PSC Research Overview (from NSF proposal)

PSC Research Plan. Measures of Interest, persistence, self-efficacy, and motivation. PSC research will focus on three main questions with targeted sub-questions. Research questions one and two will each be the subject of a WVU graduate students' doctoral thesis, under mentorship of Dr. Stewart and Dr. Williamson.

Research Question One: **How does the PSC affect students' science identity, self-efficacy, sense of belonging within their club and the scientific community, science and engineering career interest, motivation to persist, and academic achievement over time?**
These research domains will be assessed via well-grounded subscales culled, where possible, from existing instruments in the literature (see Table 1). To allow for fine time resolution, these research domain questions will be asked four times per year: pretest (beginning of school year), Winter Break, before Capstone, and posttest (after Capstone).

In order to understand the effects of the PSC separately from the effects of other relevant factors, we will obtain a comparison group by gathering survey data on *allconsenting* students in a given high school class (which will include PSC members and non-members).

Table 1: Research Domains and corresponding reference questionnaires.

Research Domain	Questionnaire	References
Science Identity	Science Identity Questionnaire (to be developed for this project from references)	Perez, Cromley & Kaplan (2014) Hazari *et al.* (2010) Aschbacher, Li, & Rotch (2010)
Self-Efficacy and associated Motivation to Persist in the face of costs and challenges	Science Motivation Questionnaire II Self-Efficacy sample statements from related research	Glynn et al (2011) Trujillo & Tanner (2014) and references therein
Sense of Belonging within the Scientific community and within the PSC club	Sense of Belonging sample statements from related research Belonging in Youth Development Programs	Trujillo & Tanner (2014) and references therein Anderson-Butcher & Conroy (2002)
Science and Engineering Career Interest	STEM-CIS STEM Career Interest Questionnaire	Kier et al (2014) Tyler-Wood, Knezek, & Christensen (2010)

Important control and demographic variables will be collected during the pretest survey, drawing from the Persistence Research in Science and Engineering (PRiSE) survey (Hazari et al 2013). For example, to control for the possibility that PSC students are more likely than other students to voluntarily participate in science activities, students will be asked to report their involvement in a variety of science enrichment activities (such as camps, afterschool programs, non-PSC clubs, museum visits, time spent watching science programming on television or on the internet). The posttest survey will collect self-reported achievement along various academic measures, such as grades in science and math for the school year, overall GPA, and PSAT/SAT/ACT scores if relevant.

An important component to this research plan is the development of a science identity instrument. While there is a plethora of research on science identity (in addition to those listed in Table 4: Brickhouse, Lowery, & Schultz 1999, Varelas 2012), there is as yet no rigorously validated, reliable instrument (Carlone, personal communication). Thus, we will draw heavily from the extant literature and iteratively refine a science identity instrument along the four sub-scales suggested by Hazari et al (2010) – performance, competence, interest, and recognition. Furthermore, it is well-recognized that science identity is often situated in context with societal norms for gender and race/ethnicity (Brickhouse, Lowery & Schultz 2000, Brown 2004, Carlone & Johnson 2007, Chemers et al 2011), so targeted interviews with underrepresented students in the new PSC Hubs will be critical in helping to ensure that the instrument is

culturally sensitive and relevant to diverse groups. We expect to have a sound instrument by the beginning of Year 2 of the PSC. A first version will be piloted before the first PSC students are enrolled. Testing of the instrument in introductory science classes at WVU and in high schools near WVU will allow validation of the new instrument with large numbers of students providing robust statistics. New iterations will be administered bi-annually; each iteration will undergo statistical analysis for reliability (Cronbach's Alpha), subscales will be validated with factor analysis, and face validity will assessed through student interviews and a panel of experts in informal science education and identity development.

Analysis of variance with repeated measures of this data for both PSC and non-PSC comparison students will provide an understanding of how the PSC leads to the evolution of these affective and cognitive domains over time, and Research Question Three will track the evolution of a subset of affective domains longitudinally. Additionally, in a manner similar to Hazari (2010) we will use Hierarchical Linear Modeling (accounting for students being nested within different clubs) to predict the observed changes in affect, achievement, and declaration of college major based on demographic variables and programmatic participation (type and level), to understand the PSC mechanisms by which these changes occur.

Research Question Two: How do STEM-ID programmatic components and events affect students' patterns of participation? Since the scientific impetus of the PSC and main participatory activity is analyzing pulsar data, we will "zoom in" on the patterns of scoring these plots as indicators of student engagement. We hypothesize that this will provide a window into programmatic features and modes of delivery that support or hinder engagement. For example, does a new pulsar discovery spark a flurry of plots scored by others? Do web chats with scientists lead to more activity than web chats with near-peer mentors, or vice versa? Most PSC students score several hundred pulsar plots over the course of the year, providing a rich data set with high time resolution that can be correlated with programmatic components. This ability to track the effects of programmatic changes on student participation over time makes the PSC an ideal environment for implementing a "design experiment" (Cobb et al 2003). Coordinating with Co-PIs and Program Managers, the research team will systematically track changes to the PSC program and monitor activity, creating a feedback loop in which the researchers help optimize the program design.

The planned design experiment will be carried out in two stages where in Year 2 and 3 detailed programmatic modifications are introduced as a result of the analysis of collected data in Year 1 and 2. The data collected is exceptionally fine grained and therefore the analysis should be able to determine if positive programmatic events such as a mentor club visit or finding a pulsar candidate generate additional scoring activity, forum posts, or web site access; the frequency and character of the programmatic event will then be optimized. Likewise, the results of events providing negative reinforcement such as failing to correctly score training plots or being notified that a pulsar candidate is a known pulsar can be correlated with a decrease in participation; these negative events can be surrounded by additional scaffolding. This analysis can be differentiated by race and gender and by participation modes to identify programmatic optimizations that increase participant retention and inclusion. In Year 3, similar data collected in Year 2 will be used to suggest additional modifications and the experiment repeated.

Passively collected, time-stamped data to monitor activity and degree of engagement includes:

- Practice data mastery level from the content "tests" students must pass to become members;
- Data plots analyzed;
- Emails initiated to scientists;
- Data analysis proficiency compared to expert—designated plots throughout the database that are also scored by astronomers;
- Online accessing of or posting in discussion forums;
- Attendance at online PSC enrichment events (web chats, webinars, follow-up observing).

Participants will also actively contribute data, but care will be taken to ensure effort is minimal:

- Through simple check boxes, astronomers and student mentors will be asked to quickly characterize incoming communication (possible pulsar, scientific question, non-scientific questions) and their response (confirm pulsar candidate, reject candidate, answer question).

- PSC mentors will be required to use the PSC website for all communication with participants and to file online reports about club visits.
- Teachers will complete an online questionnaire about the social and pedagogical learning environment of their PSC club. The learning environment assessment will be adapted from an instrument introduced by Prather et al. (2009), enhanced with additional questions inspired by observation protocols such as the Reformed Teaching Observation Protocol (Sawada 2002) and the UTeach Observation Protocol (Walkington 2011) and validated as part of this project.
- Teachers at PSC clubs will also be asked to fill out simple, regular online reports of each club meeting detailing date, duration, attendance, visits by mentors, and the reason, if known, for any student withdrawing from the club.

The analysis of this large dataset is related to that underway in Massive Open Online Courses (MOOCs), where large participant numbers have offered the possibility for significant educational discoveries (Breslow 2013). However, the MOOC participant population of older, well-educated learners (DeBoer 2013) combined with the low number of assignments required within most MOOCs have made general conclusions difficult. The PSC is a far superior laboratory for understanding online education because of the frequently repeated uniform task of scoring pulsars. Retention has been a key problem both in MOOCs (Rivard 2013, Yang 2013) and in more traditional online environments (Lee 2011); our measurement of factors impacting participation may suggest key alterations to other online experiences.

We expect this design experiment to lead to improvement of the program in Year 2 and 3 and to yield practical suggestions supported by high statistics research on how programmatic elements can be fined tuned to improve retention, affective outcomes, and inclusion. These generalizable insights will improve all programs that involve diverse groups in free-choice, authentic research.

Research Question Three: How does the PSC affect students' science identity, self-efficacy and academic achievement in context with costs and challenges longitudinally through the first two years of college? Our longitudinal research will systematically track PSC students who declare STEM-related majors *and* matched non-PSC counterparts who also declare STEM-related majors (drawn from the control groups of Research Question One) into college to better understand the long-term impacts of the program. Anecdotal evidence from past PSC participants indicates that the PSC engenders strong passion for science, with many students declaring Physics majors in college. Some of these students were hit with the stark reality that their academic preparation was lacking, but most have seemed to stay motivated to persist despite these difficulties. We hypothesize that PSC-students persist by drawing heavily on their sense of identity, self-efficacy, and belonging despite their difficulties with classes.

To better understand how the PSC influences students' persistence in a science major, PSC members and non-members will be tracked with an abridged version of Research Question One surveys that focuses on evolution of science identity in context with college barriers and perceived costs (building on the work of Perez, Cormley, & Kaplan 2014), and this longitudinal tracking survey will be given twice per year (at the end of each semester). Participants will self-report their academic achievement as assessed by courses taken, grades, and continuation of their STEM major. Ten case studies will be selected for more in-depth member-checking through email and phone interviews (Carlone & Johnson 2007) to help put survey responses in context with students' lives. Following the methods of Ashbacher, Li, and Roth (2010), stratified sampling will ensure case study participants represent diverse types of students (gender, economic level, ethnicity, and science interest). These case studies will be tracked through the first two years of college. Here, we expect to gain understandings of the complex systems that constrain PSC outcomes on students' career paths.