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Maximizing Future Potential in Physics and STEM: Evaluating a Summer Program Through a Partnership Between Science Outreach and Education Research

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Abstract

Global competitiveness of the United States is often suggested as a key outcome of developing a capable science, technology, engineering, and mathematics (STEM) workforce, a goal supported by many local, state, and national programs. Examining the effectiveness of such programs, however, may require assessment techniques that are outside their organizers' expertise. The physicists conducting the physics outreach program in the current study partnered with education researchers at the same university to achieve a more thorough measure of program effectiveness while also demonstrating how such partnerships represent an opportunity to add rigor to current evaluation. The resulting analyses demonstrated that participants in the outreach program (a) were more likely than nonparticipants to pursue an education and career in STEM, (b) were able to define and execute plans to solidify a strong foundation for pursuing a career in STEM, and (c) persisted in pursuing education in STEM after high school graduation.

Introduction

Exposure to different types of careers can support students in developing a vision for their future and understanding the steps and choices necessary to achieve those careers *(Hamilton & Hamilton, 2006; National Center for Education Statistics, 2011)*. However, many students may not successfully transition into their envisioned careers, especially professions in mathematics and science, despite being academically prepared. High school students who are unclear about their occupational futures may find that they over- or under-estimate the amount of education they will need for the type of work they wish to pursue and lack a strategic plan for accomplishing their goals *(Csikszentmihalyi & Schneider, 2000; Sabates, Harris, & Staff, 2011; Schneider & Stevenson, 1999).* Students may also lack role models and experiences that impart the knowledge and strategies needed to transition from high school to postsecondary education and to realize their career ambitions *(Rosenbaum, 2001)*.

The years in which adolescents transition from high school to postsecondary education are particularly critical for developing ambitions and academically preparing for educational and occupational futures in the fields of science, technology, engineering, and mathematics (STEM). Several key policy reports in the United States have called for significant steps to increase the national STEM labor force *(National Academies, 2010; National Science Board, 2010)*, and several initiatives and reforms are being implemented from preschool to college to encourage and inform students about opportunities in STEM. The National Science Foundation (NSF), a significant source of funding for strengthening the STEM pipeline, spent over $1 billion in 2010 on education funding *(Gonzalez, 2012)*. Options for addressing STEM labor shortages are complex, but it is clear that STEM experiences should be integrated throughout the educational system *(National Research Council, 2011)*. Although there is and should be significant attention given to closing gaps in the pipeline for those students traditionally underrepresented in STEM, there is also significant value in encouraging already interested and motivated students to realize their ambitions of pursuing a STEM career. This study evaluates the role of precollege outreach programs in the support and development of talent in STEM fields.

Uniquely positioned as a bridge between universities and students in elementary and secondary schools, precollege outreach programs can play an important part in meeting the growing demand for an increased labor supply in STEM. The goals of the present study were twofold. The primary objective was to examine one college-outreach program dedicated to STEM outreach, the Physics of Atomic Nuclei (PAN), which seeks to expose students to careers in nuclear science and offer them practical research experience. The secondary goal was to examine how the interdisciplinary partnership between an outreach program in science and researchers in social science can improve the thoroughness of the program's overall evaluation in regard to its standing and effectiveness while also contributing to the research base as it relates to the role of outreach programs.

The secondary objective was motivated by research that has shown a lack of STEM precollege programs that are able to carry out statistically appropriate evaluations. Such programs often struggle to demonstrate their ultimate impacts *(U.S. Department of Education, 2007)*. Although the present study does not intend to provide an exhaustive review of collaborative evaluations conducted on precollege programs, a brief search conducted using Google Scholar with the keyword phrases "pre-college," "evaluation," and

"STEM" returned a mixture of different types of research studies appearing since 2008. The predominant mode of evaluating precollege outreach programs is the analysis of self-reported survey measures through either cross-sectional data collection or a pre-post design. These data can inform several areas in the evaluation of the outreach programs' effectiveness, as many of these studies have suggested; however, such studies also have limitations, such as the subjectivity of participants. Additionally, current research designs have often not been able to accurately capture any knowledge or skill acquisition that reflects outreach participants' experiences in the program. As a result, several studies also incorporated the use of an assessment to strengthen their program evaluation (e.g., *Bogue, Shanahan, Marra, & Cady, 2012)*. A third mode of evaluation used to understand the impact of precollege outreach in STEM was the examination of undergraduate students who reported their participation in a precollege outreach program prior to college (e.g., *Cohen & Deterding, 2009)*. These different modes of inquiry provide several perspectives into how students benefit from particular outreach programs. Ascertaining how a student would have responded without the treatment might theoretically be achieved by randomizing students to participate in these programs; such an act, however, could violate the very goals of the outreach. The present study used statistical methods to create a comparison group to examine how this program impacted its participants compared to nonparticipants.

To evaluate the influence of PAN on student participants, this study investigated three research questions: (1) What are the benefits of participation reported by the students?; (2) How do the PAN participants compare to a statistically matched sample from national data; specifically, what are the differences in educational and occupational interests conditioning on student characteristics?; and (3) What are the long-term implications for participants as reflected in follow-up data? Our multiple analyses offered evidence that students who participated in PAN were not only more likely to be interested in majoring in STEM than members of their matched comparison group, but that PAN gave them the knowledge, skills, and strategies necessary to successfully plan and pursue careers in physics and other STEM fields.

Connecting Talented Students With Potential Careers

To support national competitiveness in an increasingly technology-driven global economy, the U.S. government has invested heavily in developing a STEM workforce to meet future demand. Students interested in pursuing careers in growing fields can meet this need. As adolescents plan their future education and occupations, knowledge of different careers can help them identify and take pragmatic steps to achieve their career goals (*Rosenbaum, 2001; Schneider & Stevenson, 1999).* However, this process of developing interests and pursuing the steps necessary to achieve career goals is not always carried out.

Of the students who finish high school academically prepared to pursue a variety of career opportunities, many never reach their occupational goals. Such students may falter because they lack access to the necessary information for developing a strategic plan to achieve their goals and may under- or overestimate the level of education they need *(Schneider & Stevenson, 1999)*. The ability of students to attain their career goals can be impeded if they are not able to articulate and understand the appropriate pathways from secondary education through college and into a chosen career. This alignment of ambitions and the education required to attain them is especially important for students pursuing careers in STEM; in prior research, students have reported difficulty in identifying realistic strategies that would help them achieve their career goals, such as how to select coursework and extracurricular activities appropriate for STEM careers *(Csikszentmihalyi & Schneider, 2000; Schneider & Stevenson, 1999)*. Parents and family are also important factors in the way students develop future goals and ambitions *(Hossler & Stage, 1992)*. Like these students, parents and family members may lack information about the specific requirements, options, or courses needed for acceptance by more selective colleges or the preparation needed for specific STEM careers.

University-based outreach programs can supplement K-12 education in improving several student outcomes, especially in STEM, including interest, knowledge, skills, and the development of postsecondary expectations *(National Academies, 2007)*. Some programs provide STEM-related professional development for teachers, leading to more effective instruction for students *(Moskal & Skokan, 2011)*. Outreach through summer camps in particular can be a successful strategy to advance student outcomes in STEM *(Foster & Shiel-Rolle, 2011)*. However, there is a dearth of studies that demonstrate their effectiveness in improving attitudes about and understanding of scientific pursuits.

Prior studies that have followed students from adolescence into adulthood showed that the selection of postsecondary institution, choice of college major, and interest in pursuing a career in STEM were associated with being able to *visualize* oneself as a college student, transform interests into *realistic actions*, and create *strategic plans (Schneider, Judy, & Mazuca, 2012)*. The current study used this framework of visualization, realistic actions, and strategic plans to understand how college-outreach programs can support each step in this transition process by (a) providing opportunities for students to visualize themselves as college students, often through on-campus experiences; (b) suggesting realistic actions and activities for students to hone their interests; and (c) supporting the development of strategic plans so students can successfully attain their educational and career goals.

Physics of Atomic Nuclei Program (PAN)

PAN is a precollege outreach program that informs students about careers in nuclear science and offers authentic research experiences for student participants. This program is a partnership between two NSF-funded entities: the Joint Institute for Nuclear Astrophysics (JINA) and the National Superconducting Cyclotron Laboratory (NSCL). JINA is a multi-institutional NSF Physics Frontier Center, a large collaboration between the primary partners of three Midwestern universities and other national and international partner organizations. JINA brings together nuclear experimentalists, nuclear theorists, and astronomers to collaborate on problems related to nuclear astrophysics. PAN is fully funded by JINA as one of its premier outreach programs, making it free to participants.

PAN is hosted by a world-leading rare isotope research facility located on the campus of a large Midwestern university. This nuclear laboratory hosts over 1,300 users from 35 countries and maintains one of the top-ranked nuclear science graduate programs. The lab contributes facilities; equipment; and additional faculty, staff, and students to support PAN. Hundreds of students from across the United States and some foreign countries have been attracted to PAN over its 20-year history. Throughout the program's evolution, the primary goal has always been to build student interest and knowledge in the field of nuclear physics. Student participants are prospective future researchers and are treated as such.

Many precollege outreach programs focus on exposing students from underrepresented groups to STEM careers. PAN seeks and accepts students from such groups, but the nature of the program draws applicants who typically are highly intelligent, science-focused, and self-motivated. It is recognized that these students usually have significant resources already, such as supportive and knowledgeable parents and access to advanced learning opportunities. Rather than introducing participants to science in general, PAN aims to support and channel their enthusiasm for science into potential college majors and specific careers in research.

PAN consists of an intensive week-long experience in the summer, featuring days packed with up to 12 hours of programming. Daily activities include one or two introductory-level lectures by JINA/NSCL faculty regarding current research, experimental methods, and detector technology. Each lecture is followed by a structured question and answer session where teams of participants can interact with the presenter. Through the students' evaluation of what was clear and unclear in the presentation, the presenter obtains valuable feedback, and the students gain further clarifications. Before beginning any research in the lab, training sessions are held to ensure that participants can safely and effectively pursue the research program. Students then conduct a series of experiments using a $1 million scintillation detector. They learn to use this detector to identify the location of a radioactive source, gain experience with the data-acquisition software, and track cosmic rays as they pass through the detector. Through this sequence of steps, they build their knowledge and confidence until they begin pursuing research in much the same way NSCL users would, making it an authentic experience. Finally, students design and present a poster explaining their research at the capstone session of the program. This exercise teaches the student participants what content is appropriate for reporting results and familiarizes them with methods of presentation, both of which are fundamental and integral components of research at any level. Evening programs supplement the above activities by acclimating the students to campus life. These auxiliary programmatic events help the participants visualize themselves as college students in this field, engage in college-level work, and continue their development of strategic plans for postsecondary pathways and opportunities in physics.

Ultimately, PAN is intended to help students see themselves pursuing a research career by (a) promoting the importance of nuclear research; (b) teaching the discipline and current topics of nuclear astrophysics; (c) introducing students to undergraduate/graduate life at a university; (d) demonstrating the nature of pure science and research careers, particularly in nuclear science; and (e) fostering interest in nuclear physics/astrophysics.

Because JINA and NSCL receive grants from the NSF, pre-college outreach programs like PAN are intended to fulfill NSF's Broader Impacts goals in these ways:

1. promote teaching, training, and learning by introducing nuclear astrophysics to new audiences;
2. broaden participation among underrepresented groups by recruiting more female students for the program;
3. enhance education partnerships by providing teachers and students with long-term support: assistance, materials, and further outreach opportunities;
4. disseminate information broadly by sharing it with the teachers of tomorrow's scientists; and
5. benefit society by encouraging science literacy and knowledge of how nuclear astrophysics affects society.

PAN sought and earned approval from the university's Institutional Review Board to collect student survey data and use it for improvement and research. Following all assent/consent and confidentiality guidelines, PAN has amassed many years of data about the effectiveness of the program through exit surveys and anecdotal evidence from alumni, but lacked expertise in assessing the success of the program relative to its goals. Some efforts to this effect have been made in recent years in collaboration with other precollege programs on campus. However, the program director and advisory committee recognized a need for a more detailed analysis to satisfy the NSF mandate, and thus formed a partnership with the College of Education at their university.

Over the past 3 years of this partnership, the survey instruments have been updated to not only include students' self-reports of their experiences, but also new items drawn from national surveys that have been validated and will allow PAN participants to be compared to a control group—a necessary comparison for understanding the impacts of the outreach and for demonstrating evidence of its effectiveness.

Method

Sample

Because PAN intends to inspire students to study science at the college level, and particularly to give them experience in research so they can make an informed decision about their future careers, the preferred candidates are those who show a clear desire and drive to pursue science. Students demonstrate this on their application by indicating such academic and extracurricular choices in high school as regularly enrolling in science and math courses, joining science-related clubs and similar extracurricular activities, committing to science programs and camps outside school, seeking out reading and other material to further their science knowledge, and applying to PAN as a way to investigate a science career. It is important to note that the application requires no GPA or test scores.

Applications must also include two teacher recommendations, which are rated by the following criteria: whether the teacher instructed the student in science/math; amount of interaction between the teacher and student; specific instances where the student has "gone the extra mile" to learn more; the teacher's rating of how inquisitive the student is, particularly if the teacher cannot answer all of his/her questions; and the teacher's rating of the student's motivation, independence, and maturity.

As one of the few summer programs in nuclear science, PAN is quite popular for students who are seeking that specific experience. Due to budget and equipment limitations, the program can accept only 24 students per year. To help promote gender parity, an equal number of male and female participants are selected. It is generally (and usually correctly) assumed that students seeking out PAN have a keen interest in science but little to no background in nuclear astrophysics, and thus all students can begin their instruction from the same level of knowledge and be successful.

Table 1 shows the applicant pool from 2007–2012. Over those 6 years, the applicant pool increased in size, and the acceptance rate declined as the program became necessarily more selective. In 2012, 179 students applied for the 24 spots, leading to an acceptance rate of just 13%. Overall, consistent patterns of applicants can be observed from year to year: more males than females apply, there is generally a larger proportion of in-state students compared to out-of-state applicants, and White students make up the majority of the pool. Given the sharp increase in applications in later years, it is important to note that between the 2008 and 2009 programs, PAN organizers completely changed advertising strategies. Before 2009, PAN was promoted by physically mailing letters to in-state high schools, but in early 2009, it was featured in several teaching and physics magazines as well as through electronic media. This campaign reached a wider audience, and eventually PAN transitioned from having only an in-state presence to gaining a broader national audience. This increased exposure created larger applicant pools and resulted in a more demanding selection process so that the admitted students tended to be highly self-motivated with extreme interest in science.

Table 1. Demographic Characteristics Applicants

			Percentage of Applicants								
Applications by Year	Total Applications	Acceptance Rate	Gender		Race/Ethnicity*				Location	
			M	F	W	B	H	A	M	O-O-S
2007	47	51.06%	62%	38%	--	--	--	--	87%	13%
2008	37	64.86%	73%	27%	--	--	--	--	86%	14%
2009	91	26.38%	63%	37%	70%	5%	3%	20%	85%	15%
2010	82	20.27%	60%	40%	72%	7%	13%	22%	55%	45%
2011	127	18.90%	76%	24%	70%	8%	6%	17%	59%	41%
2012	179	13.41%	76%	24%	68%	8%	5%	17%	49%	51%

Note. Race/ethnicity data not collected in 2007 and 2008. M= Male, F= Female, W= White, B= Black, H= Hispanic, A= Asian, M= Michigan, O-O-S= out-of-state.

To allow for comparative analyses of PAN and these rigorously selected students, a comparison sample of students from a national data set, the *Education Longitudinal Study: 2002 (ELS:2002)* was used. This data set is a nationally representative longitudinal study designed to help understand the transition of adolescents from high school through postsecondary school and work. This data set represents the most recent available longitudinal study with postsecondary outcomes. Currently, three waves of data are available: the base year sample from 2002, when students were in the 10th grade; the first follow-up during their 12th grade year in 2004; and a second follow-up in 2006. In the base year, over 16,000 students were surveyed in over 750 schools. A restricted sample of students from this data set was used as a comparison control group; the selection of this sample is detailed in the following section.

Data and Analysis

Data in this study were drawn from a diverse set of sources, including student surveys, qualitative participant data, follow-up data from former participants ("PAN alumni"), and, for the comparison group, data from *ELS:2002.* To address the first research question of how students benefit from participation in PAN, multiple years of survey data were descriptively analyzed. Data collected on student survey instruments included (a) satisfaction with PAN activities, (b) perceived benefits of their participation, (c) postsecondary and career aspirations, and (d) open-response items regarding the influence of PAN on their educational and occupational plans. To observe the long-term implications for PAN participants, follow-up data obtained from an online survey of PAN alumni was descriptively analyzed to ascertain whether participants continued in their pursuit of physics or other STEM-related majors in college and their current occupational goals.

Because of the select nature of PAN participants, to address the second research question of the program's effectiveness on the outcomes of educational and occupational interests in STEM, a comparison group of students was created from *ELS:2002* using propensity-score matching techniques. Participants with complete survey responses who participated in the PAN programs in 2011 and 2012 (n = 30) were matched to students from *ELS:2002* data on a comprehensive set of variables that included gender, race, attitudes toward math and reading, parental education level, parent interaction characteristics, and postsecondary ambitions and behavior. The selectiveness of the PAN acceptance criteria created a very narrow group of students in the *ELS:2002* sample that statistically met the criteria, such that a group of 38 students were identified as the control group using nearest neighbor matching and after covariate balance was achieved.

Results

Table 2 shows that not only did students enjoy the program, but over time, there was an increase in the percentage of students reporting that PAN influenced their interest in science, educational goals, and career plans. Participants had already self-identified as having an interest in science, so it is not surprising that they demonstrated high satisfaction with their research experience at PAN. Indeed, it proved difficult to measure changing attitudes toward science given that PAN participants already had greater interest in science than the average high school student.

PAN staff used survey feedback on specific PAN activities to improve programmatic components over the years and thus provide a better experience for students. Common trends from survey results drove two very important changes to PAN. First, participants highly valued the parts of the program that included contact with faculty and graduate students. PAN activities have therefore evolved to maximize opportunities for participant interaction with faculty and graduate students. The second highly valued aspect of

PAN was having an increasingly authentic research experience. Thus, new training sessions and experiments with the scintillation detector were introduced. The increased opportunities to work with faculty and graduate students in an environment providing authentic, hands-on research experiences help students visualize themselves as scientists and researchers. The visualization component is crucial to their experience, as it can illuminate areas of their own knowledge and skill development that they might need to improve through strategic planning while in high school, such as how they select their coursework.

Table 2. Descriptive Analysis of Participants

	Percentage of students who agreed that PAN...						
	2007	2008	2009	2010	2011	2012	Total
Increased interest in science	79%	87%	83%	100%	100%	100%	92%
Influenced career plans or future course selections	68%	70%	96%	96%	100%	96%	88%
Provided overall enjoyment of the program	89%	96%	92%	100%	100%	100%	96%

Source: PAN Student Survey

Over the years, it has been common for students to report that their perception of research careers underwent a dramatic shift during PAN. Experiencing the life of a researcher for oneself proved to be a powerful catalyst, especially when there was a large difference between perception and reality. Being placed in the role of a researcher and developing relationships with current researchers allowed PAN participants to identify with a previously unknown or misperceived career. The experience thus supported the transformation of a participant's general interest in science to a more specific and active one, wherein students began to visualize themselves in this career and were able to take strategic steps to become future scientists based on their personal experiences in the field. Open-ended responses from the PAN participant and alumni surveys were coded into two themes consistent with the visualization, strategic planning, and realistic actions framework: (a) their perceptions about careers in physics/STEM and their visualization of themselves as a future researchers and (b) the development of their strategic plans to pursue a career in physics/STEM.

One participant noted that "PAN made me realize how innovative scientists need to be, and to think outside the box." A PAN alumnus refuted a common stereotype of a scientist working alone and in isolation: "My favorite part of PAN was the fact that it incorporated teamwork, lecture, and hands-on research; this allowed us to work all parts of our brain as it simulated a real world multifaceted research experience." A crucial aspect of PAN is taking students who have an interest in science or physics and helping them develop that general interest into a career. One alumnus reflected on the influence of the program:

> I think the PAN program was great! I knew I had a peripheral interest in science as a high school student, but PAN showed me that this interest was worth pursuing in college. Now I'm a graduate student in astronomy, and I think getting involved in science early on had a great deal to do with my career choice now.

Again, PAN students are already highly interested and motivated students, but PAN supports the sharpening of their focus in regard to defining next steps and creating strategic plans so that they can solidify a strong foundation for pursuing a career in STEM, particularly in nuclear astrophysics.

There were, however, a few alumni who noted that PAN led to the discovery that experimental physics was not for them. Such an assessment still helps students develop future educational and occupational plans in the positive sense, leaving open the possibility of work in a different area of science.

Table 3 provides a summary of the PAN alumni postsecondary interests. All of the former participants report *planning to attend, attending,* or *graduating from college*. Of the alumni who completed the follow-up survey, 87% planned to major in or were currently majoring in STEM, 40% planned to major in or were currently majoring in physics, and 40% had the educational expectation of pursuing a Ph.D. Although only 152 former participants were able to be contacted for follow-up, and not all of those contacted responded, these percentages still provide evidence as to the opportunities that participants pursue after high school.

Table 3. PAN Alumni Outcomes

n = 45 respondents	%
Planning to attend, attending, or graduated from a 4-year college	100
Planning to major in or majoring in STEM	87
Planning to major in or majoring in physics or astrophysics	40
Planning to pursue a Ph.D.	40

Note. Data from the PAN Alumni Follow-Up Survey 2012.

Due to the highly selective nature of the PAN program, selection bias made estimating effects of the program challenging. Propensity score methods can provide one way to compensate for this bias. The primary advantage of using propensity score matching is that the likelihood of participating in PAN for nonparticipants (or students with similar potential to attend PAN) can be estimated given the characteristics of the PAN students *(Schneider, Carnoy, Kilpatrick, Schmidt, & Shavelson, 2007).* This essentially creates statistically equivalent groups of students that have equal propensities to be in the treatment group. Table 4 shows the similarities between the PAN students (treatment) and *ELS:2002* students (control).

Table 4. PAN Participants and *ELS:2002* Comparison Group

	Students		**Significance Test**	
	PAN	ELS	X^2	p-value
Total number of students (n)	30	38		
Student Background Characteristics (%)				
Male	50%	45%	0.19	0.67
Minority (Black and Hispanic)	10%	8%	0.09	0.76
Student Educational Expectations (%)				
Complete a master's degree	13%	30%	2.56	0.11
Complete a Ph.D.	87%	70%		
Student Attitudes and Behaviors (%)				
Gets totally absorbed in mathematics	100%	95%	3.38	0.18
Thinks math is fun	97%	97%	0.04	0.98
Thinks math is important	97%	97%	1.23	0.54
Born with math ability	43%	43%	1.57	0.67
Gets totally absorbed in reading	97%	97%	0.67	0.71
Thinks reading is fun	97%	97%	1.45	0.48
Reads in spare time	93%	89%	4.28	1.45
Parent Characteristics (%)				
At least 1 parent holds a bachelor's degree	87%	89%	0.13	0.72
Parent frequently checks homework	0%	0%	*	*
Student frequently discusses grades with parent	77%	89%	2.03	0.15
Student frequently discusses courses with parent	67%	87%	2.03	0.15

	Students		Significance Test	
	PAN	ELS	X^2	*p*-value
Student frequently discusses college wtih parent	97%	97%	0.03	0.87
Average number of postsecondary institutions applied to	8	7	-2.02**	0.05

Note. Data from NCES *Education Longitudinal Study of 2002 (ELS:2002)* and PAN Student Survey 2001 & 2001.
* No test performed, exactly equal. ** *t*-statistic from a two-sample test (equal variances).

On almost all covariates, there were no significant differences between the groups. However, two variables did show significant differences between groups. One was the frequency of students' discussing courses with their parents. PAN students showed slightly less frequency for this behavior, which may be due to differences in high schools between 2002 and 2012. Particularly in the state where this program is located, credits and standards have increased, so students have fewer choices regarding their course-taking. Currently, students must take 3 years of science and 4 years of math, including Algebra II. These more standardized coursework options might mean students have less reason to discuss course decisions with parents. The second variable that was statistically different was the number of postsecondary institutions to which students applied. We argue that this is not practically significant—a student who applies to seven institutions looks largely similar to one who applies to eight (with equal variance).

Given the statistically insignificant differences between these two groups, the final analysis used the treatment variable PAN to estimate the effect of participation using a logistic regression on the two outcomes: interest in STEM major (1 = *yes* and 0 = *no*) and STEM career (1 = *yes* and 0 = *no*). As reported in Table 5, PAN students' likelihood of pursuing a major in STEM was almost nine times that of nonparticipants. For students who participated in PAN, the likelihood of desiring a career in STEM was eight times that of the control group of students. All models were estimated with robust standard errors, and student covariates were not used as explanatory variables for either model because these controls were used to create the groups. Sensitivity analyses using these background characteristics in the models only increased the effect of PAN; thus, the ratios presented represent the most conservative estimates.

Table 5. Logistic Regression of PAN Participants on STEM Major and Career

	Major in STEM			STEM Career		
	Odds Ratio	*SE*	*p*-value	Odds Ratio	*SE*	*p*-value
PAN Program	9.99	6.95	0.001	9.23	5.57	0.000

Note. Data from NCES *Educational Longitudinal Study of 2002 (ELS:2002)* & PAN Student Survey 2011 & 2012.

Discussion

Evaluation of the PAN program is key for identifying strengths and weaknesses in implementation to improve programmatic features each year. Furthermore, such evaluation is critical to the funding and sustainability of outreach programs similarly aiming to strengthen the future opportunities of individuals in the STEM fields. PAN is an example of how outreach programs can specifically respond to the call to strengthen the pipeline of talent into STEM by helping students visualize, take realistic actions, and create strategic plans to pursue a career in physics and STEM. As described in this study, PAN provides students who are already highly interested in science with an experience that can solidify their interest into pursuing majors and careers in relevant fields. Similar students who are interested in physics and STEM who have not had such opportunities to gain insight into the field or hands-on experience in this career might fail to take the necessary steps to align their ambitions with postsecondary and occupational goals and may "leak" from this STEM pipeline.

This study presents possible evidence of the short-term and long-term impact of PAN on participants. In the short term, participants reported high levels of satisfaction with PAN and provided evidentiary support for how PAN encouraged the development and realization of their postsecondary and career goals. Comparing PAN students to similar students who did not participate in PAN illustrated the strong influence of PAN on the outcomes of pursuing a STEM major and a career in the STEM field. In the long term, a significant majority of PAN participants remain committed to pursuing a future in STEM. Although some alumni reported that PAN helped them decide not to pursue a career in physics or STEM, the program nonetheless supported the students' development of educational and occupational plans, though potentially in a different field of study.

It is worth noting that our findings are suggestive rather than conclusive about the effects of PAN. Although we argue that the statistical approaches used provide strong inferential evidence of the impact of PAN for participants, this study has several limitations. First, we acknowledge the selective nature of the application process and recognize that when selecting our comparison sample, we were unable to control for both the interest in physics specifically and the application process of attending PAN. This study was also limited by the small sample size of 24 participants each year. Although we were able to combine the previous 2 years of participant data, we also lost participants from the sample who did not complete all of the necessary pre- and postsurvey questionnaires. However, we argue that since these students are largely similar in background characteristics and interests, this response rate does not alter the overall analysis. Lastly, not all alumni responded to the follow-up survey. This shortage of alumni responses could contribute to an overrepresentation of PAN alumni in STEM because the alumni who continued to pursue physics or other related fields may be more likely to respond than those who are no longer interested.

Although the indication that PAN plays a role in students' selection of STEM careers proves satisfying for the program organizers, both the process of assessment and its ultimate result will have profound impacts on the future of PAN and other similar programs. As stated earlier, the analysis of the data was significantly delayed by the inexperience of those who collected it. The identification of a control group for comparison with the PAN participants proved singularly difficult. The requirements for generating such a group and the kinds of comparisons available will influence the kinds of survey data that will be collected in subsequent programs. Organizers will actively seek assistance from assessment experts for subsequent analyses. Other, less established programs would benefit from such scrutiny much earlier in their tenure. The STEM precollege landscape is not suffering from a dearth of programs, but it may find extraordinary value and the affirmation of funding agencies in the pursuit of connections to education researchers and a data-driven evaluation. A sister program at a nearby university reproduces much of the same experience for their summer outreach program and will likely take advantage of lessons learned through this study.

PAN exit survey results have consistently shown that it is impossible to satisfy everyone. Over the years, many participants have questioned program choices and have made thoughtful suggestions. PAN organizers have always debated whether requested changes would truly maximize program impact or simply make the participants happier. The principles of faculty interaction and laboratory immersion will continue to drive decision-making for future changes as PAN evolves. The consistent support for these two aspects in survey responses and the way they have been cited by alumni demonstrate their effectiveness and will make it easier to sift through options for PAN in the coming years. Indeed, the process of assessing PAN has brought into sharper focus (a) who the target audience is and (b) the PAN strategy for reaching that audience. That this was made possible by a cross-campus partnership also suggests that arenas for many similarly productive collaborations are just waiting to be discovered.

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