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Promoting Student Interest in Science Using Student-Delivered Professional Development

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ABSTRACT

In this work, over 400 middle school and high school students were presented science activities pertaining to authentic astronomical research. Created by a group of student research interns, these activities were delivered to classroom educators to share with their own students in person or via online instruction. This delivery took place via a series of professional development sessions delivered to teachers by the student interns, reaching a total of fifteen schools from across the United States of varying diversity and socioeconomic background. The authorship of the activities by students allowed for their voice to resonate with a wide audience of classrooms, promoting interest in science careers and confidence in independent learning across several subgroups, most notably in high school minority students. This includes a 12% increase in desire to go to college and a 14% gain in confidence in online learning in high school students. The methods for this student-teacher-student delivery are highlighted along with the now publicly available educator resources employed in this study for future implementation.

Introduction

Exploration of pedagogical strategies and practices to increase engagement in STEM fields for K-12 students continues to be a challenging field, as few solutions will ever serve as a 'silver bullet' for all teachers in all communities. However, the charge to motivate the scientists, mathematicians, and engineers of tomorrow to pursue STEM careers continues, as the job market demand for these degrees further accelerates. (Bureau of Labor Statistics, 2021)

To promote a sense of science identity to these students who may otherwise lack the exposure or confidence to engage in science, much research investigates potential influences and environments available to students that encourage STEM pursuits, otherwise characterized as 'science capital' (Nomikou and King, 2017; DeWitt et al. 2016). Studies have found compelling links between STEM career pursuits and accessibility to a scientist, such as a family member or teacher, (Archer et al. 2013) as well as the value of scientific mentorship (Estrada et al. 2016; Houseal et al. 2013), but these findings mean very little in terms of solutions for communities in which parents of students are not scientists or scientific institutions are not part of the students' neighborhood. Instead, more prescriptive practices have been laid out for subgroups of students that are underrepresented, most notably for young girls. Girls' participation in science programs, better representation, and classroom practices have all contributed to significant progress in closing the gap between male and female students pursuing degrees in STEM (Cimpian et al. 2020), with some of the most historically gender-biased fields- such as math and physics- seeing significant movement towards and even reaching gender parity. (Riegle-Crumb, 2013; Nord et al. 2011) Conversely, the underrepresentation of Black or Latin students continues to subsist as a critical area of development (Nord et al. 2011).

To this end, this work explores a strategy of collaboration between students and classroom teachers to promote science identity amongst a population with varying science capital. The objective of the presentation, rather than targeting one subgroup of students explicitly, implements a student-generated curriculum that educators across the United States share with their own students. That is to say, a set of classroom activities constructed by student voices may be effectively transmitted wherein that student voice could be preserved by teachers (Schenider et al. 2018). This 'student-led educator professional development' model allowed for a group of passionate high school students interested in STEM to create their own lessons, focusing first on what spoke most to them as future scientists. Educators then augmented these activities to fit their educational needs and classroom standards, but kept the student testimony and key concepts. By letting students drive the curriculum, student engagement authentically made the first criteria of the lesson, rather than standards or assessment.

For this work, five high school students were selected during an internship with the astronomy department at a nearby university. These students were exploring a nebula called "The Spider and the Fly", or IC417, (Figure 1) which had been extensively studied by the now retired Spitzer Telescope (Caltech, 2021). The students developed activities and demonstrations based on their research designed to communicate precisely what they do to their student peers. With the help of several scientific outreach organizations, these activities were presented online for ease of teacher accessibility (NASA JPL, 2021). The student interns then hosted a professional development workshop for teachers in order to demonstrate these activities and guide teachers to implement them at their own schools.

Figure 1. IC417 as captured by the Spitzer Telescope. Image Credit: NASA/JPL-Caltech

Fifteen of the roughly fifty teachers in attendance agreed to implement the activities in their middle school science or high school physics and astronomy classes. Participating students were surveyed before and after the activities in hopes to capture how these student-generated activities impacted their perceptions around STEM. An analysis of several student subgroups provided insight as to the efficacy of the model.

Methods

To most effectively capture the content that spoke most to students, activities and demonstrations were created by a group of high school and college researchers who had recently completed physics and astronomy coursework and were participating in astronomy internships at local universities. These activities were prepared with the guidance of teacher mentors to ensure they adequately communicated what about their research projects could excite their student peers while still addressing relevant Next Generation Science Standards for science classrooms in grades 6-12. To this end, several lessons and activities were developed using the expertise of research organizations performing both education outreach and similar research to that of the interns, such as the SETI Institute and the Infrared Processing and

Analysis Center (IPAC), alongside NASA's Education Department. In October of 2020, the student interns then shared these activities with roughly fifty teachers at an education workshop hosted by NASA Jet Propulsion Laboratory, providing testimony as to their own paths in pursuing degrees in science, and describing how these activities spoke to them as students. These lessons included several student discussions and interactives which could be performed both online and in person, as COVID-19 restrictions presented the need to be accessible to both teaching environments. The focus of the activities engaged astronomical topics and explored how scientists use light and color to detect stars utilizing the infrared portion of the electromagnetic spectrum. Lessons on art, color, and light were created in 5E lesson plans and posted on the JPL Education website for ease of access to teachers both in and out of the workshop. (Figure 2).

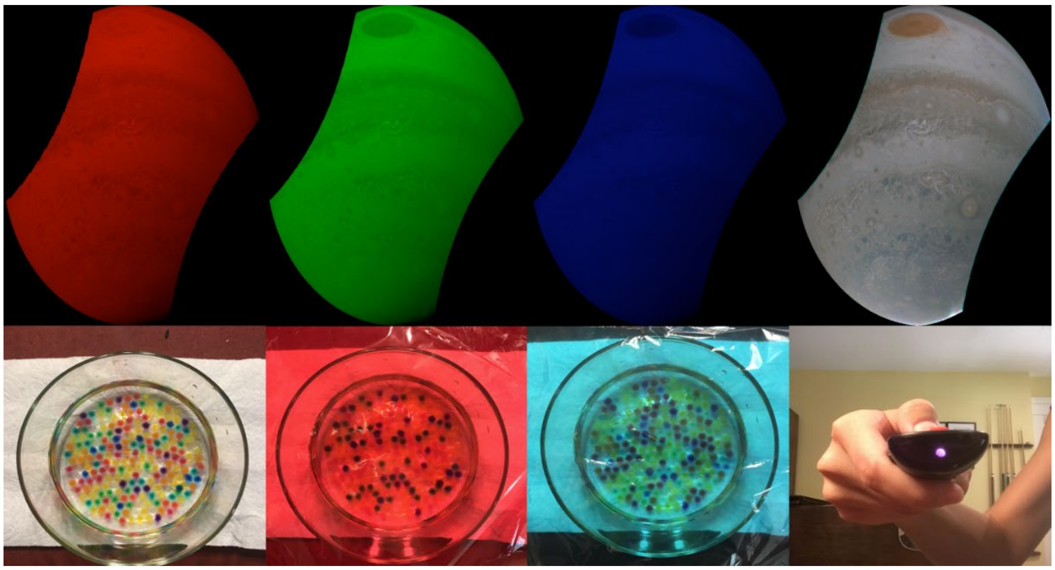

Figure 2. Images from student-generated activities in physics and astronomy, used in educator professional development to assist teachers in implementing similar activities in their own classrooms. These activities are now hosted on the NASA Jet Propulsion Laboratory Education website.

Teachers in attendance were offered a chance to volunteer and apply both these activities and student stories in their own classrooms over the course of the school year. Students were surveyed before and after the semester in which they participated in these activities, using the pre- and post-survey questions below:

1. Grade:
2. Parents' highest level of education:
3. Gender:
4. Ethnicity:
5. How confident do you feel about the following statement: I plan to go to college
6. How confident do you feel about the following statement: I am interested in science
7. How confident do you feel about the following statement: I am interested in astronomy
8. How confident do you feel about the following statement: I have considered majoring in science
9. How confident do you feel about the following statement: I have considered majoring in astronomy
10. How confident do you feel about the following statement: I feel optimistic about growing academically through online learning
11. How many astronomy-related field trips and activities have you been exposed to in the past?
12. How confident do you feel about the following statement: These demonstrations boosted my optimism towards online learning

Where questions 5-10 used a five-point Likert scale from least confident to most confident, as did question 12, which was only present on the post-survey. In total, just over 400 students were surveyed from grades 6-12 from the fifteen participating teachers. Class sizes from grades 6 through 8 were too small to be statistically relevant, and as such the analysis of impact was limited to grades 8-12. Success of the project, defined via statistical analysis of change from pre- and post-survey responses across grade level, parental education, gender, and ethnicity, identified what subgroups of students were most impacted by the program.

Data and Results

Student Demographics

In total, 55% of the students identified as female and 43% identified as male, with the remaining 2% declining to respond or selecting "other". Since less than 10 students from both 6th and 7th grades participated in the survey, their responses were eliminated to ensure a more thorough statistical analysis. The final analyses included 104 8th graders, 50 9th graders, 46 10th graders, 116 11th graders, and 14 12th graders (Table 1). Student participants were predominantly of Latin descent, particularly due to the 10th and 11th grade Title I presence in California (Figure 3).

Table 1. Student participants by ethnicity.

Gender	Asian	Black	Latin	Mid-Eastern	Mixed	White
Female	15	15	231	4	40	64
Male	20	5	185	2	24	50
Other						3
Prefer not to say		1	11		2	1

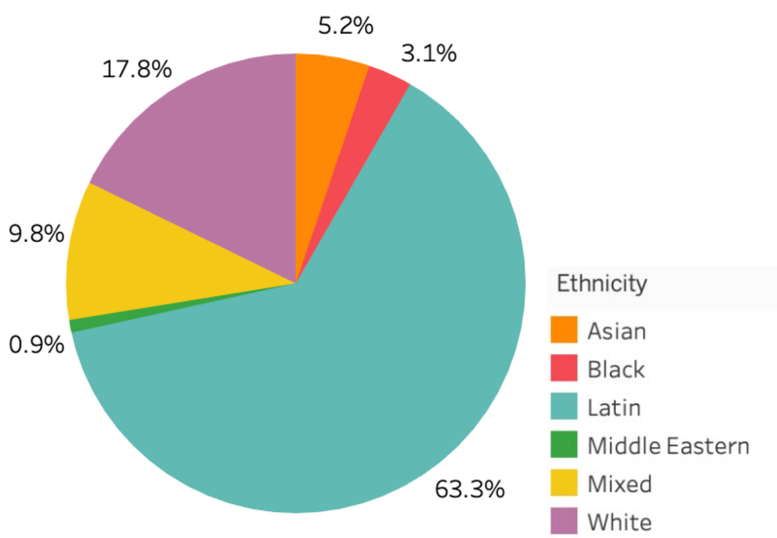

Figure 3. Relative percent of student participants by ethnicity.

Lastly, students were asked about their parents' highest level of education, as research studies have demonstrated clear correlation between 'science capital' at home (Archer et al. 2013) and scientific identity. The question was left open ended so that students could reply with one or both parents, if available. Notably, a large portion of students indicated that they did not know their parents' highest education level, which may suggest either genuine unfamiliarity, possibly reflective of a lack of familial schooling, or potentially discomfort in disclosing said information. Regardless, most students replied that they either did not know or that their parents had completed high school, with only about 10% of participants indicating their parents had a graduate degree of any kind (Figure 4).

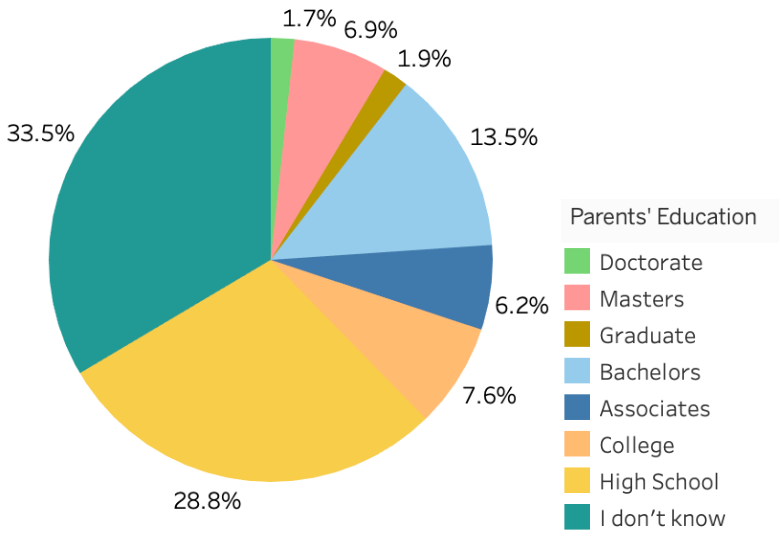

Figure 4. Relative student participants by parents' highest level of education.

Filtering the students by ethnicity and parents' highest level of education (Table 2), the data reveals over 70% of Latin respondents indicated either unfamiliarity of parents' highest education level (31%) or their parents attained a high school education or lower (40%). These marks contrast White and Asian students, who indicated 23% and 17% had graduate degrees, respectively.

Table 2. Student participant ethnicity by parent's highest level of education.

Parent Education	Asian	Black	Latin	Mid-Eastern	Mixed	White
High School	3	3	164		7	12
Some college	1	2	26		6	9
Associates	1		29		4	5
Bachelors	9	3	37	4	11	22
Some graduate	1		2			10
Masters	3	3	19	1	9	13
Doctorate	2		4		1	3
I don't know	15	7	126	1	25	39

As far as exposure to astronomy (Survey question 11), no trend stood out by grade or ethnicity, suggesting that the scientific content would largely be new to all students.

Findings

A cursory analysis of data collected from pre- and post-surveys did not show an increase in average response to survey questions 5-10 when all students were taken as a single group, as expected. Instead, analysis of impact focused on subgroups in grade level, gender, ethnicity, and parent education. In each case, 90% confidence levels were used to display the range of the average for the entire set of all student participants (dark grey line and light gray bars in Figures 5-10). Thus, between the pre- and post-survey data displayed, a confidence bar that overlaps from left to right is not statistically different across all subgroups, while nonoverlapping gray bars represent statistical confident change. Meanwhile, size of dots on the plot represents average value indicated by students with standard error. Dots that overlap are statistically similar while non-contacting dots are statistically distinct. The same goes for dots that are in or outside of the grey bars for the entire set of students: a dot marker outside of the grey area can be read as statistically distinct from the average of all students at a 90% confidence level.

For example, Figure 5 captures pre- and post-survey responses, wherein the overall average value of interest in science across all grades is slightly higher after the implementation of the intern lessons, but not within a 90% confidence level. The data suggests higher favorability for science in later grades from both male and female students, however not so much so that it can be shown as distinctly different from the average response values. Thus, examinations of the responses determine that no specific grade or gender was impacted by the lessons. It is of note though that the average level of interest in science did increase over the course of the semester and became notably higher for higher grades than lower grades. 10th grade students were statistically similar in the pre-survey, with no difference in female students by post survey, yet growth from both from the average and their female counterparts by the end of the program.

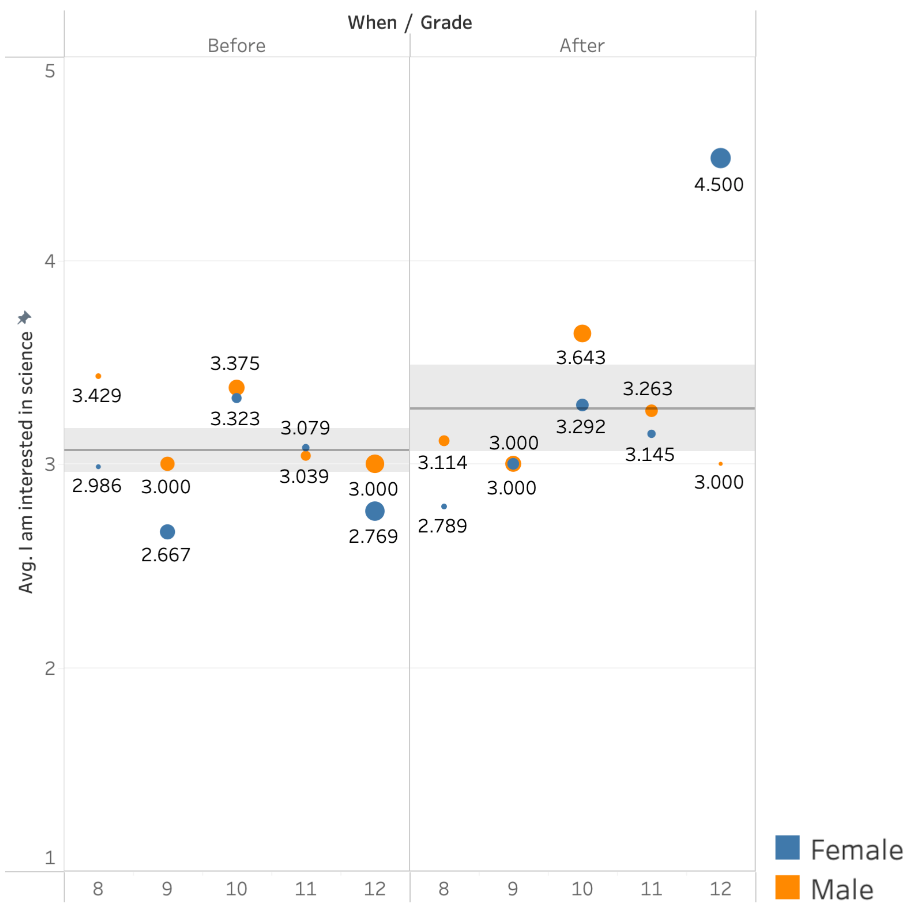

Figure 5. Interest in science by gender for all students grades 8-12. Dot size signifies value with standard deviation. Dark gray line represents average value for all grades before and after survey, with light gray representing the 90% confidence level.

Similar findings arose when students were asked specifically about astronomy (survey question 7). Here, however, 10th grade male and female students did display a greater favorability beyond their pre-survey results and the whole-group average.

By parsing the data to another level and observing grade by ethnicity, a more detailed analysis can be performed. For example, here it is observed that Latin students in particular saw growth in 10th and 11th grades, particular for male students (10% and 14% for 10th and 11th grade, respectively). Overall, most 8th grade students displayed a decline from pre- and post-survey data, suggesting that the unfamiliar or academically sophisticated content may have been off putting for lower grades. When looking at student interest in majoring in STEM (Survey question 8), the effects become much more pronounced. As seen in Figure 6, female grade 9 students move from being statistically similar to their male counterparts and below average in pre-survey data to within the overall average and distinct from male students in post-survey data. Like when asked about interest in science overall, 10th grade male students saw significant growth once again ($p = 0.13$).

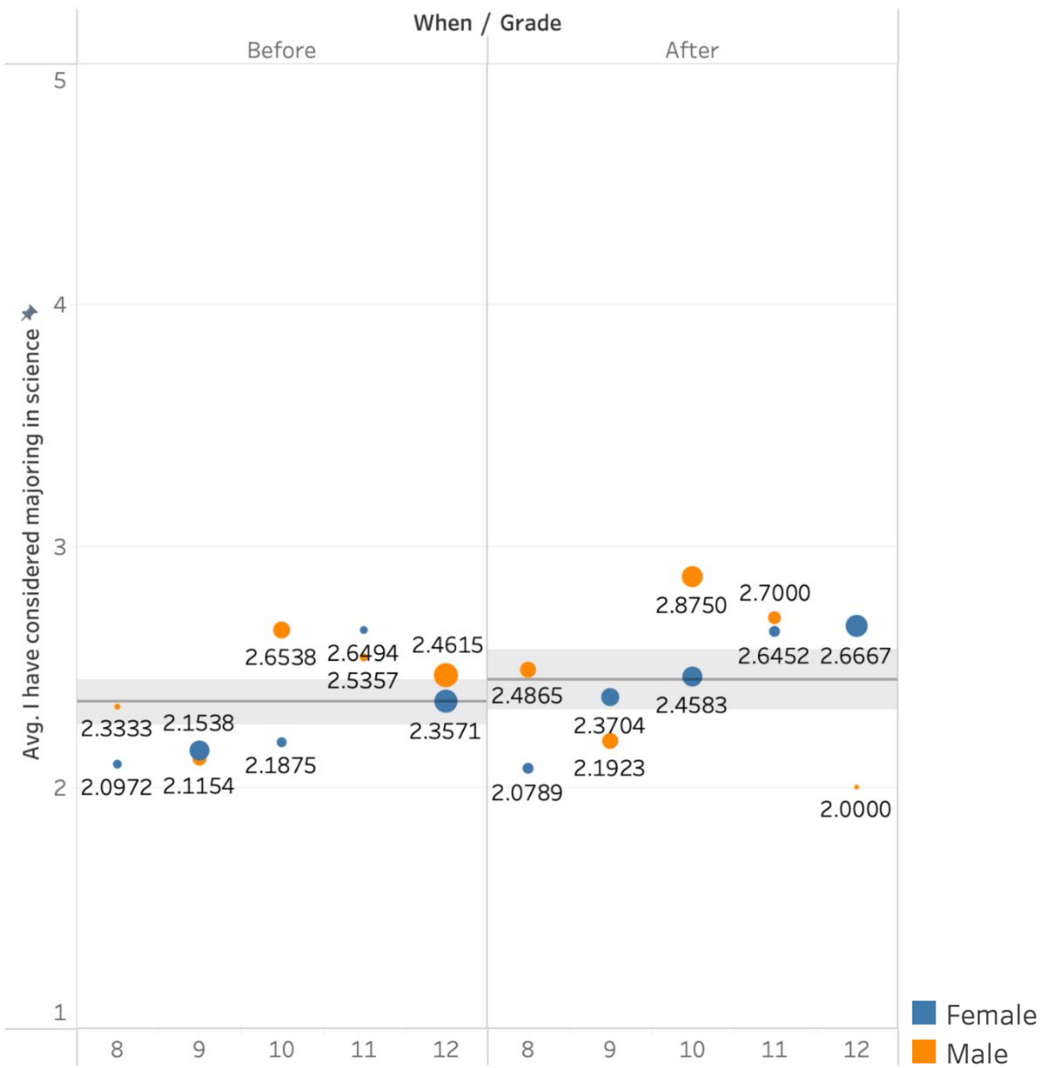

Figure 6. Desire to major in STEM field by gender for all students grades 8-12 including all parent education levels. Dot size signifies value with standard deviation. Dark gray line represents average value for all grades before and after survey, with light gray representing the 90% confidence level.

Of note while observing average values by ethnicity, the trends and relative averages show striking similarity. Aspirations for degrees in STEM show no statistically significant difference between ethnicities when looking at individual grade levels. However, when analyzing only students who indicated a parent education level of high school or lower, the numbers illustrate a stark difference in average values, revealing a much more pronounced growth from pre- and post-data figures, with p=0.07 (Figure 7).

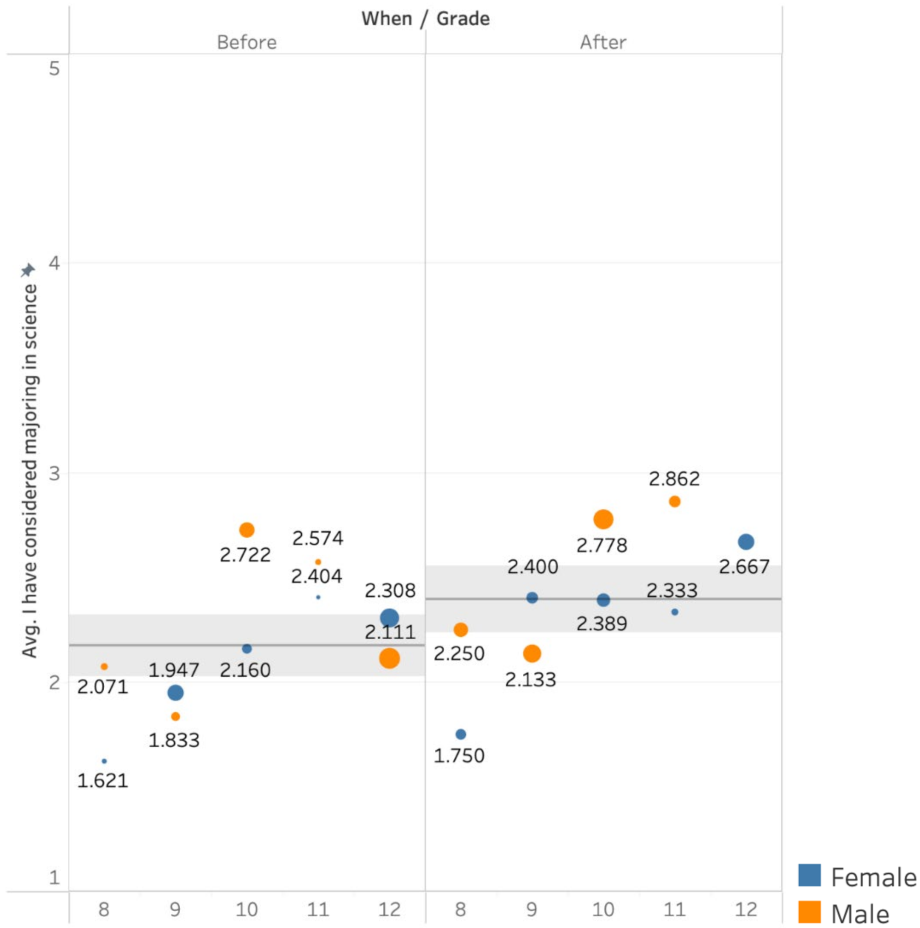

Figure 7. Desire to major in STEM field by gender for students grades 8-12 whose parents have not attended college (high school education or below). Dot size signifies value with standard deviation. Dark gray line represents average value for all grades before and after survey, with light gray representing the 90% confidence level.

Student responses in pre-survey data are almost uniformly lower than those from their higher educated parent counterparts, yet in looking at the post-survey data, responses become much more comparable, if not higher. This jump is most notable at higher grades, which, once more, may be indicative of the content age-appropriateness and college focus of the student interns. Lastly, driven by the degree of distance learning and asynchronous classwork, an exploration as to confidence in online and independent learning was performed. As per every question, a small but not statistically significant increase was observed, with attention given to subgroups. (Figure 8) Here, high school male students demonstrated the most pronounced improvement, with an average of 14% confidence boost between pre- and post-survey data (p=0.05). This upsurge couples with an increase of 12% in desire to attend college for the same students. Female students in this same subgroup observed a 0% and 3% growth respectively for the same two survey questions, but still recorded either equal or higher marks than their male counterparts in the average response (Table 3).

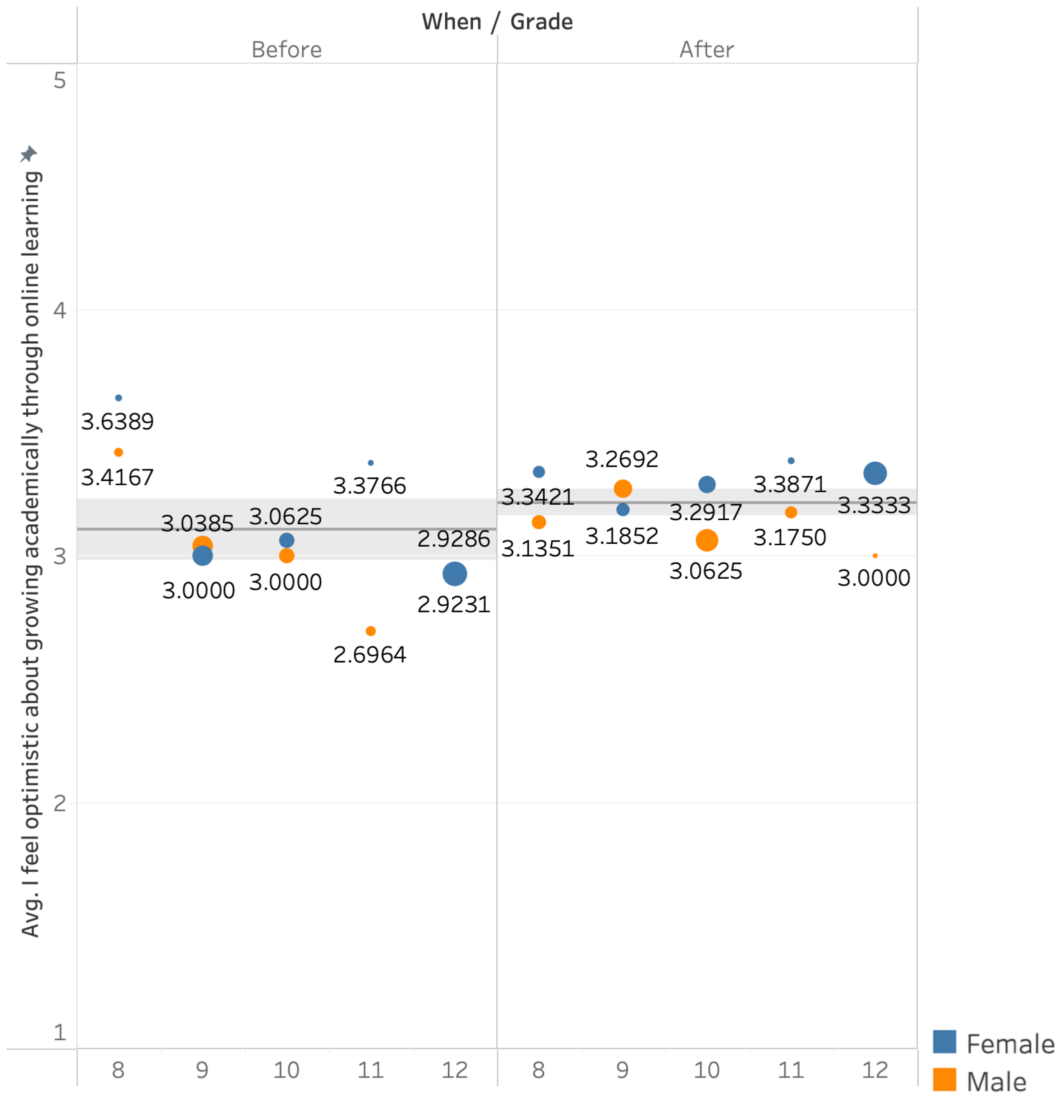

Figure 8. Optimism in online/independent learning by gender all students grade 8-12. Dot size signifies value with standard deviation. Dark gray line represents average value for all grades before and after survey, with light gray representing the 90% confidence level.

Table 3. Average student response for key survey questions in both pre and post implementation.

		Q5	Q6	Q8	Q10
BEFORE	Average	4.01	3.06	2.57	3.09
	Male	3.64	3.05	2.54	2.70
	Female	4.32	3.08	2.65	3.38

AFTER	Average	4.25	3.20	2.67	3.29
	Male	4.08	3.25	2.70	3.18
	Female	4.45	3.15	2.65	3.39

Confidence levels in online learning becomes even more pronounced when looking at the subset of students with parent education levels at high school or lower. The overall average falls not only lower, but the gap between male and female students broadens, with male students indicating a far lower confidence in virtual independent learning (Figure 9).

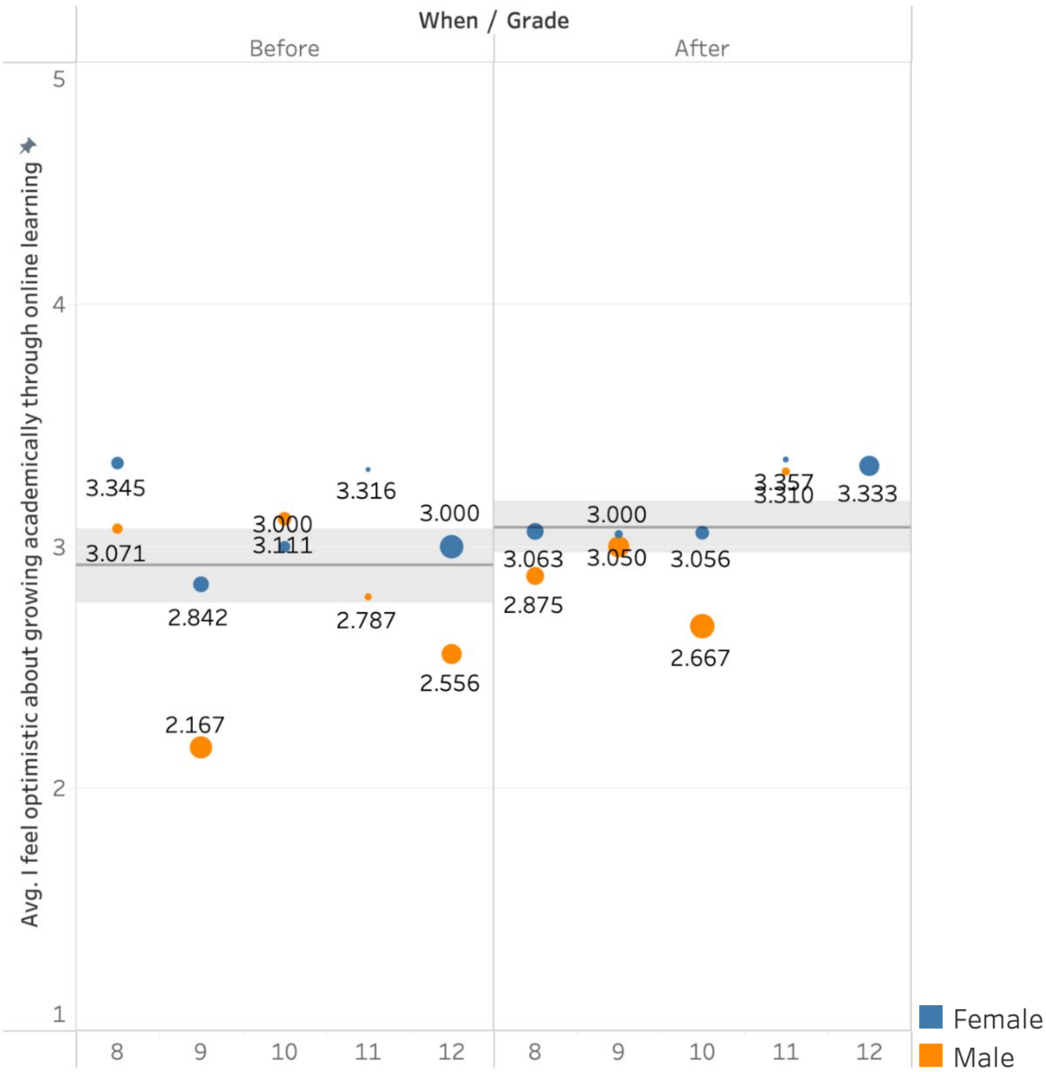

Figure 9. Optimism in online/independent learning by gender for students with parents who have not attended college.

Similarly, looking explicitly at the Latin students, we see this disparity further demonstrated and even further pronounced (Figure 10). Female students strongly tended to indicate greater interest in science and science careers than their male counterparts, with the gap widening in Latin males versus female students, and yet further again when parents did not hold college degrees or higher. Conversely, however, male students in these groups did demonstrate the highest growth from participating in these activities, allowing them to alleviate the disparity with their female peers.

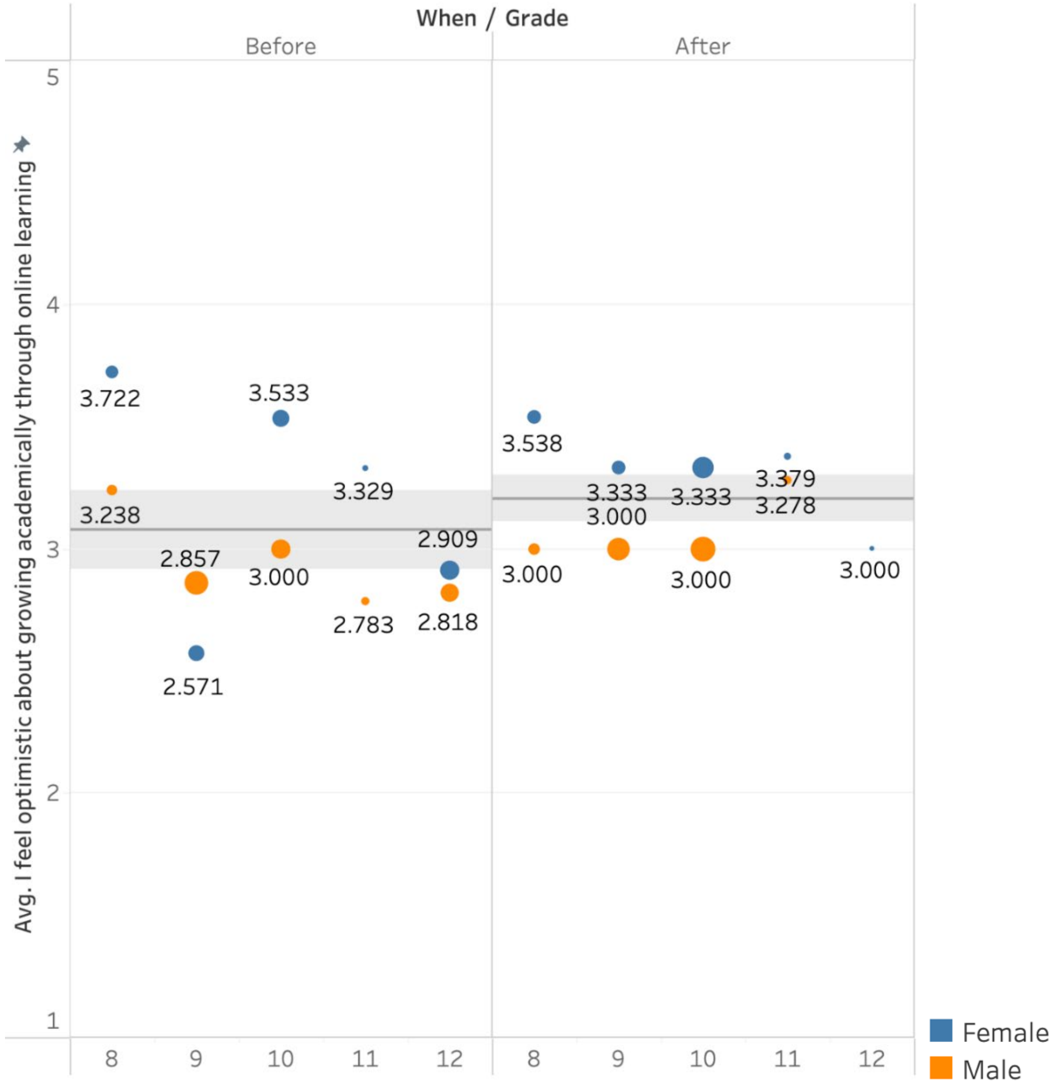

Figure 10. Optimism in online/independent learning by gender for Latin students.

Conclusions

Engaging young students in science will continue to be a complex pedagogical issue, with no one-size-fits-all solution. As such, it is not the purpose of this work to suggest that the methods employed always work for all students. However, what can be strongly argued is high school students, particularly higher grades, responded favorably in several respects when their curriculum incorporated the voices of young peer researchers.

The seminar having been developed by interns- who the classroom students never actually met- resulted in significant increases in desire to go to college, confidence in independent learning, and interest in STEM majors. This effect was most pronounced in male students, Latin students, and students with parents with only high school educations. An increase of 12% for Latin high school male students in desire to go to college and a 14% increase for the same group in confidence in online learning allowed for an at-risk demographic to begin to bridge the gap and apply to college to pursue careers in science fields.

Future work will further explore teacher background, as the fifteen participating teachers were not surveyed for their years of experience, delivery method, or confidence in the material, and certainly played a role in the overall student data. This will be explored with a larger second cohort of educators.

Most importantly, the inclusion of student voice in creating science activities provides a solution that is readily attainable. The existing field of research has clearly linked student science identity with access to parents or role models in STEM fields, but this does not prescribe a path of action for students in communities where these careers are underrepresented. Moreover, relying on scientific volunteerism for any substantial relationship-building presence with schools, too, stands as a tall order. Few schools can arrange for altruistic researchers or second-career classroom teachers with doctorates in science to commute and provide education for low-income schools. Instead, classroom teachers can and should include school alumni and students with internships into their lesson development and community of practice. Classroom educators can then focus on the standards alignment and educational goals, while students can speak to the content generation, providing insight as to what sparked their own engagement.

Declarations

- The authors have no relevant financial or non-financial interests to disclose.
- The authors have no conflicts of interest to declare that are relevant to the content of this article.
- All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.
- The authors have no financial or proprietary interests in any material discussed in this article.

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