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The Impact of a Short-Term Pharmacology Enrichment Program on Knowledge and Science Attitudes in Precollege Students

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Abstract
As our nation and the global economy place an increased demand for science, technology, engineering, and mathematics (STEM) jobs, science educators must implement innovative approaches to pique precollege student's interests in these careers. Pharmacology remains a relevant and engaging platform to teach biology and chemistry concepts, and this strategy applied over several months in the formal classroom increases science literacy in high school students. In order to improve the affordability and accessibility of this educational approach, we developed and assessed the impact of a short-term pharmacology day camp, 'Pills, Potions, and Poisons' (PPP), on high school students' science knowledge and attitudes toward science careers. The PPP program was offered annually from 2009 through 2012, and participants spent 6 days learning about pharmacology and careers in the biomedical sciences. All PPP student participants (n=134) completed surveys assessing their basic science knowledge and science attitudes before and after the program. Students achieved significant gains in their science knowledge by the end (Day 6) of the PPP program (from 41% mean test score to 65%; p<0.001). In addition, the majority of participants agreed or strongly agreed that the PPP program positively impacted their attitudes toward science (p<0.001). This study provides evidence that a short-term pharmacology-centered science enrichment program can achieve significant gains in participant's science knowledge as well as motivation and confidence towards science careers. Moreover, we report benefits experienced by the undergraduate, graduate, and professional pharmacy student teaching assistants (TAs, n=10) who reported improved communication skills and an increased interest in future educational work.

Key Words: science outreach, pharmacology, high school students, science knowledge, STEM careers

Introduction

Amidst an increasingly competitive global job market, science, technology, engineering, and mathematics (STEM) careers are pivotal for our nation's economic growth. According to the U.S. Department of Labor, 7 of the top 10 fastest-growing occupations through 2022 are projected to be in STEM fields; the health care sector specifically is estimated to account for nearly one-third of the total increase.[1] Underscoring the importance of this growth, the Obama administration has prioritized an initiative to produce 1 million more STEM majors over the next decade.[2]

There is considerable evidence that students who develop STEM career aspirations early are more likely to succeed in earning a baccalaureate degree in science.[3] One national survey reported that 4 out of 5 college STEM majors decided to pursue a STEM-related career in high school or earlier.[4] Furthermore, 57% of those surveyed stated that a teacher or class was the most influential factor in deciding to pursue a STEM career.[4] In order to take advantage of the critical precollege time window and also improve science proficiency, educators must implement innovative, best-practice approaches to increase students' science knowledge, improve their attitudes toward science, and expose them to varied STEM-related careers.

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Previous research has shown that drug topics spark young learners' interest, and teaching high school science through a pharmacology context provides an engaging and effective platform for biology and chemistry concept learning.[5-7] This educational approach applied in a science enrichment program ("Launch into Education About Pharmacology") was shown to increase science literacy in high school students.[8] In that program, students participated in a three-week pharmacology summer course, followed by a 9-month mentored research experience during the school year. Students demonstrated short-term gains in science knowledge following the summer course, as well as improved attitudes toward a future in science after completion of the entire 9-month program. Despite its successes, the program's extended duration requires tremendous resources and remains expensive to implement ($30,000/year), thus requiring external funding to remain sustainable.

In this study, we explored whether a more cost-effective, short duration program -- a one-week day camp - could effectively apply this educational approach and achieve similar learning outcomes. The Ohio State University College of Pharmacy developed the "Pills, Potions, and Poisons" program (PPP), a six-day science enrichment and career exploration program for rising 10th-12th grade students interested in the biomedical sciences (Figure 1). PPP provides students with an overview of pharmacology and its relationship to health, disease, and society, with each day focusing on a different pharmacological topic. The PPP structure includes five days containing hands-on instructional activities that apply the daily topic focus as well as a sixth day featuring a student showcase. Because pharmacology is interdisciplinary in nature, we designed activities that used drug topics as a "hook" to engage student's interests, while allowing them to learn, integrate and apply basic biology and chemistry concepts to solve more complex problems involving human systems (Table 1). In the program, students learn through a variety of hands-on, minds-on, and team-based activities including experiments, simulation, discussion, debate, and games. As students work through each activity, they document their predictions, solutions, observations, experimental designs, and findings in a student booklet (available as Supplemental Appendix 1). As a result, the PPP experience emphasizes and helps foster skills pertinent to any scientific career path including: problem-solving; experimental design, execution, and analysis; critical thinking; teamwork; and, communication. In addition, students explore a variety of biomedical careers through research laboratory visits, hospital pharmacy visits, and discussions with student (undergraduate, graduate, and Doctor of Pharmacy) teaching assistants (TAs) and faculty. Finally, the program concluded with a showcase which included student participants delivering presentations to parents and teachers about the various activities conducted throughout the week.

Figure 1. The Pills, Potions, and Poisons Program Structure.

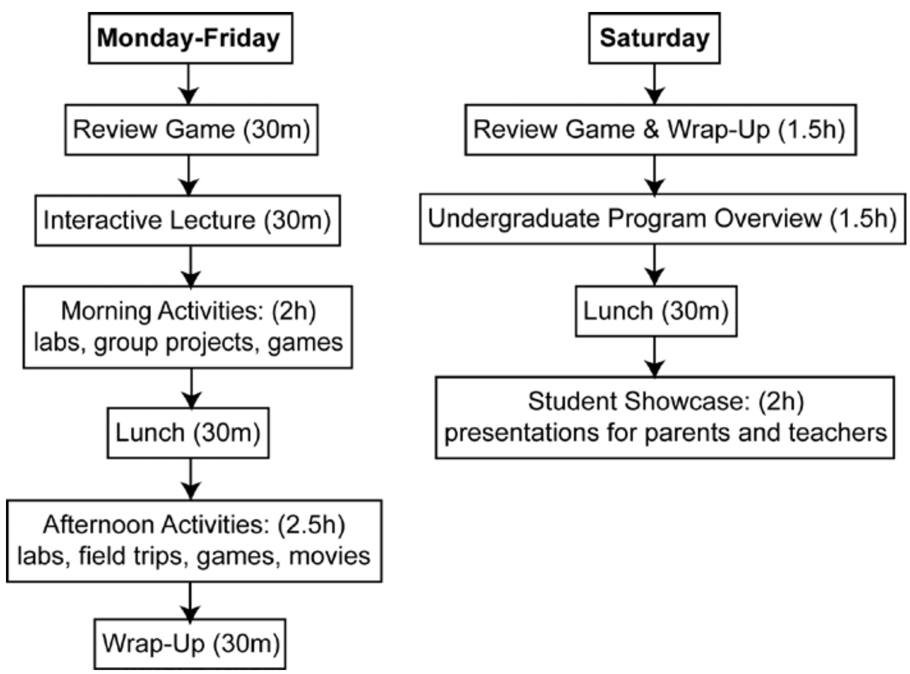


Table 1. Pills, Potions, and Poisons program activities.

Day of Week	Daily Topic Focus	Biology Content	Chemistry Content	Other
Monday	Drug Action and Drug Targets	anatomy, cell structure, receptors, transporters, enzymes, DNA	chemical bonds, drug-target binding	physiology, pathophysiology, agonist v. antagonist drugs
Tuesday	Getting Drugs In, Around, and Out of the Body	membrane transport, circulatory system, diffusion, cell types	acid/base chemistry, enzymes, solubility, polarity, ionization	medical ethics
Wednesday	Dose Response and Drug Factors	Anatomy	molarity calculations, enzymes	physiology, dose-response relationships, drug-drug interactions
Thursday	Drug Abuse and Addiction	addiction biology, DNA	neurochemistry	genetics, medical ethics
Friday	Drug Discovery and Development	bacteria life cycle, plant biology	enzymes, polarity	viruses, antibiotic resistance, genetics

Methods

Study Design

This study was approved by The Ohio State University Institutional Review Board (IRB; protocol 2008B0134). All program activities occurred on the Ohio State University main campus in Columbus, Ohio. For PPP student participants, all data were collected via self-administered, paper-based surveys administered and collected during the program or mailed approximately one month after the program. Students created unique codes that were used to match pre- and post-program surveys, but no individually-identifying information was collected or stored. For the PPP teaching assistants, all data were collected anonymously via an online survey e-mailed within one month of the program's completion.

Program administration

Offered every July during the study period, the PPP program hosted 1-2 classes of 24 high school students each year. For each class, a lead instructor (i.e., a faculty member, postdoctoral fellow, or a graduate student) oversaw the planning and teaching of the course activities. In addition, 5 TAs (i.e., undergraduate, graduate, or PharmD students) were hired to help with program activities (2 TAs per classroom, and 1 "floating" TA who coordinated activities between classes when appropriate), with many serving as a TA over multiple years. Prior to the program, the staff participated in a daylong training that outlined duties, expectations, and potential issues that might arise (Supplemental Appendix 3).

Student applicant pool

We advertised the PPP program via direct email communication to over 140 Ohio high school science teachers and guidance counselor staff each year. Additionally, we posted announcements to the internal Ohio State University faculty/staff newsletter and College of Pharmacy website. Since PPP is a not a residential program, we primarily contacted schools within a twenty mile radius of Ohio State University.

Application packages and informational materials were posted to a program website (www.go.osu.edu/ppp). During 2009, we received 38 applications for 24 available spots. From 2010 to 2012, we received an average of 69 applications for 48 available spots. We used a competitive admissions process to select PPP participants; criteria included the applicant's cumulative GPA, completed coursework in biology and chemistry, personal essay, and a teacher's letter of recommendation. We required all participants to have taken Biology 1 and earn a cumulative GPA over 3.0 (a few students had tested out of Biology 1 but had taken Biology 2). The vast majority (95% of applicants) met these criteria. We selected the final participant pool based on the student's personal essay and letter of recommendation. There was no application fee; however, once accepted, a participation fee was required to secure a student's placement in the program.

Student participant pool
During 2009-2012, 160 students participated in the PPP program; of those, 134 agreed to participate in this study. Some data were collected during the program, facilitating a 100% response rate (n=134). Some assessments occurred following completion of the program; therefore, 'n' reflects the number of participants or TAs that responded to these surveys (response rate indicated when appropriate). Each participant, along with his or her parent/guardian, provided written informed consent to participate in this study.

Assessment of science knowledge and science attitudes
To measure science knowledge gains, we administered a 10-question science concept inventory on the first (day 1) and final day (day 6) of the PPP program. This instrument, modified from a previous study[6] and included as Supplemental Appendix 2, assessed students' understanding of basic biology and chemistry concepts in the standard course of study for high school science. The program content did not "teach to the test"; rather, many of the pharmacology topics discussed in the program required students to learn and build upon these basic biology and chemistry principles. Students were not informed about the "pre/post" survey format. Therefore, it is unlikely that students purposefully prepared for the post-program survey during the week of the program. As all responses were de-identified, individual surveys could not be correlated with student demographics.

To assess knowledge gained, we calculated the mean pre- and post-PPP survey score for all participants from 2009 through 2012 (n=134). Scores are reported as mean % correct ± standard error of the mean (SEM). In addition, we further segregated knowledge gains according to biology or chemistry discipline (Questions #1, 5, 6-8, 10 assigned as "biology"; Questions #2-4, 9 assigned as "chemistry"). For all analyses, we assessed statistical significance by comparing mean pre- and post-PPP survey scores using a paired Student's t-test. For all analyses, we set the threshold for statistical significance at α=0.05.

To assess the program's outcomes on participants' science attitudes, we administered a survey to PPP participants one month following program completion (n=104, 77.6% response rate; survey questions reported in Figure 3). This survey asked participants to report their opinion of the program's impact on their understanding of science (*science knowledge*), motivation for a science career (*science motivation*), confidence to succeed in science (*science confidence*), as well as ability to form relationships with peers interested in science (*social niche*). These measures were modified from a previous study.[9] All responses were based on the Likert Scale (1 = strongly agree, 5 = strongly disagree) and tabulated as the percentage of students reporting each response (value reported within each bar in Figure 3). We used one-sample Wilcoxon signed-rank tests to test the null hypothesis that the median value for each Likert-scale response was neutral ('Neither agree nor disagree').

To determine career paths of PPP program graduates, we also tracked those program graduates that subsequently enrolled at Ohio State University following high school graduation for four years.

To assess how the PPP program impacted our undergraduate, graduate, and professional pharmacy student staff, we administered a survey to TAs who had been involved in the program from 2009 through 2012 (n=10; survey questions reported in Figure 4). All responses (n=10, 100% response rate) were based on the Likert Scale (1= strongly agree, 5 = strongly disagree) and tabulated as the percentage of TAs reporting each response (value reported within each bar in Figure 4). Given the small sample size, we did not perform statistical testing on the TA sample.

Results
Student Participant Demographics
Demographics of PPP participants reflect admission criteria regarding courses and GPA, as well as diversity in gender and ethnicity (Table 2; data collected as part of program application). The majority of PPP participants were rising juniors or seniors, likely reflecting the increased interest in college and career exploration at this point in their education.

Table 2. Demographics of PPP participants, 2009-2012.

	N	(%)
Gender		
Female	106	66.0
Male	54	34.0
Ethnicity		
Caucasian	87	54.0
Asian	49	31.0
African-American	12	7.5
Other	12	7.5
Grade Level[a]		
Sophomore (10^{th})	31	19.0
Junior (11^{th})	77	48.0
Senior (12^{th})	52	33.0
GPA		
≥ 4.0	84	52.5
3.5 – 3.99	64	40.0
3.0 – 3.49	8	5.0
Not indicated	4	2.5
Courses Taken Prior to Program		
Biology 1	154	96.3
Chemistry 1	97	60.6
Biology 2/AP[b]	62	38.8
Chemistry 2/AP[b]	44	27.5
School Type		
Public	139	86.9
Private	19	11.9
Homeschool	2	1.3
School Locale		
Suburban	117	73.1
Urban	31	19.4
Rural	10	6.3
Homeschool	2	1.3

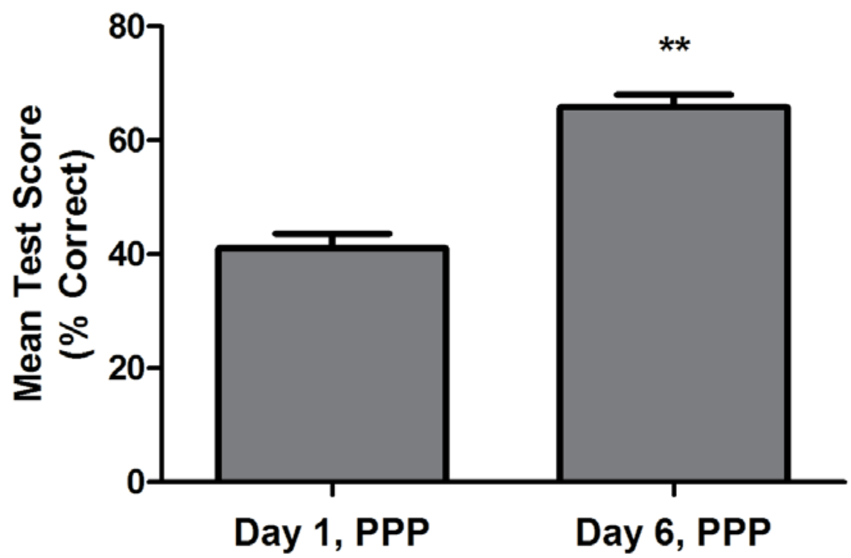
[a]Grade level reflects the participant's grade for the upcoming school year. [b]AP = Advanced Placement

Educational impact of PPP

Across all program years, compared to day 1, students scored significantly higher after the program (day 6) on the 10-question general science knowledge survey that assessed their understanding of basic biology and chemistry concepts (from 41% mean test score to 65%, **p<0.001, n=134, Figure 2). We further segregated these knowledge gains according to biology or chemistry discipline. Students achieved similar knowledge gains in biology (from 40% mean test score to 67%, p<0.001, n=134) as chemistry (from 43% mean test score to 58%, p<0.001, n=134). A 6-day science outreach program appears sufficient for students to achieve short-term gains in science knowledge. Moreover, these results reinforce that teaching science through pharmacology is an effective approach for high school students to learn basic biology and chemistry concepts.

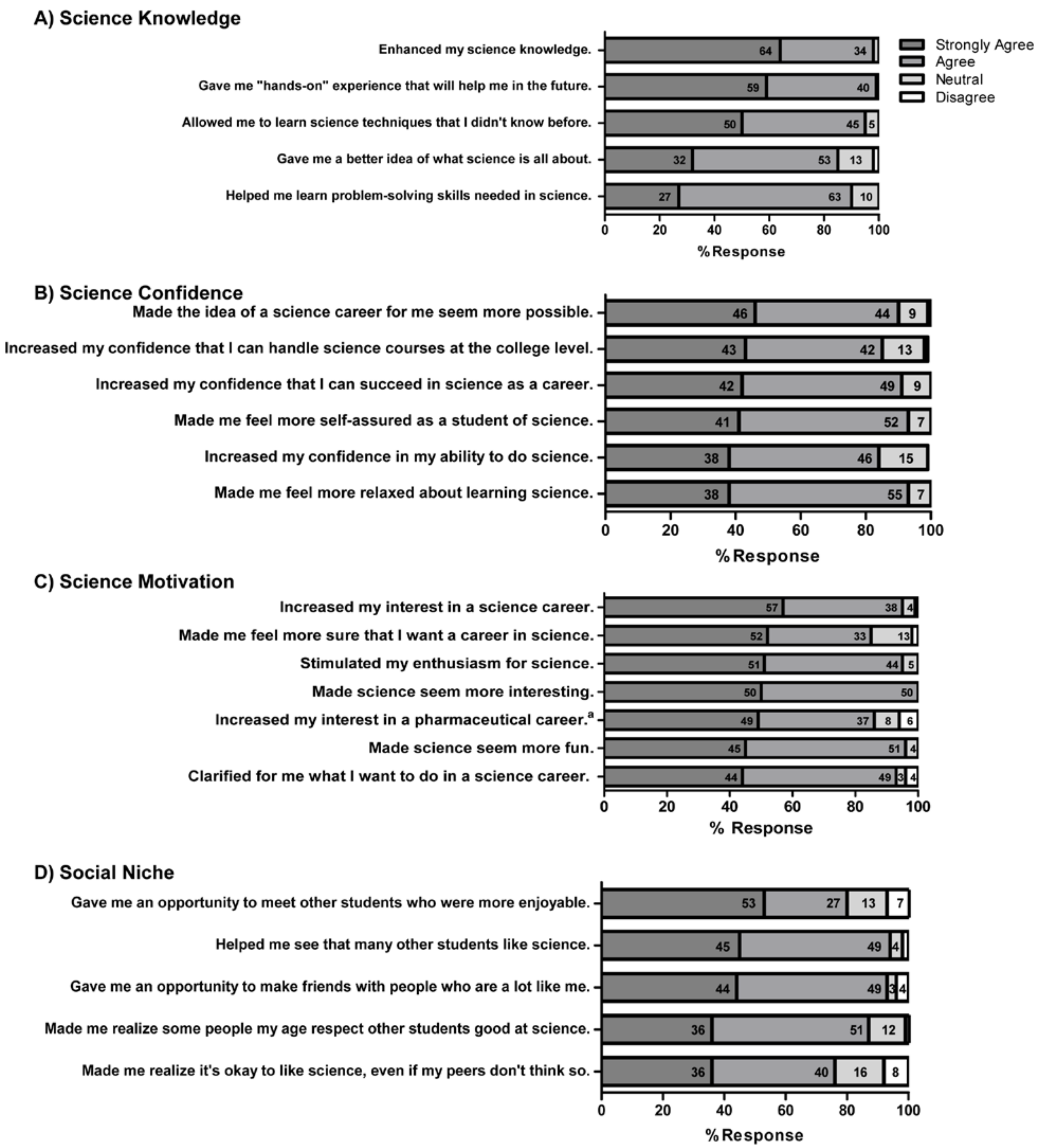
To determine if the PPP program positively impacted attitudes toward science and careers therein, we surveyed participants one month following completion of the program. That instrument assessed the program's effects on motivation, confidence, self-assessment of knowledge, and social niche. The vast majority of participants agreed or strongly agreed that the PPP program positively impacted their attitudes toward science (p<0.001, n=104, Figure 3). Participants overwhelmingly stated that the PPP program stimulated their interest in science, clarified their understanding of science as a field, and reduced their anxiety toward learning science in future courses. Moreover, the vast majority of participants believed that the PPP experience had increased their interest in a scientific career. Finally, the social element of the program was important too; participants developed a network of friendships with other science-minded high school students.

Figure 2. The impact of the PPP program on general science knowledge in high school student participants.



*error bars represent standard error

Figure 3. The impact of the PPP program on attitudes toward science in high school student participants.

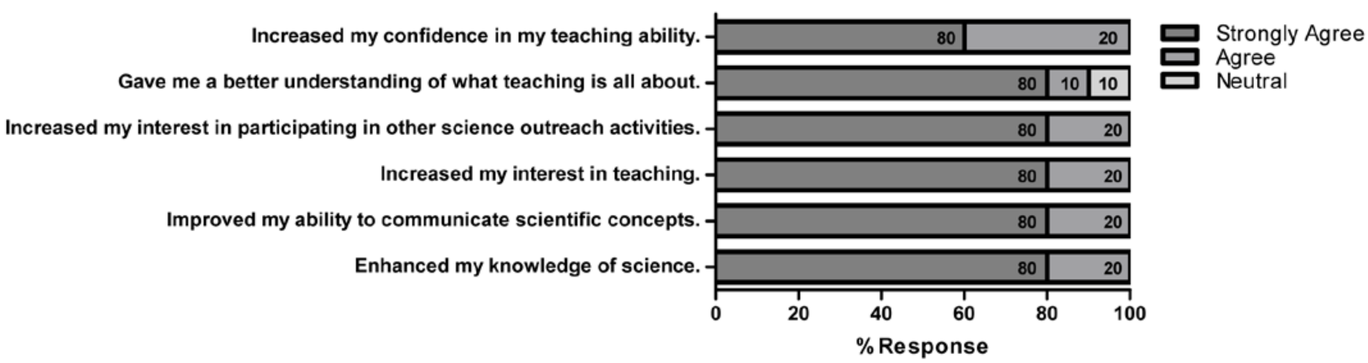


[a]This specific item was added in 2010; as such, fewer students (n=84) provided data about this statement

Of the participants who eventually enrolled at The Ohio State University (n=51), the majority matriculated in STEM-related majors (86.3%). Further, many (37.3%) enrolled in the College of Pharmacy's Pharmaceutical Sciences undergraduate degree program. This program prepares undergraduates for a variety of biomedical science careers, including a variety of both healthcare and research-based professions. However, because the PPP applicant pool was already enriched with students interested in STEM-related careers, we cannot conclude that the PPP program directly caused students to choose STEM training in college; however, it does suggest that the program fosters continued interest in STEM-related careers.

The PPP program also benefited the teaching staff, comprising undergraduate (n=5), graduate (n=1), and PharmD (n=4) students. As shown in Figure 4 and Box 1, the TAs strongly agreed that their PPP teaching experience improved their ability to communicate scientific concepts, increased their confidence in their ability to teach, and increased their overall interest in teaching professionally. In addition, students indicated that the PPP teaching experience positively impacted their future career goals.

Figure 4. The impact of the PPP program on student teaching assistants.



Box 1. Qualitative feedback from the teaching staff

How did you personally benefit from the PPP TA experience?

"My PPP teaching assistant experience helped me realize how much I truly enjoy teaching and mentoring. My experience also helped me improve my communication skills, and I have become better at explaining complicated scientific concepts in a way that the general public can understand."

"I appreciate that the TA position challenged me to think of different ways to explain difficult science concepts to high school students. I think the skills I acquired in this area will continue to help me as I care for younger and older patients alike."

Did the PPP teaching assistant experience impact your future career goal(s)? If so, how?

"I now want to incorporate teaching and precepting PharmD students into my career along with taking care of patients. The PPP TA experience provided me with valuable teaching experience and allowed me to observe how to work with students with different personalities. I am definitely more comfortable with students now than before."

"It certainly solidified my passions and opened my eyes to consider another professional endeavor. If it weren't for my PPP teaching assistant experience, I might have looked the other way at academia in pharmacy. I now will only be selecting residency programs that offer a teaching component…"

Discussion

With only 37% of high school students in the United States reaching the readiness benchmark for college-level science[10], enrichment programs play an important role in improving students' science literacy and increasing their interests and attitudes toward science-related careers. To achieve President Obama's goal to produce more than 1 million college graduates in STEM fields by 2022, one recommendation put forth by the President's Council of Advisors on Science and Technology is to create partnerships to diversify pathways to STEM careers, including support for summer enrichment programs for high school students.[2] We provide evidence that the PPP program led to positive outcomes for student participants and teaching staff. Participants achieved significant and meaningful gains in their science knowledge as well as motivation and confidence towards science careers.

We observe several advantages for colleges of pharmacy to host a program like PPP. First, the 6-day program provides a cost-effective form of science outreach. Unlike long-duration pharmacology science enrichment programs[8], PPP remains fully implementable without relying on external funding. In 2015, the entire program cost $185/participant, which included all expenses related to food, supplies, and teaching assistant stipends (these costs do not include administrator or instructor stipends, as developing and implementing PPP was a part of their expected work responsibilities). Participants paid $150 toward this total cost, leaving our institution to pay $35/participant. The participant fee increased from $90 in 2012 to $150 in 2015, allowing our institution's contribution to decrease. This fee increase had no effect on application numbers—in 2015, we received over eighty applications for 48 spots.

Second, colleges of pharmacy typically already have well-trained undergraduate and professional students to serve as TAs. Although our TAs already generally understand the pharmacology content, the PPP program introduces them to new aspects of teaching and mentoring. In our formal curricular outcomes, we often expect our undergraduate and professional students to develop strong communication, problem-solving, and inter-personal skills, yet we provide limited opportunities for them to practice these skills. PPP TAs work individually with student participants in each class activity and lead at least one activity during the program. Our TAs indicated that this teaching opportunity not only improved their communication and inter-personal skills but also encouraged them to consider including a teaching component in their future career.

Last, the PPP program provides colleges of pharmacy an engaging approach to showcase their degree programs and expose students to multiple careers in the biomedical sciences. Many of the PPP participants subsequently enrolled in our undergraduate Bachelor of Science in Pharmaceutical Sciences program. Programs like PPP not only sustain student interest in the biomedical and pharmaceutical sciences but also provide an engaging platform to recruit future high-achieving students.

Study Limitations

One limitation of evaluating the impact of science enrichment programs is that many of the participants are already high-achieving students with pre-declared interests in science and health careers. Indeed, over 95% of PPP student applicants had a GPA over 3.0 at the time they applied for the program. While our findings demonstrate the PPP program was impactful among high-achieving students and allowed them to make significant gains in their science knowledge and career attitudes, we do not know if the program would have similar impacts among students with lower GPAs or different career interests.

A second limitation of this study involves control subjects. Regarding knowledge gains, student participants served as their own control by completing the knowledge survey at the beginning (Day 1) and end (Day 6) of the program. Due to this paired study design, we elected to not administer this survey to a separate group of high school students not participating in PPP. In addition, this study only assessed participant attitudes toward science and science careers following completion of the program through a retrospective analysis.

Conclusion

Drugs clearly pique students' interests, and we believe that universities are uniquely poised to channel this interest through a science outreach program like PPP. The experience provides high school students with a unique opportunity to increase their science knowledge, improve their attitudes toward science, and increase their interests in STEM-related careers. Moreover, it provides universities with an innovative and cost-effective approach to recruit high-achieving students and encourage their pursuit of STEM-related careers.

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Supplemental Information

Appendix 1. The Pills, Potions, and Poisons Student Booklet. A booklet for student participants to document their predictions, solutions, observations, experimental designs, and findings for the various activities conducted within the program. This booklet also serves to provide future facilitators with more details about each activity referenced in Figure 1. It is available as a separate download.

Appendix 2. Survey Instrument Assessing Knowledge Gains. The science concept inventory that was administered on the first (Day 1) and last (Day 6) day of the PPP program.

Appendix 3. Teaching Assistant Training Guide. A guide that documents training objectives, as well as teaching assistant duties, expectations, and solutions to potential issues that may arise.

Appendix 2. Survey instrument assessing knowledge gains

First initial of mother's/guardian's maiden name _____
First initial of father's/guardian's middle name _____
Month of birth (in digits; e.g. 04 for April) _____
Last digit of phone number _____

Science Knowledge Survey

1. A drug injected into a vein travels throughout the circulation in the following order to reach the brain:
   A. Left side of the heart, lungs, right side of the heart, arteries, brain
   B. Right side of the heart, lungs, left side of the heart, arteries, brain
   C. Left side of the heart, lungs, right side of the heart, veins, brain
   D. Right side of the heart, lungs, left side of the heart, veins, brain
   E. don't know

2. A process by which a substance moves across a biological membrane against its concentration gradient is:
   A. active transport
   B. diffusion
   C. osmosis
   D. filtration
   E. don't know

3. An acid that does not dissociate completely in water is called:
   A. a strong acid
   B. a weak acid
   C. ionized
   D. hydrophobic
   E. don't know

4. A reaction (such as that listed below) in which the forward and reverse direction occurs at the same rate is defined as being at:

$$H_2CO_3\,(aq) \Leftrightarrow CO_2\,(aq) + H_2O\,(l)$$

   A. homeostasis
   B. neutralization
   C. capacity
   D. equilibrium
   E. don't know

5. The connection formed between 2 neurons is called the:
   A. synapse
   B. Node of Ranvier
   C. dendrite
   D. myelin
   E. don't know

6. Acetylcholine is:
   A. an enzyme
   B. a protein
   C. a receptor
   D. a neurotransmitter
   E. don't know

7. Protein synthesis proceeds in the following order:
   A. DNA is translated to mRNA, mRNA carries out transcription to a protein
   B. DNA is transcribed to mRNA, mRNA carries out translation to a protein
   C. RNA is transcribed to DNA, DNA carries out translation to a protein
   D. RNA is translated to DNA, DNA carries out transcription to a protein
   E. don't know

8. A protein that catalyzes the rate at which a reaction occurs is a(n):
   A. oxime
   B. enzyme
   C. ester
   D. receptor
   E. don't know

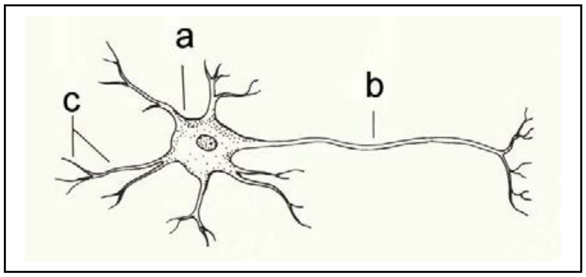
9. Aspirin, HASA, ionizes in solution, indicated by:

$$\text{HASA} \Leftrightarrow \text{H}^+ + \text{ASA}^-$$

   When adding the following to the aspirin solution, which will produce the greatest concentration of ASA^-?

   A. water
   B. a neutral solvent such as cyclohexane or benzene
   C. sodium bicarbonate of the same pH as the intestine
   D. hydrochloric acid of the same pH as the stomach
   E. don't know

10. Identify the parts of a neuron shown here:
   A. a-dendrite b-soma c-axon
   B. a-soma b-axon c-dendrite
   C. a-dendrite b-axon c-soma
   D. a-axon b-soma c-dendrite
   E. don't know



Appendix 3. Teaching Assistant (TA) Training Guide

TA Training Objectives:

- Complete or discuss each activity conducted throughout the program.
- Prepare supplies needed for each program activity.
- Identify and discuss the two activities each TA will serve as lead instructor for during the program.
- Discuss the outlined TA duties and expectations, as well as potential issues that may arise among program participants.

TA Duties:

1. Escort program participants from activity to activity, including picking-up and dropping-off participants at the identified “meeting” spot.
2. Facilitate instructors with preparing supplies for all activities.
3. Engage program participants in all activities—encourage participants to ask questions, problem solve, and arrive at their own answers.
4. Present activities with energy and enthusiasm, allowing participants to “experience” science and health as a fun, exciting career.
5. Present activities in a manner that emphasizes scientific inquiry skills, allowing participants to “think” like scientists and healthcare professionals.
6. Serve as the lead instructor for two activities conducted throughout the program.

TA Expectations:

1. Perform all outlined duties.
2. Interact and engage program participants at all times—during breaks, lunch, and all activities.
3. Do not glamorize substance use.
4. Bring a positive attitude, incorporate constructive criticism, and challenge yourself!

Potential issues that may arise:

Issue	Solution
Program participant is rude, exhibits a negative attitude, or is not participating in activities	Report observation to the instructors immediately
Program participant experiences an injury or allergic reaction	Report situation to instructor immediately; assist with calling appropriate personnel and/or treating the injury
Program participant uses their phone during an activity	Take away the device