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Initiatives to Find the "Lost Einsteins" through the Integration of Independent Scientific Research Projects in Early College

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INTRODUCTION

This exploratory study reports on findings from the integration of an independent research project into the college biology curriculum at Bard High School Early College (BHSEC) in Newark, New Jersey. This study was inspired by the claim that students in low socioeconomic environments are less likely to consider becoming innovators. Research by Bell et al. showcased that children with parents with low incomes are less likely to become inventors due to limited exposure to science and financial resources (Bell et al., 2019). In addition, the article addressed America's "lost Einsteins" and the importance of exposing children to innovation. The term the "lost Einsteins" refers to students (especially girls, minorities, and children from low-income families) who, due to limited resources and mentorship at the early stages of education, failed to explore and innovate in STEM fields (Chetty et al., 2018). As a mission to empower the "lost Einsteins" at Bard Early Colleges, the science faculty at BHSEC Newark collaborated to develop a scientific research initiative and observed whether students engaged in the independent research project within the college biology curriculum.

The mission of the project, called the Independent Scientific Research Project (ISRP), was to build an inclusive STEM classroom that focused on students' scientific contributions to their community and to enhance the pipeline of STEM innovators of tomorrow. Students were given the opportunity to choose their research topic according to their scientific curiosity. Students' research topics included environmental issues, endocrine disruptors, energy technology, public policy, and diverse scientific innovations. Through the ISRP process, students honed their skills in scientific research, policy analysis, writing, and oral presentation. Instructors assisted students with identifying the proper scientific resources to use, how to write a scientific proposal, how to allocate funding for laboratory supplies, and they also trained students on maintaining animal models to use for their respective projects. According to research by Shambaugh et al., one of the current challenges faced by the United States related to productivity growth and living standards is the lack of representation by women and minorities in innovation activities (2017). Students who were exposed to the ISRP explored various science disciplines and policy tools that aimed to spur innovation and assist students with their future career prospects.

The long-term endeavor of ISRP is to assist students to fill future positions in STEM in America. Presently, people of color are underrepresented in the STEM workforce. African Americans make up 11% of the U.S. workforce overall but represent 9% of STEM workers, while Hispanics comprise 16% of the U.S. workforce but only 7% of all STEM workers. Among employed adults with a bachelor's degree or higher, African Americans are just 7% and Hispanics are 6% of the STEM workforce (Funk & Parker, 2018). The ISRP integration into the college biology course seeks to enhance racial and ethnic diversity at STEM workplaces in the state of NJ.

In Newark, educational attainment varies with a strong gap in the higher education degrees obtained. The education demographics showed that about 75% of students graduate with a high school diploma. Newark residents 25 years of age and older obtained the following educational degrees: about 18.7% have some college, 5.7% graduated with an associate's degree, 10.9% graduated with a bachelor's degree, 3.1% graduated with a master's degree, and 1.3% obtained a professional or doctorate degree. Interestingly, of the 42.2% of students who enter college with an interest in STEM careers, only 21.2% of students graduate with a bachelor's degree in the STEM fields (Newark, New Jersey Education Data, 2019). STEM programs are losing students during the first four years of college. What can be the reasons for this exodus? One sure thing is that students who are deprived from a lab experience need STEM nurtured earlier than in college and must have faculty/teacher mentorship to ensure guidance and support. This exodus is not beneficial to the city's socioeconomic status in a highly technological era.

Despite the great initiatives by the Newark public school district to collaborate with S2S (Students to Science), a program that introduces Newark students to virtual high school chemistry laboratory modules once a month during the academic year and provides one invitation to a state-of-the-art scientific laboratory facility, the lab exposure time is not sufficient. In order to maintain an inclusive science curriculum compared to other affluent counterpart school districts, a continuous hands-on laboratory experience is necessary to enhance scientific invention and innovation.

This preliminary study analysis is intended to facilitate a greater understanding of the effects of the integration of ISRP into a higher-level science course in an early college education model. The findings shed light on students' ability to proceed with a scientific task with limited resources. From the science education aspect, two major questions will be addressed in this study:

> 1. Did the majority of students engage in the ISRP activity? Student engagement will be evaluated based on which research stage level the student completed.
>
> 2. Does integration of ISRP activity benefit student grade distribution over time? One of the greatest fears for some science educators is to sacrifice students' school district assessment test grades by spending more time on other curricular activities and not enough time preparing students for the district assessments. For some school districts, the higher the student's assessment grades, the higher the teacher's salary and job security (Daly, 2014). For this reason, some educators and administrators prefer to put their academic effort mostly on preparing students for the test rather than getting hands-on experience in general laboratory skills essential in the current biotechnology era.

In institutions with limited resources, a science educator's role goes beyond the lesson planning; educators must struggle to adjust their lesson plan because their classrooms have limited science equipment or lab resources to run the appropriate labs for their curriculum. Educators are forced to use virtual labs as opposed to actual labs, thereby limiting the opportunity to teach realistic lab protocols. These are some issues the science faculty at BHSEC Newark faced in the past few years. Similarly, the progression of this project had its own challenges. This paper will discuss those challenges and how the science faculty overcame them. The following questions will be addressed:

> 3. What were the challenges of incorporating the ISRP initiative in a low-cost school setting?
>
> 4. What has been learned about driving this STEM initiative in a district with limited resources?

This paper aims at providing preliminary data analysis of the ISRP integration project but also a reflection of the authors' journey to find the "lost Einsteins" in their community.

METHODS

I. PARTICIPANTS' INFORMATION

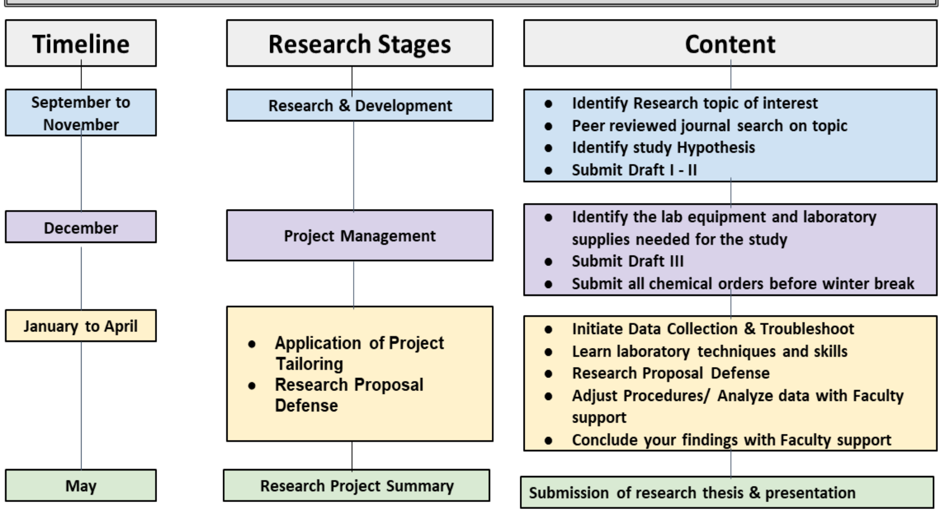
BHSEC Newark is a partnership between Bard College and Newark Public Schools. BHSEC combines a rigorous high school curriculum with two years of a tuition-free liberal arts college program. Students who successfully complete the program earn a New Jersey high school diploma, transferable college credits, and an associate of arts degree from Bard College.

The student demographics at BHSEC mirror the diversity of Newark itself. In the 2018-19 school year, the student body totaled 392, of which 64% identified as Black, 31% identified as Latinx, 3% identified as white, and 2% identified as Asian. As a measure of economic level, more than 91% of students' families are Pell Grant eligible and 76% self-report as Free and Reduced-Price Lunch eligible.

II. PROCESS OF THE INDEPENDENT SCIENTIFIC RESEARCH PROJECT (ISRP) CURRICULUM

The ISRP process required students to complete the following stages througout one academic year: (1) research proposal development, (2) identify and organize research study materials & methods, (3) initiate data collection, analyze data, and conclude findings, and (4) showcase the final research project presentation. Students were given a rubric that indicates how they would be graded for this project.

Figure 1 : Process of the ISRP requirement for the Academic Year



As shown in Figure 1, each research stage had a corresponding time frame and a student expectation described in the *Content* tab. These were assignments that students were required to complete before moving to the next stage. This process is an example of a metacognitive strategy; students are able to respond positively to feedback, set goals, and manage their progress towards these goals, which leads to strategic learning and deeper conceptual understanding of project content (Darling-Hammond et al., 2020). These individual assignments are scaffolds for self-monitoring of thinking and actions to help guide the students through the research process. Studies have suggested that when students have opportunities for self-regulation, including setting their own goals, developing their own strategies to troubleshoot a problem, and taking ownership of their own learning, they are more likely to succeed after high school (Conley, 2011).

To enhance students' motivation, they were advised to focus on solving a community or societal issue. In addition, instructors offered feedback throughout the learning process, encouraged students to revise their work, and allowed peer feedback during the seminar presentations. The aim was to support a growth mindset. Furthermore, faculty mentorship was delivered twice a month during the lab sessions in class. Optionally, students were advised to join the after school research program to enhance their lab skills and to troubleshoot any issues in their projects. All projects were completed in the school facility.

Each year, two seminar series events took place at the institution. The first event was in February and the second one in May. The purpose of these events was to create a collegiate environment where students, faculty, administrators, and staff could share their feedback to the students. In the first event, students defended and showcased their research proposals, and then received feedback to improve their project management in the weeks to come. In the second event, students showcased their final research outcomes and what they learned through the scientific experience of the ISRP.

Ultimately, the ISRP's research process gave students the opportunity to learn diverse laboratory techniques, an important asset to their education. The experience aimed to help students with a four-year degree in a STEM program transition and prepare for a career position in the laboratory setting.

DESCRIPTION OF RESEARCH STAGES

STAGE 1 | RESEARCH & DEVELOPMENT

In the first stage, students choose their research topic according to their scientific curiosity. In this stage, students embrace their curiosity and wonder. They become explorers seeking out new information and thinking critically. Students grow more empathetic as they design meaningful research proposals which they launch to their community. During this stage, instructors will assist students with seeking out the type of scientific resources to use, how to write a scientific proposal, allocating funding for laboratory supplies, and identifying the type of animal models to use for their respective projects. Students must follow the timeline given to them in their course syllabus. In this stage students must submit two drafts of their research proposal before entering the next stage.

STAGE 2 | PROJECT MANAGEMENT: IDENTIFY AND ORGANIZE RESEARCH MATERIALS & METHODS

During this stage, students focus on improving the procedures guiding their project. Students identify and locate the lab equipment or supplies needed for their project. If chemical or lab supplies are not found in the lab, all students must submit a list of the supplies needed, showcasing the following information: item name, company name, company website link, quantity, price of the item, and total cost of the order. If the amount exceeds $30, students need science faculty approval. This information must be submitted by the second week of December.

STAGE 3 | APPLICATION OF PROJECT TAILORING: DATA COLLECTION, DATA ANALYSIS, AND CONCLUDING FINDINGS

Students and faculty mentors work together as a team to coordinate the procedures and allocate specific time for laboratory use. Faculty will guide students with proper laboratory skills that pertain to their scientific projects. If students are interested in continuing their scientific projects beyond class time, they are able to join the optional after-school research program called "Einstein's Dreamers." During this time, students receive further scientific guidance from peers and faculty, can troubleshoot any issues, increase their trials of experimentation, analyze data using statistical software PRISM with faculty assistance, and get assistance with the project's storyline for presentation purposes.

STAGE 4 | RESEARCH PROJECT SUMMARY: CONDUCTING SCIENCE COMMUNICATION TO THE COMMUNITY

The fourth and final stage of the ISRP takes place after the research study has culminated. During this stage, students showcase their final research project through a presentation at the school, scientific conference, or science fair.

III. MEASURE 1: COMPARING THE NUMBER OF ISRP SUBMISSIONS OVER TWO ACADEMIC YEARS

PARTICIPANTS

Students were randomly selected for the ISRP exposure group based on their academic course schedule. Students who registered for Dr. Agapito's college biology course between Fall 2018 and Spring 2020 represented the group with the ISRP exposure. During the 2018-2019 academic year, there were a total of 55 students registered to the science course containing the ISRP exposure. In the 2019-2020 academic year, there were 92 students exposed to the ISRP integration.

DATA ANALYSIS

The students' ISRP progression was monitored by recording the students' project submissions per academic year. The data was normalized to percentile value to compare the two academic years (as shown in Figure 2B).

IV. MEAUSRE 2: ISRP EVALUATION ON STUDENTS' PROJECT PROGRESSION

The rubric shown in Figure 2A showcases the ISRP evaluation rubric to monitor students' progression of the project. The ratings are as follows: A rating of *zero* was given to students that showed no effort to do the project and failed to start the project. A rating of *one* was given to the students who developed an idea but failed to complete the next stages of the project. A rating of *two* was given to students who submitted an idea and developed a research proposal. The proposal may have been submitted but not presented to peers for feedback. In addition, these students did not initiate any scientific work. A rating of *three* is given to students who submitted an idea, a final research proposal, presented their research proposal to peers, initiated the first few procedures and/or initiated to collect preliminary data. The highest rating of *four* was given to students who successfully completed their research project by submitting a final report of the project showcasing the following: introduction, claim question, methods, results and analysis, and final concluding remarks.

Figure 2 : Assessment of Student Engagement with ISRP Integration

A

ISRP Evaluation rubric to monitor students' progression of the project

Rating 0 = No student effort at all

Rating 1= Student developed a scientific idea

Rating 2 = Student develop proposal or presented research proposal to peers

Rating 3 = Student initiated procedure steps or obtained preliminary data

Rating 4 = Students successfully completed their project and presented to peers or students, exceptional work will be those who present their work at a scientific conference

B

Student Submission Rate of ISRP Topics

	N	# of Submissions	%	# of No Submissions	%
Academic Year 2018/19	59	55	***93%***	4	***7%***
Academic Year 2019/20	92	83	***90%***	9	***10%***

C

Evaluation of ISRP Student Progression

Score Rating	0	1	2	3	4
Academic Year 2018/19	4	5	8	24	18
Normalized to %	7%	8%	13%	41%	31%
Academic Year 2019/20	9	8	36	39	0
Normalized to %	10%	9%	39%	42%	0%

The ISRP required that students exhibit their presentation to their class peers and school community. A designation of "exceptional work" was reserved for those students who present their work at other academic institutions. It has been suggested that participating in learning communities contributes positively to student engagement, which in turn may affect education attainment and smoother progression of education. Students' progression in their ISRP projects was evaluated using this rubric.

Over the course of the study's two years of ISRP exposure, projects were evaluated according to how engaged the students were throughout the academic year in pursuit of the culmination of the ISRP. The rubric shown in Figure 2A was used to identify the rating factor for each project per academic year. The project ratings were summed according to their category scores. The raw data and the normalized data values were showcased for the two academic years (data shown in Figure 2C). The number of student projects and the assessment of students' progression were analyzed.

V. MEASURE 3: CORRELATION BETWEEN ISRP EXPOSURE AND STUDENTS' GRADE GROWTH PER ACADEMIC YEAR

PARTICIPANTS

Four different academic years were evaluated to measure the correlation between ISRP exposure and students' grade growth in the college biology course. A total of 178 students' grade records were evaluated for this study. The course grade values were compared between the non-ISRP curriculum group (reference group) and the ISRP curriculum group.

The grade records from the 2016-2017 academic year through spring 2018 were evaluated to represent the reference group (those *not* exposed to the ISRP curriculum). Anaylsis of 90 student grade records from this group identified the set point average grade for the college biology course. Students did not have any knowledge of the ISRP since this project arose two years later. For this reason, the students' grade records from this group were the ideal reference point.

The grade records from the 2018-2019 academic year through spring 2020 were used to represent the group exposed to the ISRP curriculum. Selection of participants to this group was random and depended on the students' academic year schedule; only 88 students were registered to Dr. Agapito's college biology course in which the ISRP curriculum was administered for a full academic year.

DATA ANALYSIS

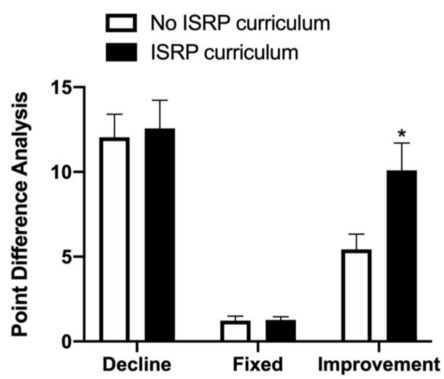
The data was analyzed based on grade changes from semester 1 to semester 2. Each grade was categorized as either a *decline*, *fixed* or *improvement* grade value. The following criteria were used to distribute each grade value into its respective category. A *decline* grade group refers to grades that drop by four points or more from semester 1 to semester 2; a *fixed* grade group attributes to grades that remain the same or change only slightly (drop one to three points or increase by one point) from semester 1 to semester 2; and an *improvement* grade group pertains to grades that increase by two points or more from semester 1 to semester 2. Figure 5 showcases the raw and percentile values to showcase the effects of ISRP integration on students' grades.

In order to account for class grade variables, the *fixed* and *decline* groups needed to be adjusted. The fixed grade group had a three-point grade difference because towards the end of semester 2, students submitted class assignments late, resulting in several points lost for lateness. Students managed to submit their work; however, this trend is what has been observed throughout the year and since we added the ISRP factor to it, we wanted to adjust for this variable. Furthermore, the *decline* grade group has a four-point difference (or greater) from semester 1 to semester 2 to account for chronic student absences. The significant drop in grades was due to students skipping class in semester 2. In order to better evaluate grade distributions, the above criteria were developed.

VI. MEASURE 4: EVALUATING THE DIFFERENCE IN POINT CHANGES PER CATEGORY

The previous data collection evaluates whether students' grades changed to a decline, fixed, or improved state, but did not showcase what is the exact point difference per category. For that reason, the point changes between semester 1 and semester 2 were recorded for each individual. The average data per each category (*decline*, *fixed* or *improvement* groups) was analyzed using the unpaired t-Test using Welch t-test post-test. A p value of < 0.05 was considered significant. This data is shown in Figure 6.

Figure 6: Evaluating the Difference in Point Changes per Category



*T-Test analysis showcases a P value < 0.01,

RESULTS

STUDENT ENGAGEMENT ANALYSIS UPON ISRP INTEGRATION

Two academic years were evaluated to assess the outcome of the ISRP integration (Figure 2B). In the first pilot year, 55 students (93%) out of 59 students engaged in proposing a research idea or research proposal, and only 4 (7%) students failed to engage in the ISRP assignment. Twenty-two research topics were developed. Among the 59 students, only 16 students (27%) completed their research projects, and one group showcased their study at the NJ Academy of Science annual meeting. In the second pilot year, 83 students (90%) out of 92 students engaged in proposing a research idea or research proposal, and only 9 (10%) students failed to engage in the ISRP assignment. Thirty-six research topics were developed this academic year, but none of the projects were able to be presented at any scientific meeting due to the COVID-19 pandemic. The ISRP submission rate difference between the two academic years is 3%. This is such a small percentage, one can suggest that there was a minimal difference between the two years.

Table 1a: 1st Year Pilot of Scientific Exposure: Academic Year 2018 - 2019

Academic Year 2018 - 2019 Course: College Biology N (students) = 59

Research Proposal Title	# of Students	Research Proposal Outcomes
How does acid rain affect the growth of plants?	3 students	Propose research idea, research proposal but research project not completed
Can electricity or an electrical current have an effect on the growth or development of a plant?	3 students	Propose research idea, research proposal but research project not completed
What concentration of Copper II Sulfate will affect seed germination	2 students	Propose research idea, scientific research project completed
Effects of Artificial Sugars on mortality rate of ants (Solenopsis invicta)	6 students	Propose research idea, research proposal but research project not completed
Caffeine vs. nicotine and Its Effects on Brine Shrimp	3 students	Propose research idea, research proposal but research project not completed
Effects of acute ethanol exposure on cell regeneration using planarians as a model system	1 students	Propose research idea, research proposal but research project not completed
How does environmental factors (i.e. rainwater and plants) affect the regeneration rate of planarians?	1 students	Propose research idea, research proposal but research project not completed

Table 1b: 1st Year Pilot of Scientific Exposure: Academic Year 2018 - 2019

Academic Year 2018 - 2019 Course: College Biology N (students) = 59

Research Proposal Title	# of Students	Research Proposal Outcomes
Pretty Pennies Independent Research Project	2 students	Propose research idea, research proposal but research project not completed
Designing the house of tomorrow	2 students	Propose research idea, research proposal but research project not completed
Acid Rain: How it Affects Productivity of Abiotic and Biotic Factors	3 students	Propose research idea and scientific research project submitted
Testing the effects of tap water from diverse school locations in Brick city on nematode behavior and reproduction	3 students	Propose research idea, research proposal but research project not completed
Testing ants (Solenopsis invicta) eating behavior to determine whether ants are more attracted to process sugars (such as candy) vs. the natural sugars (ie. fruits).	2 students	Propose research idea, research proposal but research project not completed
The effects of Clostridium puniceum on potatoes	3 students	Propose research idea and scientific research project completed

Table 1c: 1st Year Pilot of Scientific Exposure: Academic Year 2018 - 2019

Academic Year 2018 - 2019 Course: College Biology N (students) = 59

Research Proposal Title	# of Students	Research Proposal Outcomes
Seed Germination and Environmental Factors	2 students	Propose research idea, research proposal but research project not completed
Studying about brine shrimp	2 students	Propose research idea and research proposal
How does the decrease in pH in aquatic organisms affect organisms (brine shrimp)?	2 students	Propose research idea and research proposal
Effects of Cigarette Fumes on Plant Life	2 students	Propose research idea and research proposal
Where the water come have an effect on plant life?	2 students	Propose research idea and research proposal
Effects of Germination using Different Water samples	4 students	Propose research idea, research proposal but research project not completed
Effects of diverse salinity levels on brine shrimp	1 student	Propose research idea

The science topics featured in students' projects range from general biology, behavioral analysis, environmental community initiatives, botany, aerospace-models, environmental science, and plant development. The students' ISRPs used diverse model systems such as nematodes (*C. elegans*), planarians, ants

(*Solenopsis invicta*), brine shrimp, and plants. Some projects were more elaborate than others and involved multiple team members (Tables 1A-C and 2A-D), while others involved just one member. In the projects that only showcased one student, the project development was less likely to be successful. This indicates that teamwork is imperative for students' academic development. The ISRP integration enhanced students' laboratory skills. For example, students learned how to use an autoclave, how to micropipette, and how to make media and solutions for their respective lab protocols in an aseptic manner. In addition, students were exposed to a diverse range of animal models and made observations about animal behavior, reproduction rate, and growth development (Figure 4). The ISRP integration allowed students and faculty members to engage in authentic scientific research. The students expanded their imagination, creativity, critical thinking skills, and their scientific contribution.

Table 2a: 2nd Year Pilot of Scientific Exposure: Academic Year 2019 - 2020

Academic Year 2019 - 2020 **Course: College Biology** **N (students) = 92**

Research Proposal Title	# of Students	Research Proposal Outcomes
Evaluating diverse Newark household water samples by examining roots, horizontal and vertical stem growth in *Arabidopsis thaliana*	2 students	Proposed research idea and research proposal, but research project not completed
The effects of Newark City's water source, vitamin C and calcium exposure on plant viability using *Zea Mays* as a model system	3 students	Proposed research idea and research proposal, but research project not completed
Testing the effect of high temperature on the flowering process of *Arabidopsis thaliana*	4 students	Proposed research idea and research proposal, but research project not completed
The genetic growth of *Arabidopsis thaliana* develops the process of plant cells	2 students	Proposed research idea and research proposal, but research project not completed
What happens if we mix *E. coli* with *Arabidopsis thaliana*?	4 students	Proposed research idea and research proposal, but research project not completed
Developing earthly plant life on Martian soil model	4 students	Proposed research idea and research proposal, but research project not completed
The exposure of Newark, NJ tap water from dwellings that tested positive for high lead levels alters the flowering rate of *Arabidopsis thaliana*	3 students	Proposed research idea and research proposal, but research project not completed
The development of plants under harsh conditions	2 students	Proposed research idea and research proposal, but research project not completed
Does RedBull affect the growth of *Arabidopsis thaliana*?	3 students	Proposed research idea and research proposal, but research project not completed

Table 2b: 2nd Year Pilot of Scientific Exposure: Academic Year 2019 - 2020

Academic Year 2019 - 2020 **Course: College Biology** **N (students) = 92**

Research Proposal Title	# of Students	Research Proposal Outcomes
Plants on a high	3 students	Proposed research idea and research proposal, but research project not completed
Effects of diverse light colors on growth *Arabidopsis thaliana*	3 students	Proposed research idea and research proposal, but research project not completed
Will it sprout in oasis or drought?	2 students	Proposed research idea and research proposal, but research project not completed
Comparing the height of *Arabidopsis thaliana* to a tomato plant	1 students	Proposed research idea and research proposal, but research project not completed
Growing food Indoors: Is it more efficient to grow a plant in artificial light or sunlight?	3 students	Proposed research idea and research proposal, but research project not completed
Can diverse pH in solutions alter plant growth?	3 students	Proposed research idea and research proposal, but research project not completed
Changes in temperature to increase plant growth of *Arabidopsis thaliana*	3 students	Proposed research idea and research proposal, but research project not completed
Biotic components assist in resistance to lead exposure by aiding plant growth	1 students	Proposed research idea and research proposal, but research project not completed
The effects of lead water on the *Arabidopsis thaliana*	1 students	Proposed research idea and research proposal, but research project not completed

Table 2c: 2nd Year Pilot of Scientific Exposure: Academic Year 2019 - 2020

Academic Year 2019 - 2020 **Course: College Biology** **N (students) = 92**

Research Proposal Title	# of Students	Research Proposal Outcomes
Biotic exposure alters the growth of *Arabidopsis thaliana*	2 students	Proposed research idea and research proposal, but research project not completed
Lead water project	1 students	Proposed research idea and research proposal, but research project not completed
Ready set grow: Studies of sound on plants	2 students	Proposed research idea and research proposal, but research project not completed
Rain water effects on *Arabidopsis thaliana*	1 students	Proposed research idea and research proposal, but research project not completed
Salt vs. sugar water: The effects on plant growth	2 students	Proposed research idea and research proposal, but research project not completed
Improving *Arabidopsis thaliana* growth in Martian soil	3 students	Proposed research idea and research proposal, but research project not completed
The effect of soil on the growth of plants	4 students	Proposed research idea and research proposal, but research project not completed
Growing an *Arabidopsis thaliana* plant	3 students	Proposed research idea and research proposal, but research project not completed
Arabidopsis thaliana: I wet my plants! Growth experiment	3 students	Proposed research idea and research proposal, but research project not completed

Table 2d: 2nd Year Pilot of Scientific Exposure: Academic Year 2019 - 2020

Academic Year 2019 - 2020 **Course: College Biology** **N (students) = 92**

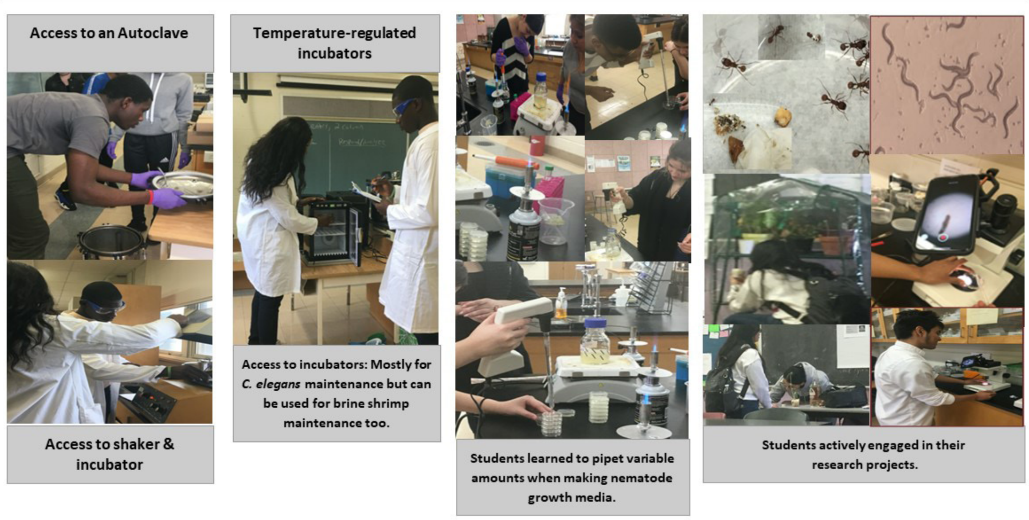
Research Proposal Title	# of Students	Research Proposal Outcomes
Will the amount of water given to a plant daily affect its growth rate?	1 student	Proposed research idea and research proposal, but research project not completed
Queen of Namib flower and the effects of light	4 students	Proposed research idea and research proposal, but research project not completed
What is the best water to use for the growth of a Thaliana flowering plant?	3 students	Proposed research idea and research proposal, but research project not completed
Environmental initiative: Operation beach cleanup	1 student	Proposed research idea and research proposal, but research project not completed
Environmental initiative: Conserving water and tree planting	2 students	Proposed research idea and research proposal, but research project not completed
Environmental initiative: Bard environmental awareness instagram	1 student	Proposed research idea
Environmental initiative: Initiate school recycling and develop recycling lesson plan for Earth Day primary school activity	1 student	Proposed research idea
Environmental initiative: Bard environmental club	1 student	Proposed research idea
Environmental Initiative: Operation school clean-up and beach clean-up	1 student	Proposed research idea

Early college students (or high school students) are actively curious young individuals with background knowledge and a wide range of literacy skills that they may or may not be using in school. Capitalizing on their skills involves gaining their participation. Aside from the data discussed in this study, there was also a more qualitative finding: the classroom community transformed into an intellectual and learning environment. As per the instructor's classroom observations, the ISRP integration addressed the students' needs, interests, and dispositions. Five habits or skills were showcased by students during the ISRP integration: (1) Autonomy, or student self-control. Students were given the option to choose an animal model and/or a scientific topic to investigate, and they were eager to identify a problem that they could address or question. As a result of their ability to follow their curiosity, students gained a sense of ownership. (2) A developing technology interest. Students needed to research, analyze, read, write, communicate, and present their topic of interest. As a result, students were motivated to use both new and familiar technology and thus reinforce their skills. (3) It met the need for students to be heard. The project provided opportunities for scientific writing/speaking for an audience beyond the instructor. Through this activity, students voiced an issue and created awareness about the problem. (4) It reinforced the students' need to make a difference. Students were able to set up opportunities for apprenticeships and/or convert their research into real issues. The ISRP integration created a classroom culture that reinforced classroom norms in support of the development of community thinkers, innovators, and leaders. (5) Sense of accomplishment. This project taught students how to participate in goal setting, project management, and working as a team through the completion of the project (Figure 3).

Figure 3 : The ISRP Integration Addressed the Students' Needs, Interests and Dispositions

Students' needs, interests, and dispositions	Classroom Setting Observation
Autonomy (student self- control)	Students were given an option to choose a scientific topic to investigate and to use diverse animal models. Students were eager to identify a problem that they could address or question. As a result, it gave students a sense of ownership for their ISRP project..
Developing technology interest	Students needed to research, analyze, read, write, communicate and present their topic of interest, as a result students were motivated to use technology thus reinforce their technology and critical thinking skills.
The need for students to be heard	The project provided expectation and opportunities for scientific writing/speaking for an audience beyond the instructor. In this manner, students had a voice on an issue and created awareness of the problem.
Reinforced students' need to make a difference	Students were able to set up opportunities for apprenticeships and/or convert their research into real issues, the ISRP integration created a classroom of culture and reinforced classroom norms that support the development of community thinkers, innovators and leaders.
Sense of accomplishment	This project taught students how to participate in goal setting, project management, and working as a team for completion of the project.

Figure 4: Laboratory Techniques Applied by Students



To account for students' ISRP progression throughout the academic year, each ISRP project was rated according to the rubric showcased in Figure 2A. The data demonstrates that over the two years of ISRP integration, students increased their motivation in developing their research proposals and presenting their ideas to their classmates (Figure 2C). Scores with a rating of *two* increased from

13% to 39%; this is a three-fold increase. The rating of *three* had a minimal increase by 1%, whereas the rating of *four* dropped significantly to zero. This decline in ratings of *four* was due to the COVID-19 pandemic which caused the school district to close, and, as a result, students could neither finalize nor present their scientific projects. Despite the challenges in the second year of the study, one can suggest that students' contributions in the form of a research proposal increased over the two-year period. This might be due to consistent faculty support, student expectations from previous years, students' interest in learning and exploring new laboratory techniques, or just more interest tied to increased STEM awareness.

CORRELATION OF STUDENTS' GRADE GROWTH WITH OR WITHOUT ISRP IN THEIR SCIENCE COURSE

In the United States, it is expected that STEM careers will rise in demand, but that there will not be enough workers to meet the criteria for these jobs in 2030. Studies have suggested that minorities in underserved school districts are at risk of being left behind in tackling STEM preparation, a scenario that has far-reaching economic consequences for the United States. One reason for this gap in STEM career preparation in some schools is that students who live in underserved communities typically lack access to what are now considered STEM basics such as up-to-date laboratories, laptop or tablet computers, access to the Internet, and independent research experience, while their more affluent counterparts are ready to tackle careers in STEM.

The demographic breakdown at our institution, BHSEC Newark, is 64% Black, 31% Latinx, 3% white and 2% Asian. Newark, NJ is one of the top three poorest cities in the state. One can suggest that the "lost Einsteins" might be any student in our academic institution. In unity, our diverse science faculty team explored ideas that were implausible but not impossible. As a result, the BHSEC Newark science faculty revised the college biology curriculum with the ISRP to enhance students' laboratory skills and encourage them to consider STEM disciplines. Surprisingly, the outcome of this project had unexpected results.

The data from the college biology course over four different academic years were analyzed to address the correlation between ISRP integration and students' grade growth. Students registered for the college biology from Fall 2016–Spring 2018 (two academic years) represented the group that lacked the ISRP exposure; this group included ninety participants. Students registered for college biology from Fall 2018 to Spring 2020 (two academic years) represented the group with the ISRP exposure; this group included eighty-eight participants. The class grades for both groups (non-ISRP and ISRP group) were divided into three groups: *decline*, *fixed*, or *improvement*. A *decline* grade group refers to grades that drop by four points or more from semester 1 to semester 2; a *fixed* grade group attributes to grades that remain the same or change only slightly (drop one to three points or increase by one point) from semester 1 to semester 2; and an *improvement* grade group pertains to grades that increase by two points or more from semester 1 to semester 2.

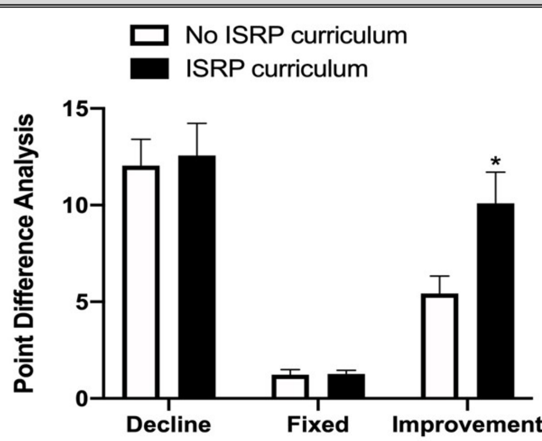
Figure 5: Effects of ISRP Integration on Students' Grade Growth

College Biology Student's Grade Growth				
	N= Sample size	Decline Grade (S1->S2	Fixed Grade (S1->S2)	Improvement Grade (S1->S2)
No ISRP curriculum (2 academic years)	90	43 (48%)	28 (31%)	19 (21%)
ISRP curriculum (2 academic years)	88	28 (32%)	26 (30%)	34 (38%)

Figure 5: Effects of ISRP integration to students' grade growth. A decline grade group refers to grades that drop by four points or below from semester 1 to semester 2; a fixed grade group attributes to grades that remain the same or change only by 3 points below from semester 1 to semester 2; and an improvement grade group pertains to grades that increase by two points or more from semester 1 to semester 2.

Figure 5 showsthat there was a 16% difference in *decline* grades. This means that declining grades from semester 1 to semester 2 were reduced upon ISRP integration. Moreover, there was a 17% difference in *improvement* grades. This means that grades were higher upon ISRP integration. This data indicates that ISRP integration influences students' academic performance.

Figure 6: Evaluating the Difference in Point Changes per Category



*T-Test analysis showcases a P value < 0.01,

To further explain the changes in grade points in non-ISRP and ISRP groups, each student's course grade was evaluated per semester, and the point differences between semester 1 and semester 2 were recorded. Each point difference was categorized into either the *decline*, *fixed* or *improvement* grade group. Figure 6 illustrates how both the *decline* and *fixed* groups showcased no difference between non-ISRP and ISRP curriculum integration. However, the *improvement* group showed a significant point difference between non-ISRP curriculum and ISRP curriculum integration. This data reaffirms the positive contribution of ISRP integration curriculum into helping minority students with their academic performance.

CONCLUSION

The underachievement and underrepresentation of women and minorities in STEM has been explored for many years, yet even in 2021 we are still facing the same issues. How do we maintain students' interest in STEM careers? Studies by Oakes (1990) described three critical factors necessary to successfully surpass the educational pipeline: students must have opportunities to learn science and math, students must excel in these subjects, and students must make the decision to pursue careers in STEM. In this study, two critical factors were addressed as suggested by Oakes: the ISRP integration to encourage students to learn new scientific skills while improving their class grade.

One question posed earlier in the introduction was "How can students develop interest in STEM careers when their school communities lack the scientific resources to grant them the same science education in comparison to their more affluent peers in neighboring cities?" One of the solutions to address this problem is to create a curriculum that amplifies students' engagement, innovation, creativity, and their scientific and mathematical skills.

Various literature defined student engagement as a measure of the extent to which a student willingly participates in schooling activities. Researchers believed that student engagement has multiple dimensions: behavioral, emotional, cognitive, and academic. Academic engagement refers to the intent of the student to participate in the academic work of schooling such as completing homework, attending class, and completing traditional class activities. Behavioral engagement is based on the idea of participation and includes involvement in academic, social, or extracurricular activities. This type of engagement is considered crucial for achieving positive academic outcomes, and can be measured using attendance, grades, or disciplinary records (Connell & Wellborn, 1991; Finn, 1989). Emotional and cognitive engagement is not always measured in school. Emotional engagement refers to the student's feelings of belonging to the school, classroom, teacher, or peers, or a sense of ownership, whereas cognitive engagement is a measure of a student's levels of investment in their learning. This is closely related to the perceived relevance of what the student is learning in the classroom and how that connects to their long-term goals (Institute of Education Sciences, 2015).

In this study, the following key indicators were used to monitor student engagement and academic growth: (1) submission rate of research projects per academic year, (2) the number of student presentations showcased to peers or to a scientific community, and (3) observational measures such as students' final grade for the course in relationship to ISRP engagement. This preliminary study demonstrated that students with independent research exposure were more likely to improve their academic grade in the science course. According to the data collected, students were more engaged and the science information was better absorbed in classes which had the ISRP integration. Students not only increased in their academic achievement but also learned key skills like project management, collaboration, and communication. The ISRP integration prepared and empowered students with innovation skills, ownership, a voice of choice, and developed their interest in the sciences. As observed from the data collected, students' proposal submissions increased over the last two years. The data showed an increase from 13% the first year to 39% the second year, a three-fold increase. This data indicated that students were interested in innovative projects. Furthermore, Figure 3 and Figure 4, showcase the formative assessments that showed students engaging in hands-on laboratory inquiry, teamwork, and the usage of diverse laboratory skills. Both Figure 5 and Figure 6 demonstrate that integration of the ISRP curriculum into the college biology course enhanced student grade growth. In summary, one can conclude that once students are given the opportunity to innovate or research their own interests, without the knowledge of any disadvantages or limitations, they can succeed in a similar manner to their counterparts from affluent communities.

What were the challenges in incorporating the ISRP initiative in a low-cost school setting? We know school districts with limited funding don't have sufficient budgets to maintain laboratory supplies, equipment, and a lab manager. As a result, most science educators are forced to seek out other resources, such as virtual labs, to limit the cost. This was not the case at our intuition. The early college model follows both high school- and college-level curricula. How do we compete with other higher education institutions or even other Bard Early Colleges with a limited budget? The BHSEC Newark science team tackled the problem by writing and applying to science-driven educational grants and by crowdsourcing through Donors Choose and GoFundMe. As a team, the authors developed ideas which incorporated all of the science disciplines into their grant initiatives. It took some personal time from faculty and staff members to develop the grant and the project's proposal. The rewarding aspect was observing the students engage, communicate, and create awareness about their respective scientific projects.

There are many recommendations by political leaders to improve STEM education, but no results have been seen yet, especially in low socio-economic communities. According to the authors, in order to improve the quality of education in challenging school districts, the Board of Education should provide schools with the necessary laboratory settings, equipment, and supplies to establish a rigorous STEM curriculum that meets the needs of this scientific technological era. In this way, school administrators and educators from challenged school districts can focus their energy on improving their STEM curriculum development and develop ways to implement innovation in their courses. According to STEM leaders, evaluative inquiry, problem-solving and decision-making skills, and collaborative teamwork are necessary to improve the advancement for STEM education (ICASE, 2013). The only way to find the "lost Einsteins" in disadvantaged school districts is by redesigning high school/early college curriculum to be more inclusive through inquiry-based group projects, which promote diversity, equity, and inclusion (Key, 2020).

What has been learned about driving this STEM initiative in a challenged district with limited resources? It was easy to get the BHSEC Newark science team involved in this project; the authors shared the same problem of limited laboratory resources, and they knew that by working together they could improve the likelihood of grant acquisition. The authors encountered a minimal setback, a purchasing department issue. When it was time to purchase the laboratory items, as per the district regulations, the purchases needed to be from a particular district vendor and not of the educators' choice.

The authors' suggestions to improve the STEM high school or early college curriculum in budget-limited school districts are outlined below.

1. There is a need to initiate cross-talks between district leaders, administrators, and STEM educators. All of these leaders must be present at the same time and place to exchange ideas, data, and budget allocation. The information for improving the laboratory setting in all institutions should be discussed first before revamping any science curriculum. Educators' need for space, equipment, and supplies should be addressed for each school within the district, especially school districts with limited resources, so it can be budgeted. There is still room for improvement when dealing with enhancing STEM education and finding more "Lost Einsteins" in low-income communities.

2. The science department budget should be increased, and cannot be split into equal budget plans with other disciplines of study. Science laboratory supplies and equipment are expensive, leading to a higher department budget requirement. Distributing an equal budget cost to all educational departments within the school can be troublesome. Thus, distribution of department budgets should accommodate the disparity factor of scientific supply cost difference.

3. Students and science faculty should be granted stipends. For institutions with limited resources, it can be challenging to meet the guidelines and expectations of the current science curriculum as suggested by the state or federal educational departments. As a result, many low-income educational institutions do not have an adequate laboratory setting. Science educators are faced with a constant battle of how to engage students with limited resources while upholding the science curriculum expectations. District leaders and administrators should embrace educators who create innovative instructional ideas to motivate students by supporting the educators with a nominal stipend

during the academic year or summer. Educators can use the summertime to enhance curricular development or initiate scientific research as their professional development focus. Teachers can expand their curriculum, work on preparing for their next academic year, continue their research, or perform lab maintenance for state coding purposes. In regard to students' stipends, in order to promote students entering STEM careers, it will be beneficial to have a side budget for students who want to assist science educators as laboratory assistants. Many schools don't have a budget for science laboratory manager positions, thus the science educators are forced to develop class curriculum modules, teach the course, grade the class assignments, attend faculty and committee meetings, prepare for laboratory class sessions, and clean-up the lab after each class. There is a limited time for performing all of these tasks within a 7-8 hour work day. For this reason, some science educators who work in challenging school districts prefer virtual labs. This means that the students will miss out on obtaining the following laboratory skills: micropipette, making media, using the microscope, molecular biology techniques, making their own slides, cell staining, dissecting, growing a plant, or maintaining animal models. These are essential skills for students of this technological era of molecular biology. By providing students with a stipend, they can assist educators with laboratory maintenance and avoid seeking retail or food service jobs that may not be related to their actual career of interest. Meanwhile, educators will have more time to manage student projects and enhance their feedback to students. The goal is to assist students in gaining laboratory experience that they can use in the future at the college level or even in the industry. The faculty stipends can enhance science educator recruitment and retention in disadvantaged communities, enhance faculty leadership, and lastly allow professional development growth among the STEM community.

4. Faculty development focused on grant writing is imperative to science educators. There are always limitations to budgets for the sciences, and in order to overcome these challenges, science instructors must improve their skills of writing grants and determining budget costs. Especially for science educators who work in low-cost institutions, grant writing and crowdfunding experience will help them end laboratory equipment and supplies challenges.

An instructor's limited conditions should not shape the academic goal. It is passion and enthusiasm for science education that drives the educator to success. One can agree that science educators may be financially undervalued for their time and effort, however let's not forget that students observe our tenacity in the classroom, and they understand the current classroom conditions. If we as educators can overcome our own obstacles, we teach our students to do the same tomorrow; they are the leaders of tomorrow.

President Obama stated that as educators and administrators, we must “reach, inspire, and empower every student, regardless of background, to make sure that our country is a place where if you work hard, you have a chance to get ahead” (United States Executive Office of the President, 2014, p. 2). In academia, we are lacking STEM role models of color, and students of color have great difficulty relating to the lack of faculty diversity at the college level. At the K-12 level, families in underserved communities may have a language barrier to communicate with the teachers or may not have the time to meet with them because of work or financial demands. Present times have tested administrators’, educators’, students’, and families’ resilience to cope with virtual education. The COVID-19 health crisis has resurfaced the great disparities in education. Recent data from Dorn et al. (2020) suggests a worrisome outcome: “Students affected by COVID-19 will probably be less skilled and therefore less productive than students from generations that did not experience a similar gap in learning” (para. 20). However, the disparity in education has existed for many years; this is not new. Political and educational leaders need to revamp their education reform strategies to allow more funding for marginalized academic institutions. Technology has opened new windows of opportunity for how education can be delivered around the world. A new education path is opening, who will stay or who will leave is the question.

In summary, the ISRP integration curricular model not only taught students scientific laboratory skills or critical thinking, but also allowed the students to overcome their academic and personal challenges so they may excel in their future careers. Innovation is the key to enhancing diverse STEM leaders. Imagine what our students could accomplish if the appropriate resources were given to them? In the future, the authors will continue with the ISRP integration. Students will be surveyed for career choice updates and reflections on their experience after they have graduated. Also, district standardized assessments will be evaluated to observe global academic growth. It is our hope that through these experiences our students were able to obtain the necessary skills needed to embark into the 2030 STEM era.

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REFERENCES

Bell, A., Chetty, R., Jaravel, X., Petkova, N., & Van Reenen, J. (2019). Who becomes an inventor in America? The importance of exposure to innovation. *The Quarterly Journal of Economics, 134*(2), 647–713. https://doi.org/10.1093/qje/qjy028

Chetty, R., & Reeves R. (2018). America's "lost Einstein's": the importance of exposing children to innovation [Audio podcast episode.] In *Brookings.* Brookings Institution Press. https://www.brookings.edu/podcast-episode/americas-lost-einsteins-the-importance-of-exposing-children-to-innovation/

Conley, D. (2011). Building on the common core. *Educational Leadership, 68*(6), 16-20.

Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relate ness: a motivational analysis of self-system processes. In M.R. Gunnar and L. A. Sroufe (Eds.), *Self-processes and development: Minnesota Symposium on Child Psychology* (Vol. 23, pp. 43-77). Lawrence Erlbaum Associates, Inc.

Daly, J. (2014). Good grades = higher teacher pay: Compensating teachers for student achievement. *Edutopia*. https://www.edutopia.org/good-grades-higher-teacher-pay

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020) Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Dorn, E., Hancock, B., Sarakatsannis, J., & Viruleg, E. (2020). COVID-19 and student learning in the United States: The hurt could last a lifetime. *McKinsey & Company.* https://www.mckinsey.com/industries/public-and-social-sector/our-insights/covid-19-and-student-learning-in-the-united-states-the-hurt-could-last-a-lifetime

Finn, J. D. (1989). Withdrawing from school. *Review of Educational Research, 59,* 117-142.

Funk, C. & Parker, K. (2018). Diversity in the STEM workforce varies widely across jobs. *Pew Research Center.* https://www.pewresearch.org/social-trends/2018/01/09/diversity-in-the-stem-workforce-varies-widely-across-jobs/

ICASE (2013). Kuching declaration on science and technology education. *Final proceedings of the World Conference on Science and Technology*

Education (WorldSTE2013). http://www.icaseonline.net/ICASE%20Kuching%20Declaration_Final.pdf

Institute of education sciences. (2015). *What is student engagement and how do we measure it?* [Video]. YouTube. https://www.youtube.com/watch?v=IsuFUC6kgE8

Key, S. (2020). Finding the lost Einsteins: How to make academic inventing more inclusive. *Forbes*. https://www.forbes.com/sites/stephenkey/2020/06/24/finding-the-lost-einsteins-how-to-make-academic-inventing-more-inclusive/?sh=1f53ae8a3a28

Newark, New Jersey education data. (2019, December 15) Towncharts.com. Retrieved January 3, 2021, from https://www.towncharts.com/New-Jersey/Education/Newark-city-NJ-Education-data.html

Oakes, J. (1990). Lost talent: The under-participation of women, minorities, and disabled persons in science. Santa Monica, CA: The Rand Corporation.

Shambaugh, J., Nunn, R., & Portman, B. (2017). Eleven facts about innovation and patents. *Brookings.* https://www.brookings.edu/research/eleven-facts-about-innovation-and-patents/

United States Executive Office of the President. (2014). Increasing college opportunity for low-income students: Promising models and a call to action. Washington, D.C.: Executive Office of the President. Retrieved May 1, 2021 from https://obamawhitehouse.archives.gov/sites/default/files/docs/increasing_college_opportunity_for_low-income_students_report.pdf