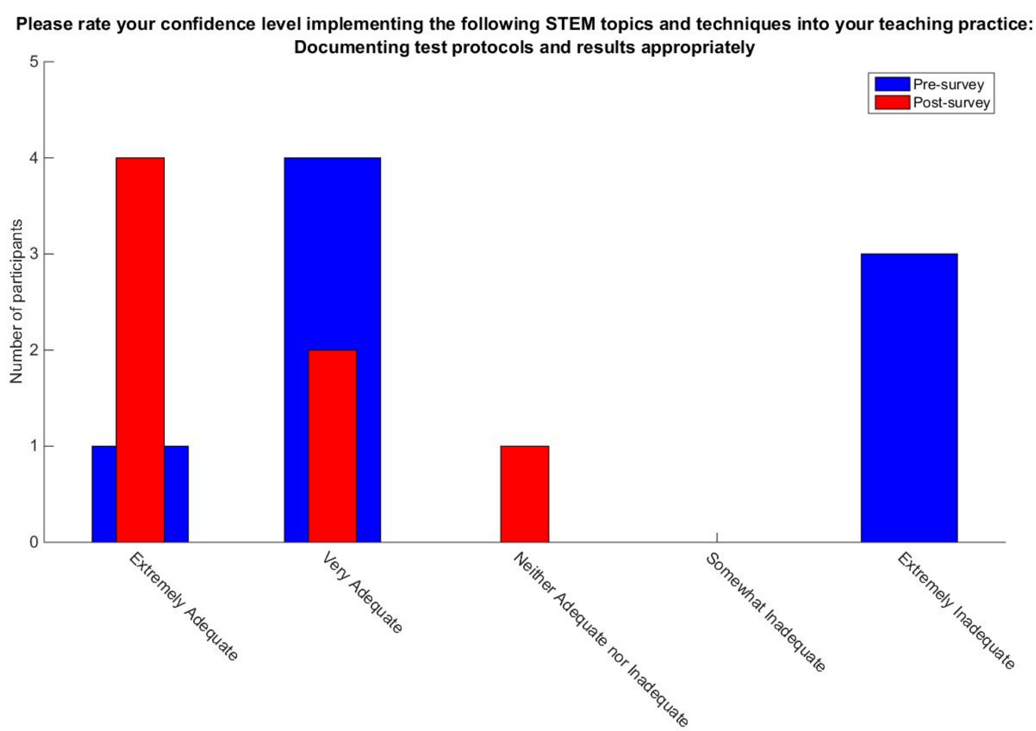

Figure 4. BEST teacher fellows confidence in documenting test protocols and results appropriately increased after completing the program.

In the post-implementation survey, when asked, “What specific successes did you experience with teaching your BEST curriculum?” the responses were as follows:

- “The students were highly engaged and it was completely student-centered activity where the students had design 3D models and print them.”
- “The most successful aspect of the lesson was the student engagement. Once I invited the students to take a journey with me they were willing. The hands on aspect of the lesson was captivating to them.”
- “Students were very engaged throughout the program and appreciated being able to work on hands-on collaborative projects.”

When asked, “What barriers and challenges did you face in teaching of your BEST curriculum?”, all participants responded that it was difficult to find the time to implement their new curriculum.

As the third largest school district in the United States, the Chicago Public School system is comprised of a rich diversity of students and educational environments. The CPS district is comprised of more than 600 schools employing more than 20,000 teachers and serving more than 400,000 students in grades K–12. Currently, 45% of its student population is African-American, 41% Hispanic, 8% Caucasian, 3% Asian, 2.8% Multi-Racial, and 0.2% Native American. About 13% of the students are categorized as limited English-proficient and 87% of the district’s students are from low-income homes. Chicago has 174 total high schools, including selective enrollment schools, magnet schools, charter schools, and neighborhood schools. The average ACT score in CPS is 18, with some selective enrollment schools having an ACT average over 29, and neighborhood high schools with an average as low as 14. Data are similar for graduation rates in the CPS. While the average for the district is 71.9%, neighborhood high schools’ graduation rates are as low as 49% while their selective enrollment counterparts are as high as 97% [5]. Participants were selected with an emphasis on diversity of teaching experience, type of school, and school demographics in order to reach as broad a range of students as possible. This information is outlined in Table 2.

Efforts were made to draw from the diversity of the CPS district; for this reason participants from selective enrollment schools as well as neighborhood schools, and high-performing to under-performing schools, were selected. Due to the breadth of educational environments and student populations, BEST teacher fellows development lesson plans with their own classrooms in mind.

Teacher	**School**	**School Types and**	**Outcome**

		Demographics	
KC Latina female 2.5 Years Teaching Experience	Kenwood Academy High School	Neighborhood school, Student population: 84% Black, 5% Hispanic, 4% White, 60% low income	Successful completion of program and will be implementing curriculum in Academic year 2016-17.
SC White male 2.5 Years Teaching Experience	Air Force Academy High School	Magnet/military academy, Student population: 45% Black, 44% Hispanic, 9% White, 90% low income	During summer program, SC was laid off and found another teaching position at Jones College Preparatory High School within CPS. Successful completion of program and intends to implement curriculum in Academic year 2016-17.
SH Black female 2.5 Years Teaching Experience	Michelle Clark Academic Prep Magnet High School	Magnet school, Student population: 97% Black, 2% Hispanic, 94% low income	At start of the summer program, SH had to decline acceptance for personal reasons.
KJ Asian female 2.5 Years Teaching Experience	North-Grand High School	Neighborhood school, Student population: 14% Black, 84% Hispanic, 1% White, 95% low income	Successful completion of program and will be implementing curriculum in Academic year 2016-17.
DL Black female 2.5 Years Teaching Experience	William Rainey Harper High School	Neighborhood school, Student population: 95% Black, 4% Hispanic, 100% low income	Successful completion of program and will be implementing curriculum in Academic year 2016-17.
LM Black female 2.5 Years Teaching Experience	George Westinghouse College Prep	Selective enrollment school, Student population: 53% Black, 39% Hispanic, 5% Asian, 80% low income	During summer program, LM left teaching position for administrative role in district. Successful completion of program.
JO	Wells	Neighborhood school,	During summer program, JO

White male 2.5 Years Teaching Experience	Community Academy High School	Student population: 53% Black, 44% Hispanic, 93% low income	was laid off and found another teaching position at Crane Medical Preparatory High School in district. Successful completion of program and intends to implement curriculum in Academic year 2016-17.
VT Latino male 2.5 Years Teaching Experience	Walter Payton College Preparatory High School	Selective enrollment school, Student population: 13% Black, 22% Hispanic, 43% White, 17% Asian, 31% low income	Successful completion of program and will be implementing curriculum in Academic year 2016-17.

Table 2. Teacher participants, their school information, and the outcome of their participation.

At the conclusion of the program, the participants uploaded their curricula to the the BEST Program website as an open-access repository for all teachers to use and adapt for their own classrooms. An example is shown in the Appendix and it can be accessed online at https://bestbioe.uic.edu/curriculum-library/2016-curriculum.

4. Program Challenges and Modifications

The nature of working in large urban school districts creates additional challenges for teachers and students. Likewise, as this program works with teachers within CPS, there were several unanticipated challenges that affected the planned implementation of the program. Teacher mobility is significant challenge in urban districts, especially in low-performing and under-resourced schools. High turnover rates and an influx of new teachers are common in low performing schools. In Chicago, about 40% of new teachers leave teaching within five years, with turnover being as high as 80% in some schools. With this in mind, teacher mobility was a challenge in the BEST program as well.

Although eight teachers were accepted into the program, only six teachers will be able to implement curriculum in the 2016-2017 academic year. Much effort was made to select a diverse cohort of participants based upon their experience and where they were teaching, but several of the teachers did not return to the schools in which they taught the previous academic year. As mentioned previously, one teacher left just before the start of the program. A second teacher left her teaching position for an administrative role in the district midway through the program. As a BEST fellow, she did develop a complete unit curriculum plan, but as an administrator, is unable to implement it. Two other teachers left their schools for new positions while in the BEST program. The first teacher chose to leave the one school for a position at another school within the CPS district. The other teacher's position was eliminated, and he eventually took a position at a neighborhood school. So, while we selected participants with an intended diverse student audience, the students who will benefit from the bioengineering curriculum will differ from the intended audience. Both redeployed teachers indicated intent to implement their curriculum, but the design of the curriculum was based on the specific classes they were teaching. As these challenges could not be anticipated, and are a facet of the realities of large urban school districts, the BEST Program aims to be as adaptable as possible. At a minimum, we hope that other teachers (whom did not participate in the BEST summer program), will access these curricula through the curriculum library on the BEST program website. A future goal for academic year 2017-18 is to work with the school district to advertise the online curriculum library as a resource.

The first year of implementation of the BEST program highlighted areas of improvement to enhance the program experience. Given the challenge of translating highly technical bioengineering laboratory research to high school science classrooms, additional time in curriculum workshops will be provided in Summer 2017 for participants to have adequate time to develop quality curriculum materials. We plan to expand this by an additional 1⁄2 day of Curriculum Workshop at the end of the program, in preparation for final presentations and completion of their curriculum materials.

In addition, each BEST fellow submitted a materials/supplies list for the classroom materials related to their curriculum, and BEST program faculty facilitated the purchase of these supplies. However, as each BEST fellow's list was developed towards the end of the program, delayed purchase of the materials was an issue. For Summer 2017, the BEST program intends to work directly with each associated CPS High School to provide these funds for each teacher.

Finally, we acknowledge that placing a high school science teacher into a bioengineering research lab can be challenging without adequate mentorship. Unlike a graduate student or research associate, the BEST participants are not trained biomedical engineers. Therefore, adequate scoping of projects that provide exposure and experience to bioengineering research while staying cognizant of their ultimate goal of translating this into a high school classroom is critical. The BEST Program will help set expectations for both faculty and BEST fellows, ad provide more specific guidance for the Bioengineering faculty to host high school science teachers in their laboratories. There is a significant investment of time by each faculty member to bring the BEST participant "up to speed" in their lab, so we want to ensure a mutually beneficial experience for both participants.

Institutions looking to implement a similar program are encouraged to begin by fostering strong faculty buy-in. This is not a Research Experience for Undergraduates which many faculty members are more familiar with. Teachers are looking to translate their lab experience into a curriculum that they can disseminate to students, making their goals different from a student focused on becoming a better researcher. Additionally, flexibility needs to be afforded to the teachers in how they choose to implement their experience. Teachers have different student populations and school conditions and know how to best reach their specific environment.

5. Conclusion

The BEST program was conceived as a method of bringing cutting-edge bioengineering research into local classrooms. It was noted that a shortcoming of similar programs was the difficulty of translating the research experiences from the participant to their students. To address this, a major component of the BEST program was weekly meetings with faculty from the College of Education.

Learning from the feedback provided by the first-year participants, future iterations of the program will increase the amount of time spent developing their curriculum with the College of Education faculty. Additionally, UIC faculty mentors will be better educated on what skillsets to expect from the BEST participants to smooth the transition into research. At the same time, these faculty mentors can also reach out to their respective participant earlier and give them more time to familiarize themselves with the background skills and knowledge used in their laboratory.

While implementation in some of the participants' classrooms is still underway, the feedback from the first year of this program has been overwhelmingly positive. One participant stated that during the implementation of their new curriculum, "the students were highly engaged and it was completely student-centered activity where the students had design 3D models and print them." Another participant who has completed implementation said that, "students were very engaged throughout the program and appreciated being able to work on hands-on collaborative projects." It has shown the efficacy for immersing teachers in laboratories and working closely with mentors in the College of Education to translate their experience to their students.

6. Acknowledgements

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8. Appendix

Sample Lesson Plan

Daily Lessons (Block Schedule 90 minutes)			
Biotechnology Curriculum	**SCHEDULE** **Module 8. Cutting Edge**		
NGSS Standards Focus	**Day**	**Class Activity**	**Homework**
Connections to Engineering, Technology, and Applications of Science **Influence of Science, Engineering, and Technology on Society and the Natural World**	1	Introduction to Nanotechnology • Opening question(s): What is nanotechnology? How has nanotechnology impacted your life? • Lecture/discussion on nanotechnology and its impact on humanity (so far) • BEST Summer Program video on Multifunctional Bone Nano-Implant Project	Watch video on nanotechnology and its impact on humanity Read lab instruction for Making a Titanium Nanotube (TNT) Update journal
Connections to Engineering, Technology, and Applications of Science **Influence of Science, Engineering, and Technology on Society and the Natural World**	2	*Guided Lab*: Making a Titanium Nanotube (TNT) conducted by bioengineering student from Dr. Shokuhfar lab	Download 123D Design App Update journal
Asking Questions and Defining Problems **Constructing Explanations and Designing Solutions** **ETS1.A: Defining and Delimiting Engineering Problems**	3	*Open-Inquiry* Engineering Lab: Modeling Cell Adhesion to Nanotubes with Different Topographies (Part 1 – Day 1 of 3) • Learn how to use 123D Design App and use 3D printer • Brainstorm and design 3D printed surfaces with varying roughness and nanotube diameter lengths • Develop a standardize method to establish the varying levels of	Work on designing nanotubes and different topographies using 123D Design App

ETS1.B: Developing Possible Solutions **Systems and System Models**		surface roughness and nanotube diameter lengths	Update journal
Asking Questions and Defining Problems **Constructing Explanations and Designing Solutions** **ETS1.A: Defining and Delimiting Engineering Problems** **ETS1.B: Developing Possible Solutions** **Systems and System Models**	4	*Open-Inquiry* Engineering Lab: Modeling Cell Adhesion to Nanotubes with Different Topographies (Part 1 – Day 2 of 3) • Learn how to use 123D Design App and use 3D printer • Brainstorm and design 3D printed surfaces with varying roughness and nanotube diameter lengths • Develop a standardize method to establish the varying levels of surface roughness and nanotube diameter lengths • Print designs and test for adhesion	Work on designing nanotubes and different topographies using 123D Design App Update journal
Asking Questions and Defining Problems **Constructing Explanations and Designing Solutions** **ETS1.A: Defining and Delimiting Engineering Problems** **ETS1.B: Developing Possible Solutions** **Systems and System Models**	5	*Open-Inquiry* Engineering Lab: Modeling Cell Adhesion to Nanotubes with Different Topographies (Part 1 – Day 3 of 3) • Learn how to use 123D Design App and use 3D printer • Brainstorm and design nanotube with different topographies • Print designs and test for adhesion	Work on designing nanotubes and different topographies using 123D Design App Update journal
Asking Questions and Defining Problems **Constructing Explanations and Designing Solutions** **ETS1.A: Defining and Delimiting Engineering Problems** **ETS1.B: Developing Possible Solutions** **ETS1.C: Optimizing the Design Solution** **Systems and System Models**	6	*Open-Inquiry* Engineering Lab: Modeling Cell Adhesion to Nanotubes with Different Topographies (Part 2 – Day 1 of 3) • Design and test to determine optimal nanotube diameter length with surface roughness	Work on designing nanotubes and different topographies using 123D Design App Write lab report due day 8 Update journal

Asking Questions and Defining Problems **Constructing Explanations and Designing Solutions** **ETS1.A: Defining and Delimiting Engineering Problems** **ETS1.B: Developing Possible Solutions** **ETS1.C: Optimizing the Design Solution** **Systems and System Models**	7	*Open-Inquiry* Engineering Lab: Modeling Cell Adhesion to Nanotubes with Different Topographies (Part 2 - Day 2 of 3) • Design and test to determine optimal nanotube diameter length with surface roughness	Work on designing nanotubes and different topographies using 123D Design App Write lab report due day 8 Update journal
Asking Questions and Defining Problems **Constructing Explanations and Designing Solutions** **ETS1.A: Defining and Delimiting Engineering Problems** **ETS1.B: Developing Possible Solutions** **ETS1.C: Optimizing the Design Solution** **Systems and System Models**	8	*Open-Inquiry* Engineering Lab: Modeling Cell Adhesion to Nanotubes with Different Topographies (Part 2 - Day 3 of 3) • Design and test to determine optimal nanotube diameter length with surface roughness	Work on designing nanotubes and different topographies using 123D Design App Write lab report due day 8 Update journal

Assessment Evidence

Performance Tasks:

- Science Journal Report
- Lab report