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INTEGRATING TECHNOLOGY IN STEM EDUCATION

Priya Chacko, Sarah Appelbaum, Heejoo Kim, Jinhui Zhao, Jin Kim Montclare

New York University Polytechnic School of Engineering

United States

priya.chacko92@gmail.com, sappel01@gmail.com, shuaheejoo.kim@gmail.com, elizabethzhao1@gmail.com, montclare@nyu.edu

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Abstract

Students have access to the Internet at their fingertips via e-tablets and smart phones. However, the STEM fields are struggling to remain relevant in students' lives outside the classroom. In an effort to improve high school science curricula and to keep students engaged in the classroom, we developed a technology-rich bioengineering summer program for high school students in grades 9-12. The program utilized touch screen technology in conjunction with hands-on experiments and traditional lecturing to create an entertaining, relevant, and effective classroom experience.

Keywords – Technology, Classrooms, Education, STEM.

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1 INTRODUCTION

In elementary school classrooms five years ago, children were struggling with cursive – attempting to make the graceful curves and connected letters that teachers claimed would be used in high school and postsecondary education (Wallace & Schomer, 1994). Although cursive came in handy 100 years ago when all legal documents were hand written (Supon, 2009), the world has largely turned to new and progressive technologies – rendering those difficult cursive letters almost obsolete. Recently for English classes, teachers have created websites dedicated to their curriculum (Dunn, 2011), while students submit essays online to prevent plagiarism and seek out supplemental material to augment their course work (Baek & Freehling, 2007). In a world where technology is ever changing through innovation, STEM classrooms appear to be left behind (Pitler, 2011). The challenge for STEM educators in the coming years is to answer the age-old question: How can students with very little motivation or interest in STEM be engaged in the classroom?

A brief survey of what students are doing in their free time points to one solution to this problem: electronic devices. With four generations of iPads out, new smart phones every month, and better laptops every year, students are actively engaging with hundreds of thousands of new touch screen applications (or apps) (Freierman, 2011). With such technologies available, students are less willing to sit in a classroom and attempt to decipher complex chemical formulas, equations, or abstract concepts.

Using a paperless classroom model, the program taught students about the frontiers of bioengineering through a combination of lectures, classroom activities, case studies, practical laboratory exercises, and research techniques. Each week focused on a different disease, diabetes, cancer, and HIV/AIDS, and each student was expected to decide upon a topic of research. The students conducted and presented independent research projects at the end of the four weeks based on what they had learned.

2 OBJECTIVES

The overarching objective of the research was to investigate how incorporating “paperless” technology would benefit education and increase an interest in the STEM fields. By incorporating a curriculum that focuses gradually on students learning independently rather than relying on textbooks and lecture-based learning traditionally utilized in STEM classrooms, students were to increase their understanding of topics covered as well as create an independent research project to present at the end of four weeks.

3 APPROACH

For the last two years, two groups of students in 9th through 12th grade from various New York City schools participated in a paperless summer science program in which technology was fully integrated into science education. This program aimed to educate high school students about health related topics including diabetes, cancer and HIV/AIDS while encouraging them to conduct independent research. The four week program ran from July-August for a group of an average of 18 students (the number of students who participated in the program varied from year to year, but overall attendance never waivered from week to week). Each topic was introduced by a technical lecture. Once the students were given the background information, laboratory experiments were conducted in small groups. Afterwards, students and instructors discussed the results. Using what they learned from the lecture and lab, students were then given classroom activities to complete based on the course curriculum (Table 1). For our curriculum, classroom activity is defined as experiences involving students manipulating their knowledge by participating in discussions, creating presentations, assessing case studies, watching videos, and topic related games/activities. At the end of every week, students were given an evaluation of the module to determine whether or not they had increased their understanding in the STEM field covered and their interest level in pursuing a STEM field as a career after high school. In this way, the modules could be evaluated by data provided by students.

Week 1: Diabetes			
Monday	***Tuesday***	***Wednesday***	***Thursday***
Introduction to program	*Lecture: Biology of diabetes*	*Lecture: How to make a scientific poster*	*Lecture: Chemistry of glucose and insulin*
Lecture: Introduction to Epidemiology	*Activity: Diabetes treasure hunt*	*Lecture: Technology and diabetes*	*Activity: Creating professional PowerPoint slides*
Lecture: Introduction to epidemiology	*Lab: Diabetes*	*Activity: Diabetes business case study*	*Independent presentation drafting*
Lecture: Introduction to diabetes	*Activity: Genetics and diabetes*	*Lecture: Do’s and don’ts of making science-related presentations*	*Mock Presentations*
Week 2: Cancer			
Monday	***Tuesday***	***Wednesday***	***Thursday***
Activity: Immortal Life of Henrietta Lacks reading	*Lecture: Types of cancer treatments*	*Lecture: Computational modeling*	*Activity: Henrietta Lacks Jeapordy game*
Lecture: Biology of cancer	*Lab: DNA Restriction lab*	*Activity: Guest Lecture Industry Researcher*	*Lecture: Future of cancer research*
Activity: Causes of cancer		*Independent Poster Drafting*	*Independent Poster Drafting*
Lecture: Guest Speaker Academic Researcher	*Activity: Immortal Life of Henrietta Lacks medical ethics discussion*		

Week 3: HIV			
Monday	**Tuesday**	**Wednesday**	**Thursday**
Lecture: Science of AIDS	*Lecture: Intro to epidemiological statistics*	*Lecture: Biochemistry of HIV*	*International AIDS vaccine initiative site visit*
Activity: Viewing "And the Band Played On"	*Lab: HIV HLA lab exercise*	*Lecture: Technologies to fight HIV*	
		Activity: Paraphrasing	
Activity: Post film discussion, reflections	*Activity: AIDS Statistics, Gapminder*	*Activity: Spread of AIDS*	
Week 4: Presentation			
Monday	**Tuesday**	**Wednesday**	**Thursday**
Lecture: Intro to Project Week	*Drafting a business Plan for biomedical technology*	*Independent project drafting*	*Independent project drafting*
Independent project drafting			
Project Updates	*Project Updates*	*Project Updates*	*Project Updates*

Table 1. Lesson plan schedule for the Course

The first week of the program was focused on basic lessons on epidemiology and diabetes as well as an introduction on how to make science presentations. The purpose of the first week was to introduce the students to a concept that they were familiar with (diabetes) and to outline the expectations of the summer program from an academic standpoint. In doing so, students understood the concept of a paperless classroom and self-directed learning. The second week focused on cancer in which the students read The Immortal Life of Henrietta Lacks by Rebecca Skloot (2010) and discussed the progress of biomedical research over the past 50 years as well as the ethical implications of patient consent. The second week helped reinforce the paperless classroom model of teaching. Students were able to discuss more complex topics like cancer while beginning to research the topics that they wanted to focus on by the end of the summer program. In addition to lectures on cancer biology, causes, and treatment, two guest lecturers also visited the classroom to talk about academic and industrial research. The first lecturer was a professor at a university while the second was a practicing and researching physician at the NYU Langone Medical Center. The third week of the program was based on HIV/AIDS in which the science of AIDS, epidemiology, biochemistry and technologies to combat it were discussed. The students visited the International AIDS Vaccine Initiative (IAVI) site in order to establish the relationship between what they were learning and academia/industry. The site visit allowed the students to apply their knowledge of new technologies to ensure the safe, effective development of AIDS vaccines (the goal of IAVI). In order to understand the social and historical background of AIDS, the students viewed a movie titled "And The Band Played On" (Spottiswoode, 1993). This movie, based on a nonfiction book, discusses the discovery and battle against AIDS. Students used it to explore the impact of AIDS in the political, social and scientific communities. The third week curriculum finalized the paperless curriculum. The students utilized fewer lectures and more activities, labs, and site visits to learn about HIV and AIDS. Utilizing the evaluation of the modules (Figures 1-2), it was possible to see that the paperless classroom model was a success because students increased their understanding of the STEM topics while challenging themselves.

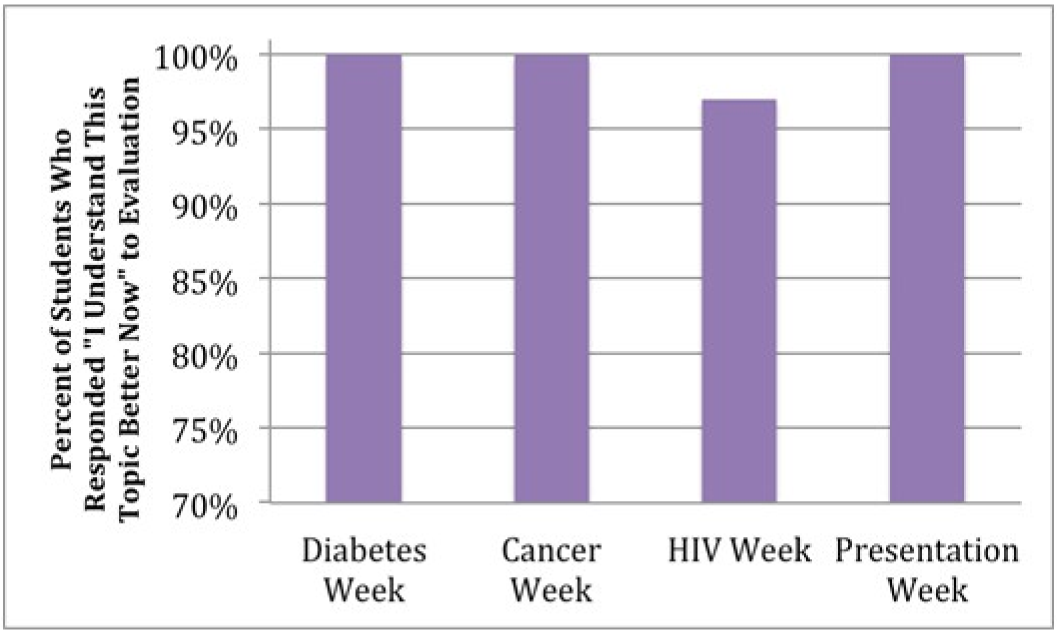

Figure 1. Percentage of students who responded "I Understand This Topic Better Now" to evaluations of each week of the program

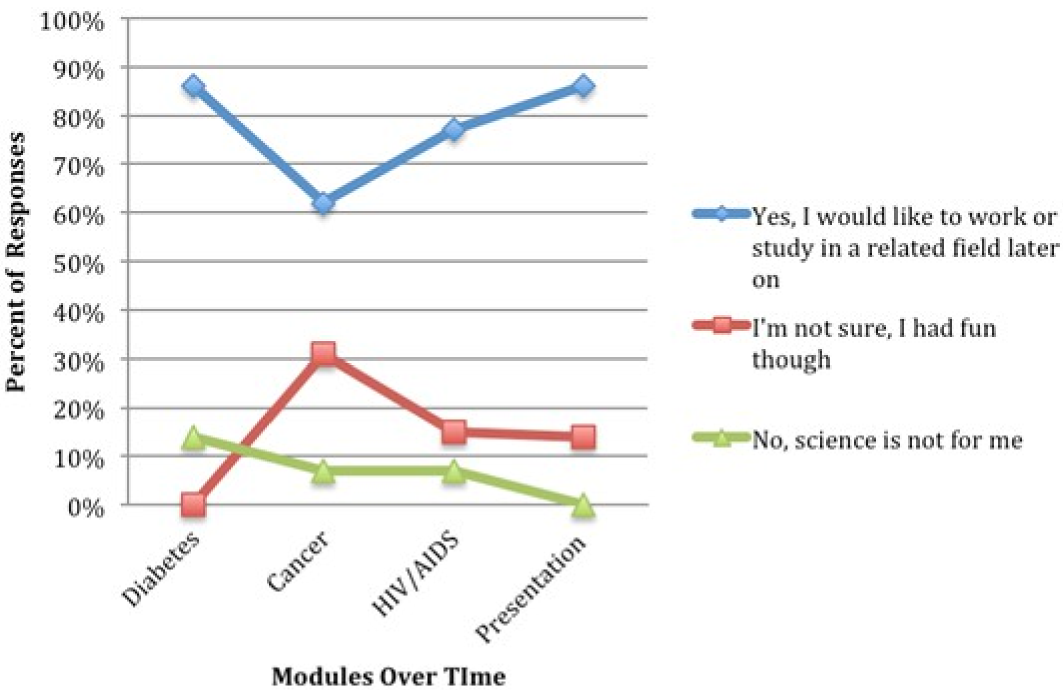

Figure 2. Students were asked "Has This Lesson Triggered Your Interest in Science For the Future" and their responses (taken from anonymous evaluations) are charted over the four modules

The final week of the program was dedicated to the students using technology and resources provided to them (Table 2) to research the topics they chose at the beginning of the program. At the end, students presented to each other and then to a panel of third party judges who evaluated their presentations. An overall theme of the program was to engage students in and outside the classroom using technology where they were constantly required to participate. The lessons learned from the classroom activities, videos and online resources provided students the tools for independent study and successful self-learning. By the end of the summer, the students created independent research projects, culminating with a formal oral presentation of their research. At the beginning of the program, students seemed daunted by the sheer amount of information about to be presented to them. However, a combination of hands on activities, interactive websites, and videos made the material digestible and engaging. The students were exposed to various methods of teaching the same material, reinforcing what they learned. In doing so, the paperless curriculum model provided an alternative to the paper and pencil, lecture-based classrooms that are traditionally utilized in STEM classrooms. By self-directing the learning for the fourth week of the summer camp, students were able to perfect their research skills and strategies and produce a high-level independent research projects instead of relying on lecturers.

Resource	***Description***
EBSCO Host (http://www.ebscohost.com/)	*Research database service that contains online articles from various academic journals available to view from a computer/iPad.*
PubMed (http://www.ncbi.nlm.nih.gov/pubmed)	*Hosted by the NCBI, this search engine contains 22 million citations for biomedical literature from various scientific journals*
NYU Libraries (http://library.nyu.edu/)	*Students were allowed access to the journals at Dibner Library on NYU-Poly's campus.*
PhD Students at NYU-Poly *Academic Researcher* *Industry Researcher*	*Students were encouraged to talk to PhD students from NYU-Poly if they were interested in similar topics that the PhD candidate was researching.*
Google (book/scholar search) *http://scholar.google.com/* *http://books.google.com/*	*Students were encouraged to use Google Scholar and Google Books to research new and developing technologies in the scientific community*

Table 2. Online and Resources Provided to Students for Independent Research

After using all of these tools, if students had questions, wanted to share the information they learned, or wanted to explore more, they participated in an educational blog set up for the program. The blog was run internally using school servers and Google Docs, so it would be a safe online community only accessible by the students and teachers. Students were able to submit assignments online, post links relevant to classroom lessons, and host discussions about classroom material and extracurriculars. Students also stored their research on the blog in team folders so they could have access to the information regardless of where they were. Helpful videos and links to academic journal articles were posted regularly. Links and questions meant to begin student discussions were posted and moderated by the teachers, but were largely contributed to by the students. None of the blog work was mandatory, but incentives (such as jokes and funny videos) were emailed to students who participated.

In addition to the online tools, students were encouraged to remain in contact with the guest lecturers who visited the classroom. The students contacted instructional mentors who were graduate students for more information about the topics covered and research questions. This access to scientists on all levels (from graduate students to physicians/scientists) allowed the students to directly engage with those working on the cutting edge of bioengineering in the field of research. This combination of virtual and in person interactions emphasized the importance of active engagement in the classroom.

4 RESULTS AND DISCUSSION

The evaluation for modules 1 and 2 on diabetes and HIV/AIDS respectively resulted in 100% of the students understanding the topic (Figure 1). While 7% of the students expressed that the 3rd module on cancer did not improve their understanding of it, a 93% majority indicated that they gained insights into cancer (Figure 1). As there was much to cover for the cancer module due to the complexity in terms of types and pathways to cancer, the students suggested that the lesson plan be extended beyond the single week. For the final independent study/research project, all of the students as demonstrated by the 100% response improved their understanding of their selected research topic. In literature, the percentage of students (specifically those in control groups) indicating sustained interest were below 80% (Kim, Chacko, Zhao & Montclare, 2014), suggesting that the students in this program had a high level of positive response. This was also corroborated by the judges' evaluations of their presentations (the grading rubrics can be examined in Tables 3-5). They commented that the students were able to not only effectively articulate scientific concepts and research studies but also respond to challenging questions during their presentation.

Group 1							
Category	***Unsatisfactory***			***Satisfactory***			***Excellent***
Oral Communication (eye contact, etc)	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Poster layout and design	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Demonstrated depth of knowledge	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Research practice (referencing, etc)	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Ability to address questions	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Teamwork (equal distribution of effort)	*1*	*2*	*3*	*4*	*5*	*6*	*7*

Table 3. Sample Judges Grading Rubric

	Exceeds standard (4)	***Meets standard (3)***	***Emerging (2)***	***Attempt made (1)***
Content accuracy	*All content throughout the presentation is accurate. There are no factual errors.*	*Most of the content is accurate but there is one piece of information that seems inaccurate.*	*The content is generally accurate, but one piece of information is clearly inaccurate.*	*Content confusing or contains more than one factual error.*
Sequencing of information	*Information is organized in a clear, logical way. It is easy to anticipate the next slide.*	*Most information is organized in a clear, logical way. One slide or piece of information seems out of place.*	*Some information is logically sequenced. An occasional slide or piece of information seems out of place.*	*There is no clear plan for the organization of information.*
Effectiveness	*Project includes all material needed to give a good understanding of the topic. The project is consistent with the driving question.*	*Project is lacking one or two key elements. Project is consistent with driving question most of the time.*	*Project is missing more than two key elements. It is rarely consistent with the driving question.*	*Project is lacking several key elements and has inaccuracies. Project is completely inconsistent with driving question.*
Use of graphics	*All graphics are attractive (size and colors) and support the topic of the presentation.*	*A few graphics are not attractive but all support the topic of the presentation.*	*All graphics are attractive but a few do not support the topic of the presentation.*	*Several graphics are unattractive AND detract from the content of the presentation.*

	Exceeds standard (4)	***Meets standard (3)***	***Emerging (2)***	***Attempt made (1)***
Text – font choice & formatting	*Font formats (color, bold, italic) have been carefully planned to enhance readability and content.*	*Font formats have been carefully planned to enhance readability.*	*Font formatting has been carefully planned to complement the content. It may be a little hard to read.*	*Font formatting makes it very difficult to read the material.*
Spelling & grammar	*Presentation has no misspellings or grammatical errors.*	*Presentation has 1-2 misspellings, but no grammatical errors.*	*Presentation has 1-2 grammatical errors but no misspellings.*	*Presentation has more than 2 grammatical and/or spelling errors.*
Cooperation	*Group shares tasks and all performed responsibly all of the time.*	*Group shares tasks and performed responsibly most of the time.*	*Group shares tasks and performs responsibly some of the time.*	*Group often is not effective in sharing tasks and/or sharing responsibility.*

Level 4 indicates competence in all standards/benchmarks and exceptional performance in a few
Level 3 indicates general competence in all standards/benchmarks
Level 2 indicates general competence in most standards/benchmarks with difficulties in some
Level 1 indicates difficulties in a majority of standards/benchmarks

Table 4. Sample Powerpoint Slide Grading Rubric

Motivations for the students to enter the STEM fields also improved over the course of the program. While 86% of students responded after the first week of the program that the diabetes lesson inspired them to work or study in a related field, 14% of students noted that STEM fields were not of interest to them at all (Figure 2). However, by the end of the program during the week on presentations, 100% of the students indicated interest in STEM fields.. In fact, 86% of the students were motivated to pursue a STEM field in the future. While the remaining 14% of students were unsure if the final lesson triggered their STEM interest, they enjoyed it. Overall, the program resulted in students giving science a chance –the 14% of students who initially were not interested in STEM fields changed their minds because they were engaged and had fun while doing the lessons.

Utilizing videos, articles, and websites on their laptops and/or iPads also resulted in students using their free time to explore their specific interests. Students were exposed to a virtual playground where they were allowed to safely frolic in information that would help them gain a stronger understanding of various scientific topics. These tools encouraged students to conduct their own research by clicking from educational link to educational link. Thus, if a student began the day trying to learn more about diabetes, he or she could explore the different types of diabetes, the current and emerging detection methods, and factors that complicate the disease within two or three hours without being lectured once! By creating an interactive community outside of the classroom, students were encouraged to learn and reinforce what they were being taught. These approaches facilitated students to become self-motivated and engaged in the classroom. This required the students to use metacognitive skills, directing them to understand what they were studying and, most importantly, why they were studying it (Schraw, 1998).

	Exceeds standard (4)	Meets standard (3)	Emerging (2)	Attempt made (1)
Subject knowledge	*Demonstrates mastery of the topic*	*Demonstrates accurate knowledge of the topic*	*Demonstrates some knowledge of the topic*	*Demonstrates little knowledge of the topic*
Organization and coherence	*Organizes information coherently and stays on the topic*	*Organizes most information and stays on the topic*	*Generally organizes information, occasionally straying from the topic*	*Poorly organizes information and often strays from the topic*
Physical gestures	*Actively engages the audience by making and maintaining eye contact and using movement (facial expressions, posture, gestures) to focus attention and interest*	*Usually engages the audience by making and maintaining eye contact and using movement (facial expressions, posture, gestures) to focus attention and interest*	*Occasionally engages the audience by making and maintaining eye contact and using movement (facial expressions, posture, gestures) to focus attention and interest*	*Neglects to engage the audience by rarely making and maintaining eye contact or using movement (facial expressions, posture, gestures) to focus attention and interest*
Voice	*Always speaks clearly/loudly*	*Usually speaks clearly/loudly*	*Speaks clearly/loudly*	*Does not speak clearly/loudly*
Language conventions	*Uses appropriate grammar and vocabulary*	*Uses mostly appropriate grammar and vocabulary*	*Makes some errors in grammar and vocabulary*	*Makes many grammatical mistakes*
Visual aids	*Creatively uses a variety of visual aids and/or other methods of delivery*	*Uses a variety of visual aids and/or other methods of delivery*	*Moderately ineffective use of some visual aids and/or other methods of delivery*	*Does not/ineffective use of some visual aids and/or other methods of delivery*
Appearance	*Thoroughly demonstrates appropriate appearance*	*Generally demonstrates appropriate appearance*	*Demonstrates minimal understanding of appropriate appearance*	*Fails to demonstrate appropriate appearance*

Level 4 indicates competence in all standards/benchmarks and exceptional performance in a few
Level 3 indicates general competence in all standards/benchmarks
Level 2 indicates general competence in most standards/benchmarks with difficulties in some
Level 1 indicates difficulties in a majority of standards/benchmarks

Table 5. Sample Presentation Grading Rubric

5 CONCLUSIONS

By integrating technology in STEM education, the program encouraged students to become self-motivated learners and researchers. For our summer program, we provided students the tools for independent research, study, and learning through a technology-rich lesson plan. The program was interactive to encourage independent exploration and engagement through labs, lessons and exposure to scientists. Using the methodology outlined in this paper, it is demonstratably possible for a bioengineering summer program to utilize a technology-rich science curriculum. More significantly, the students who participated in this program benefited from it. Due to the overwhelming increase in understanding from week to week (Figure 1), the paperless classroom model utilized for these summer programs can be deemed a success. Additionally, the paperless classroom model and the methodology utilized for this summer program also increased the percentage of students who desired to pursue a science-related field in the future (Figure 2). Most importantly, the percentage of students who had decided that science was not for them decreased from 13% to 0% by the end of the program (Figure 2). The world is not what it was five years ago – we have undergone a technological revolution (Collins & Halverson, 2010). Most other facets of education – from standardized testing to submission of assignments are electronic now; because the curriculum outlined in this paper was a success, shouldn't more technology-rich science education be integrated in classrooms world wide?

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AUTHOR BIOGRAPHY

Priya Chacko

Priya Chacko graduated from the NYU School of Engineering in 2014. As a tutor and teacher's assistant, her passion has always been teaching. She currently works as a process engineer for Estee Lauder in Melville, NY where her interests include process optimization, reformulation, and new products.

Sarah Appelbaum

Sarah Appelbaum graduated from NYU School of Engineering in 2015 with a Master's in Management of Technology and a Bachelor's in Chemical and Biomolecular Engineering which were completed concurrently. Sarah works as a Business Technology Analyst for Deloitte Consulting where her work is focused on data analysis, technology implementation and process efficiency. She currently resides in Brooklyn, NY.

Heejoo Kim

Heejoo Kim works as a full time research assistant in NYU School of Engineering. She recieved a BS degree in Biomedical Science in 2013 from NYU Polytechnic School of Engineering. She worked as a mentor in Chem-Bio Technology Lab during 2011-2013 and helped developing lessons and modules based on touch-screen technology. She had helped 10th grade girls in Urban Assembly Institute of Math and Science as a mentor and motivated students to pursue their studies in STEM field.

Jinhui Zhao

Jinhui Zhao obtained her Bachelor of Science degree in Biomolecular Sciences with a concentration in Chemistry from the NYU Polytechnic School of Engineering in 2012. While there, as a Dreyfus Fellow (2010-2012) and American Chemical Society's Science Coach (2011-2012), she worked on novel teaching strategies using hands-on technology and helped develop the iPad App, LewisDots. She is currently a candidate for Doctor of Medicine at the State University of New York Downstate Medical Center.

Jin Kim Montclare

Jin Kim Montclare, PhD, is an Associate Professor in the Department of Chemical and Biomolecular Engineering at NYU Polytechnic School of Engineering. She runs a research group that specializes in synthetic biology with a focus on protein design. Since 2008, she has been involved in K-12 Education and inspiring the next generation to pursue STEM fields.

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