STEM-ID Annual Report 2018
Reporting period October 2017-August 2018

Introduction

The education research component of the Pulsar Search Collaboratory (PSC) seeks to determine how the PSC experience affects the science identity and STEM career intentions of its participants and how individual programmatic elements influence persistence. These questions are investigated by comparing pre-survey and post-survey results and by examining the participant's interaction with the PSC online portal.

In order for students to become fully certified to participate in the PSC, they must complete several steps. First, they must join a "team" set up by their teacher and register with the program. Once registered there are multiple training videos and documents for the students to review to learn how to properly identify pulsars from the data. Once students have fully reviewed these materials on their own or as part of their school's PSC club, they are required to complete two sub-tests of their pulsar grading skills to become fully certified to score pulsar plots as members of the PSC. This process requires them to pass both tests with perfect scores, but does not limit the number of attempts. Once they have passed both tests, they can begin to examine and score original pulsar data in an attempt to identify new pulsars. Students who score a sufficient number of pulsars are eligible to participate in a capstone event or to attend PSC summer camp.

Teachers use the PSC in many ways. Some form optional afterschool clubs, some use the data and scoring activity as part of their curricula, and some use the data to support student participation in other science activities.

Measures

The PSC survey examines participants' STEM intentions along a number of dimensions: Science/Engineering Identity, Self-Efficacy, Science Career Interest, and Sense of Belonging. Each construct is probed with multiple Likert scale questions. The individual questions are presented in the appendix. Exploratory Factor Analysis (EFA) showed that each of the constructs factored separately. Further, EFA within the individual sub-scales showed the Science/Engineering Identity, Self-Efficacy, and Science Career Interest sub-scales as single factors while the Belonging sub-scaled separated into three sub-factors: Recognition (by teachers, mentors, etc.), Belonging Amongst Peers, and Negative Feelings. Confirmatory factor analysis demonstrated that the belonging sub-scales were robust producing a Comparative Fit Index (CFI) of 0.96.

Methods

For students participating in the PSC, pre-surveys were distributed through the PSC Web-Portal before completing any training and post-surveys at the end of the academic year. Surveys from a control sample of students, i.e. students in the same science classes at the same schools as PSC participants but not in the PSC, were also collected. For those students participating in the control sample, surveys were collected in their science class and sent to the PSC research team for analysis on a similar time scale to that of the PSC participants. Mean levels for each individual item for both the Pre and Post surveys can be found in the Appendix. All items were scored on a 5-point scale.

There were 263 complete records in the pre-survey for PSC participants and 149 in the control sample. For the post-survey, there were 103 PSC participants and 149 control survey participants (only matched control survey pairs were retained). Additionally, there were 103 matched pairs on the Pre and Post surveys for the PSC participants and 149 matched pairs in the control sample.

Results

PRE-Survey: PSC Participants vs Control Participants

Table 1 presents a comparison of subscale means between PSC participants and the control sample for the pre-survey. T-tests showed that there were significant differences between the groups in the domains of Self-Efficacy, Science Identity, and STEM Intentions. This result was expected; students choosing to participate in a STEM-focused activity should be more likely to already have a greater affinity for STEM above that of other high school students. Cohen's d was used to characterize effect sizes. Cohen's convention indicates 0.2 as a small effect, 0.5 as a medium effect, and 0.8 as a large effect. The differences in Self-Efficacy, Science Identity, and STEM Intentions represent all very large effects.

Table 1 – Pre-Survey Results

	Mean ± SD		t-test	
	PSC Participants (N = 263)	Control Participants (N = 149)	t	Cohen's d
Self-Efficacy	76.4 ± 16.7	56.7 ± 20.5	9.99[c]	1.08
Science Identity	67.4 ± 12.1	53.2 ± 14.3	10.23[c]	1.10
STEM Intentions	77.5 ± 20.1	53.8 ± 24.4	10.08[c]	1.09

"a" p < 0.05, "b" p< 0.01, "c" p<0.001

Table 2 presents a comparison of post-survey results for PSC students and students in the control sample. With the sample sizes finally large enough for statistical conclusions at the highest confidence levels, it appears that differences in the mean levels of Self-Efficacy, Science

Identity, and STEM Intentions remain large on the post survey, though smaller than on the pre-survey.

Table 2 – Post-Survey Results

	Mean ± SD		t-test	
	PSC Participants (N = 103)	Control Participants (N = 149)	t	Cohen's d
Self-Efficacy	74.4 ± 22.8	57.7 ± 21.5	5.83[c]	0.76
Science Identity	72.9 ± 22.2	53.9 ± 20.4	6.89[c]	0.90
STEM Intentions	71.8 ± 24.3	52.3 ± 26.7	6.01[c]	0.76

"a" $p < 0.05$, "b" $p < 0.01$, "c" $p < 0.001$

Table 3 presents matched pre-survey and post-survey results for PSC students and Table 4 similar data for Control group. The results show a general decline in both Self-Efficacy and STEM intentions for PSC students with an increase in Science Identity. The control group, by contrast, does not show a significant change across any of the domains. We hypothesize that the decrease in Self-Efficacy and STEM Intentions was caused by multiple factors such as an inflated sense of both at the start of the PSC due to excitement over participation in the event. As time passes and the PSC becomes a normal part of the student's life and the difficulties associated with participation in a "real" science project set in a student gains a more realistic understand of what science is. Even with these decreases, these students still have significantly higher Self-Efficacy and STEM Intention than their control sample peers.

Table 3 – Matched PSC Participants Pre/Post-Survey Results

	Mean ± SD		t-test	
	Pre-Survey (N = 103)	Post Survey (N = 103)	t	Cohen's d
Self-Efficacy	78.1 ± 17.3	74.0 ± 22.1	-3.19[b]	0.21
Science Identity	67.9 ± 13.9	72.7 ± 21.6	3.26[b]	0.26
STEM Intentions	77.9 ± 21.7	71.3 ± 24.7	-4.33[c]	0.28

"a" $p < 0.05$, "b" $p < 0.01$, "c" $p < 0.001$

Table 4 – Control Participants Pre/Post-Survey Results

	Mean ± SD		t-test	
	Pre-Survey (N = 149)	Post Survey (N = 149)	t	Cohen's d
Self-Efficacy	56.7 ± 20.5	57.7 ± 21.5	0.44	0.05
Science Identity	53.2 ± 14.3	53.9 ± 20.4	0.35	0.04

STEM Intentions	53.8 ± 24.4	52.3 ± 26.7	+0.53	0.06

"a" $p < 0.05$, "b" $p < 0.01$, "c" $p < 0.001$

Qualitative Research

While quantitative research in the form of surveys and web analysis is helpful, qualitative work is needed to fully understand the PSC experience. Student focus groups have yielded valuable insight into the program.

Questions asked of students included: What is your favorite (and least favorite) part of the PSC? What is the most interesting thing you learned? Which activities were most helpful for your learning? What would you add to the PSC? Why have you chosen to participate in the PSC over other opportunities? How has the PSC affected your career path? What have you learned from mentors? What have you learned about being a scientist? And, what is the biggest challenge in the year ahead? Student responses to these questions indicated that their favorite aspects of the PSC were Capstone and Camp activities, such as StarLab, the GBO Exhibit Hall, soldering, using the hands-on 40-ft telescope on site, and hearing lectures. A big message from participants was that the certification tests were too difficult.

As seen in the quantitative data, the PSC attracts students who already identify with science, but the PSC helped them gain insight into a broader range of STEM disciplines and ways to participate in research about space, ex: engineering telescopes. Student comments also indicated that they appreciated the mentors, who seemed relatable and were good at translating complicated concepts. Finally, students recognized the difficulty of getting their peers engaged and staying engaged during the school year beyond Camp. They noted that it's difficult to hear about the PSC outside of West Virginia, but they wanted to tell their peers to join. They also wanted more ways to stay engaged themselves throughout the year beyond pulsar scoring. They asked for more data analysis marathons and opportunities for more advanced data analysis.

Design Research

The complexity of the scaled-up PSC has presented several challenges, which, when addressed with solutions that are grounded in pedagogy and education literature, make the program ideal for design-based research. To this end, the PSC research team has begun collecting artifacts and other qualitative data in an effort to document and inform the design changes moving forward.

The goal of design-based research is to provide a rich description of context, guiding and emerging theory, design features of intervention, and impact on participation and learning. The design approach is similar to the engineering fields where rapid, disposable prototypes are iteratively tested. To ensure that findings from the PSC design iterations are not merely a program evaluation or description of a "boutique" project, the process *must* be framed within the literature. Therefore, we are continually articulating the pedagogical and motivational theories guiding programmatic decisions, as well as monitoring specific outcome measures.

Both qualitative and quantitative artifacts suggested the difficulty and scaffolding of the certification tests were a barrier to continued participation. Over the last year, the certification tests were greatly modified transitioning from two relatively equivalent exams to four exams that increased in difficulty and gave the students feedback that allowed the student to learn from taking the test. The new certification tests were piloted at the summer camp this year (with very positive feedback from the students) and will be deployed to all PSC students this fall. We should be able to detect whether the change improves persistence in the program.

Future Research: The PSC has collected data from a sufficient sample of participants to have statistical power to begin to answer more sophisticated questions than the simple comparison tests provided in this report. Beyond exploring whether the new certification tests improve retention, we plan to investigate:

- The effect of the PSC on student attitudes controlling for the attitude before joining the PSC.
- The factors in the pre-survey that predict persistence through the certification tests.
- The effect of passing or failing the certification tests on student attitudes.

The results of these analyses will be prepared for publication over the course of the year.

Conclusion: The research methodology described in the proposal for investigating the effect of the PSC has moved to its third stage where research findings have informed design experiments to improve the PSC, the PSC has been modified to implement the experiment, and data will be collected to determine the efficacy of the change. We continue to work to improve sample size and have published the first paper about the work and continue presenting at conferences. Our first manuscript for The Physics Teacher magazine was accepted and should appear this fall.

Products:

Cabot Zabriskie, Kathryn Williamson, and John Stewart. "The Pulsar Search Collaboratory – A Citizen-Science Program." American Association of Physics Teachers Summer Meeting 2018, Washington, DC.

Kathryn Williamson, John Stewart, Maura McLaughlin, Sue Ann Heatherly, Harsha Blumer, Cabot Zabriskie, and Ryan Lynch. "The Pulsar Search Collaboratory: Expanding Nationwide," The Physics Teacher, (accepted 2018).

Appendix

PRE-Survey Descriptive Statistics

Science/Engineering Identity

ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
Sci1	88.0	19.9	65.4	27.8	I am curious about discoveries in science and engineering.
Sci2	87.6	19.6	65.8	26.1	I enjoy learning science and engineering.
Sci3	90.6	16.3	68.5	25.9	I think science and engineering is interesting.
Sci4	77.0	26.3	48.5	30.9	I see myself as a "science or engineering person."
Sci5	70.3	27.0	36.4	28.7	Being a scientist or engineer is an important reflection of who I am.
Sci6	77.0	25.3	48.2	29.7	I think I could be a good scientist or engineer one day.
Sci7	29.9	30.1	59.2	34.1	Science and engineering is okay but not for me.
Sci8	72.4	24.0	48.7	21.9	My teacher thinks I could be a good scientist or engineer one day.
Sci9	19.6	25.8	38.3	27.0	I don't really value science or engineering that much.
Sci	67.9	13.9	53.2	14.3	Aggregate Science/Engineering Identity

Self-Efficacy

ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
SEF1	70.7	21.6	50.0	28.9	Science and/or engineering is easy for me.
SEF2	67.5	28.4	39.1	27.6	I know more about science than most of my classmates.
SEF3	79.7	18.8	61.9	25.8	I am confident I will do well on science labs and projects.
SEF4	82.7	19.3	53.9	29.6	I believe I can master science knowledge and skills.
SEF5	84.8	18.4	69.1	23.9	I am sure I can understand science.
SEF6	84.1	20.8	66.1	28.8	I am capable of getting straight A's in a science or engineering class.
SEF	78.2	17.3	56.7	20.5	Aggregate Self-Efficacy

Sense of Belonging

ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
BL1	67.3	28.6	60.9	28.2	I feel a real part of my school.
BL2	70.7	26.2	63.9	26.4	Other students here like me the way I am.
BL3	59.3	29.5	47.5	28.4	I feel very different from most other students here.
BL4	74.4	24.4	64.6	25.8	I am treated with as much respect as other students.
BL5	81.7	19.0	72.0	26.1	The teachers here respect me.
BL6	80.7	20.7	74.3	23.4	People here know I can do good work.
BL7	67.5	27.0	56.4	25.2	Other students at my school take my opinions seriously.
BL8	81.3	22.0	71.3	26.7	Most teachers at my school care about my success.
BL9	72.4	25.2	NA	NA	People here notice when I'm good at something.
BL10	35.0	26.8	39.1	29.8	It is hard for people like me to feel accepted here.
BL11	78.0	21.7	54.4	25.8	When I am in a science or engineering setting, I feel comfortable.
BL12	39.2	27.0	49.5	27.0	When I am in a science or engineering setting, I try to say as little as possible.
BL13	51.8	21.9	52.0	22.8	I feel very different from most people I've seen who do science and or engineering
BL.RECOG	81.2	17.7	72.5	21.5	Aggregate factor of: BL5, BL6, and BL8 (CFI .96)
BL.PEER	70.0	22.7	61.5	20.3	Aggregate factor of: BL1, BL2, BL4, and BL7 (CFI .96)
BL.NEG	47.1	23.5	43.3	22.6	Aggregate factor of: BL3 and BL10 (CFI .96)

Science Career Interests

ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
ScC1	78.9	27.5	48.8	33.7	I would like to have a career in science.
ScC2	77.0	28.8	48.7	32.3	I will graduate with a college degree in a major area needed for a career in science.
ScC3	77.2	25.0	55.2	28.1	A career in science would enable me to work with others in meaningful ways.
ScC4	81.9	24.3	53.7	32.3	I plan to use science in my future career.
ScC5	74.4	25.7	59.2	27.8	My parents would like it if I choose a science career.
ScC6	82.7	24.5	54.2	31.8	I am interested in careers that use science.
ScC7	69.7	27.6	46.0	30.1	I have a role model in a science career.
ScC8	77.2	24.6	57.7	27.4	I would feel comfortable talking to people who work in science careers.
ScC9	83.3	23.4	61.1	30.3	Understanding science will benefit me in my career.
ScC	78.0	21.6	53.8	24.4	Aggregate Science Career Interests

POST-Survey Descriptive Statistics

Science/Engineering Identity

ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
Sci1	82.7	25.7	62.1	30.0	I am curious about discoveries in science and engineering.
Sci2	82.5	24.5	64.6	28.3	I enjoy learning science and engineering.
Sci3	83.5	24.2	67.4	27.7	I think science and engineering is interesting.
Sci4	77.0	27.4	47.5	33.7	I see myself as a “science or engineering person”.
Sci5	69.9	29.4	34.6	31.6	Being a scientist or engineer is an important reflection of who I am.
Sci6	75.0	28.7	46.5	32.0	I think I could be a good scientist or engineer one day.
Sci7	40.6	36.0	55.7	33.3	Science and engineering is okay but not for me.
Sci8	71.1	25.5	53.0	24.5	My teacher thinks I could be a good scientist or engineer one day.
Sci9	29.1	32.1	38.3	29.7	I don’t really value science or engineering that much.
Sci	72.8	21.5	53.9	20.4	Aggregate Science/Engineering Identity

Self-Efficacy

ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
SEF1	66.9	28.8	50.3	27.3	Science and/or engineering is easy for me.
SEF2	67.1	27.6	40.4	29.7	I know more about science than most of my classmates.
SEF3	75.8	22.3	63.1	24.4	I am confident I will do well on science labs and projects.
SEF4	78.7	22.7	56.5	28.2	I believe I can master science knowledge and skills.
SEF5	78.1	23.8	67.6	24.6	I am sure I can understand science.
SEF6	77.8	25.4	68.5	28.5	I am capable of getting straight A’s in a science or engineering class.
SEF	74.1	22.0	57.7	21.5	Aggregate Self-Efficacy

Sense of Belonging

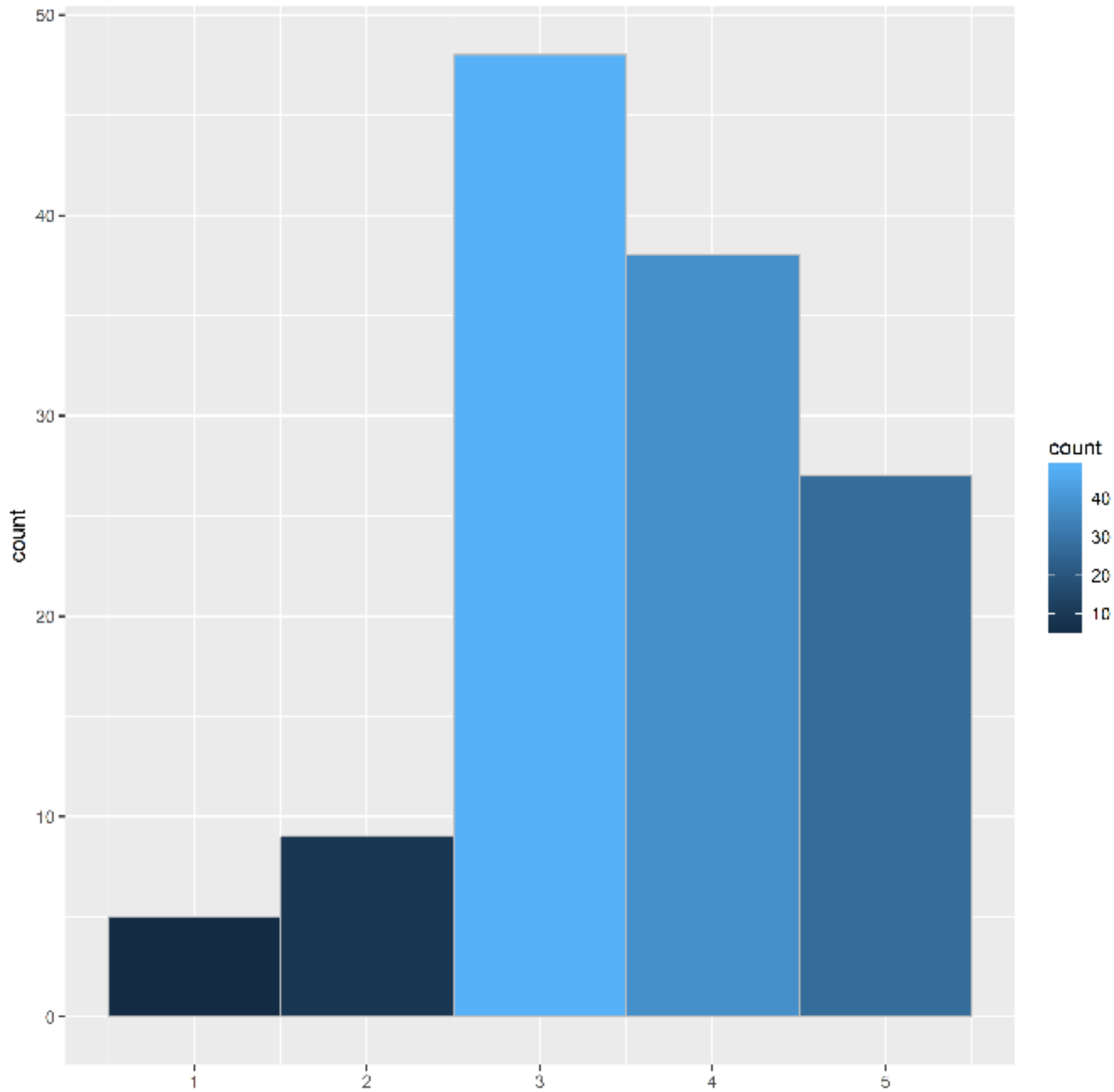
ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
BL1	62.8	29.4	58.4	30.6	I feel a real part of my school.
BL2	57.7	28.1	66.8	26.4	Other students here like me the way I am.
BL3	64.2	26.1	51.2	28.5	I feel very different from most other students here.
BL4	66.9	27.1	66.9	26.7	I am treated with as much respect as other students.
BL5	73.2	25.2	68.6	25.9	The teachers here respect me.
BL6	74.0	25.1	76.7	23.4	People here know I can do good work.
BL7	64.2	28.3	60.6	27.8	Other students at my school take my opinions seriously.
BL8	71.5	27.6	70.3	25.7	Most teachers at my school care about my success.
BL9	67.5	27.3	NA	NA	People here notice when I'm good at something.
BL10	38.0	29.5	36.2	28.1	It is hard for people like me to feel accepted here.
BL11	75.0	25.2	53.5	26.8	When I am in a science or engineering setting, I feel comfortable.
BL12	39.2	30.0	49.2	26.7	When I am in a science or engineering setting, I try to say as little as possible.
BL13	51.2	27.3	51.3	24.5	I feel very different from most people I've seen who do science and or engineering
BL.RECOG	72.9	24.2	71.9	21.2	Aggregate factor of: BL5, BL6, and BL8 (CFI .96)
BL.PEER	62.9	21.3	63.2	22.6	Aggregate factor of: BL1, BL2, BL4, and BL7 (CFI .96)
BL.NEG	51.1	18.4	43.7	23.2	Aggregate factor of: BL3 and BL10 (CFI .96)

Science Career Interests

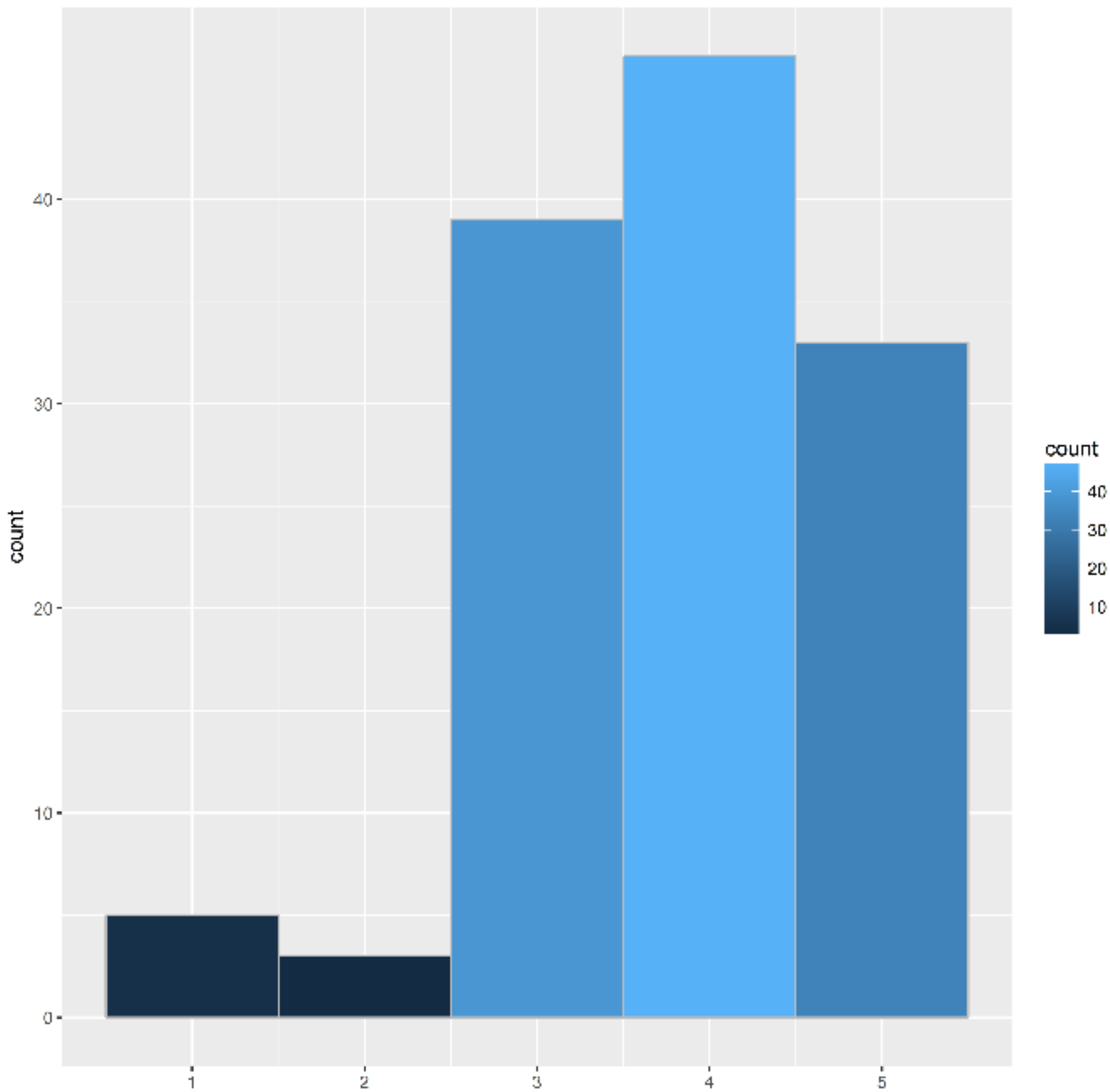
ID	Mean (PSC)	SD (PSC)	Mean (Control)	SD (Control)	Question
ScC1	72.2	29.1	45.6	34.4	I would like to have a career in science.
ScC2	70.7	29.4	48.8	33.6	I will graduate with a college degree in a major area needed for a career in science.
ScC3	71.1	28.4	57.4	31.2	A career in science would enable me to work with others in meaningful ways.
ScC4	72.2	28.0	53.0	32.6	I plan to use science in my future career.
ScC5	68.9	24.9	54.0	29.8	My parents would like it if I choose a science career.
ScC6	74.2	26.2	53.0	33.0	I am interested in careers that use science.
ScC7	65.6	29.0	42.8	30.5	I have a role model in a science career.
ScC8	72.4	25.7	55.9	30.1	I would feel comfortable talking to people who work in science careers.
ScC9	76.0	25.9	59.9	30.3	Understanding science will benefit me in my career.
ScC	71.5	24.6	52.3	26.7	Aggregate Science Career Interests

Program Satisfaction

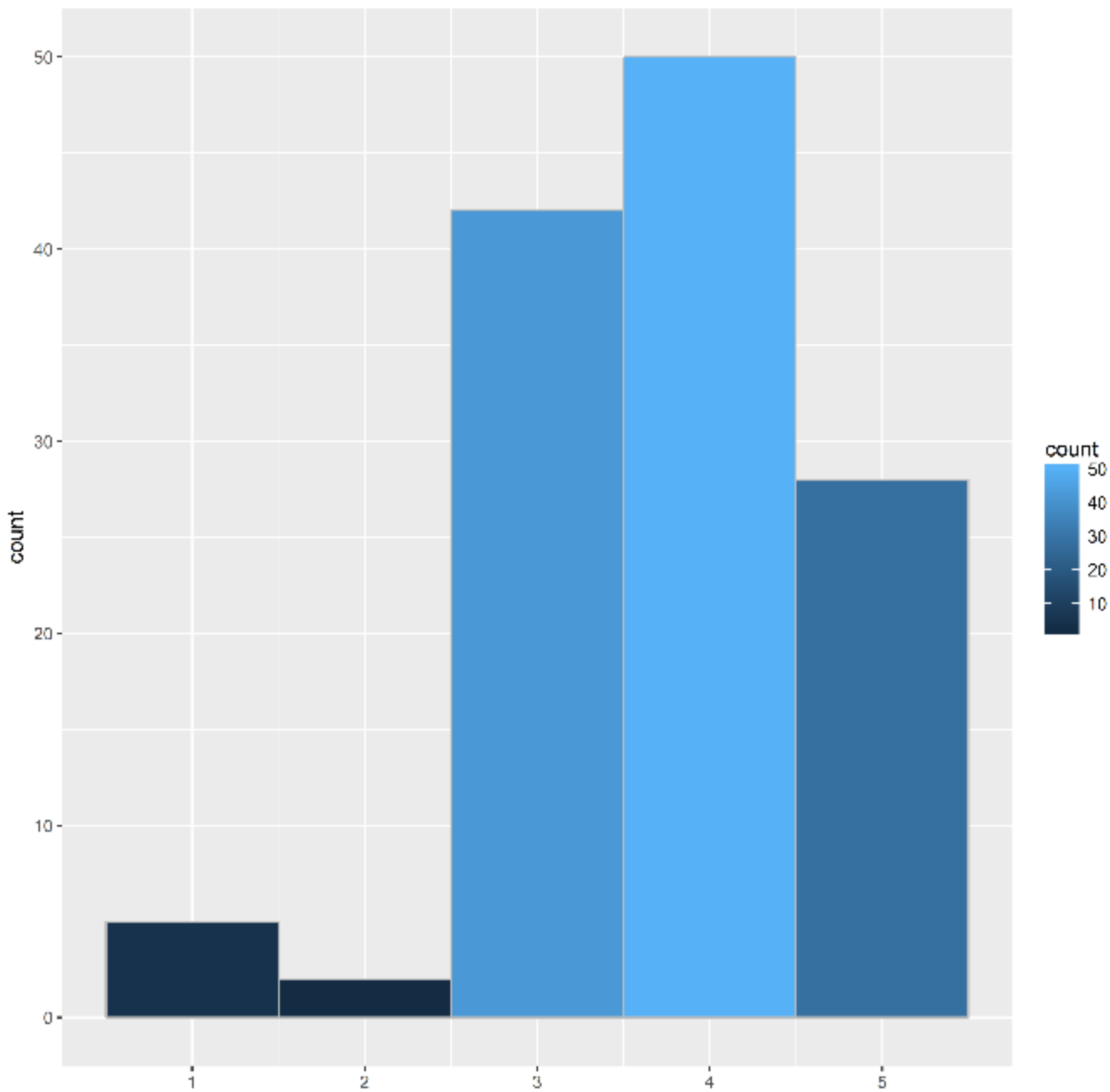
Being Part of the PSC Helps Me Advance my College or Career Goals



I Felt Like I was Contributing to Science



The PSC was Fun/Enjoyable



I Am Happy to Have Gained New Knowledge