ARTICLE

Interactive Student-Centered Neuroscience Workshops for Sixth Graders Enhance Science Knowledge and Education Attitudes

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UCNeuro, a University of California, Riverside student-run organization, developed, implemented, and tested a school-based supplemental science intervention. The purpose of this intervention was to improve students' neuroscience knowledge and education attitudes and meet, in part, California's new elementary science education standards. The intervention consisted of interactive, hands-on neuroscience workshops on the structure of a neuron, neuron-to-neuron communication, brain structure and function, autonomic nervous system function, and drug effects on the brain. Under the supervision of a faculty neuroscientist, undergraduate students implemented the intervention with 77 sixth-grade students in one school in Riverside County, California. Pre- and post-test results showed increases in students' neuroscience knowledge, confidence in achieving their goals, likeliness to go to college, and desire to attend school. Excitement about learning science material and school learning opportunities did not change after the workshops. We hope that the UCNeuro workshops can be employed and adapted to the existing curriculum to improve knowledge in the life sciences while California's new elementary science standards are being operationalized.

Key words: outreach, assessment, attitudes toward science; attitudes toward college; hands-on activities; STEM, undergraduate student teachers

INTRODUCTION

Need for Supplementary Science Education in Riverside County, California

Residents of Riverside County, the 11th most populous county in the U.S., have low rates of college attendance. According to the United States Census (2017), 81.1 % of the county's population 25 years and older are high school graduates, yet only 21.5% of the county's population 25 years and older have a bachelor's or higher degree. This amount is markedly lower than the California average of 32.6% having at least a Bachelor's degree (U.S. Census Bureau, 2017). The low percent of college-educated people may explain the county's lower per capita income in 2016 ($24,443) relative to the California average of $31,458. One of the main driving factors of low college graduation rates and overall success relates to inadequate academic preparation that's experienced by low-income families whose members are not ready for college. Families with an income of less than $25,000 per year had only 21% of their members considered highly-qualified for a four-year college/university while families with incomes greater than $75,000 showed a rate of 56% being highly qualified (U.S. Department of Education, 2011). Members of underrepresented minorities and low-income families have attributes, when compared to middle or higher-income families, that are associated with less student engagement in the high school classroom and educational success (Gillborn and Mirza, 2001; Jensen, 2013) and these attributes may pertain to overall health, distress, and/or the requirement for a growth mindset. To add, these attributes can affect the transition between high school and college, which has been regarded as an important period influenced by academic, social, economic and cultural factors (Terenzini, 1993; Terenzini et al., 1994; Gerardi, 2006; Myers et al., 2010). They may also contribute to lower retention rates of underrepresented minority and low-income college students (Dixon and Chung, 2008; Wells, 2009). This study describes a supplementary science education intervention that is designed to improve the education outcomes of 77 sixth grade students. Our hope is that this intervention, if effective, could be used to improve education and engagement in science for students in Riverside County and counties with similar demography.

Supplementary Education and Educational Outcomes

Supplementary educational programs implemented in high school and college can enhance college attendance and completion (Barton & Coley, 2011). Although similar programs at the K-8 level are scarce, evidence shows that early intervention can be effective. For example, enrichment during preschool through the third grade can increase college attendance and completion of associate's degrees, as demonstrated by a longitudinal study of young low-income minority children in high-poverty areas in Illinois (Reynolds et al., 2018). For these students, 4 to 6 years of intervention resulted in a 48% higher rate of obtaining a degree, after high school, and overall, the study showed a linear association between duration of intervention and post-secondary outcomes. A study examining the effects of developmental mentorship between high school students and at-risk fifth graders who would eventually be attending high schools with the highest dropout rates in their city found

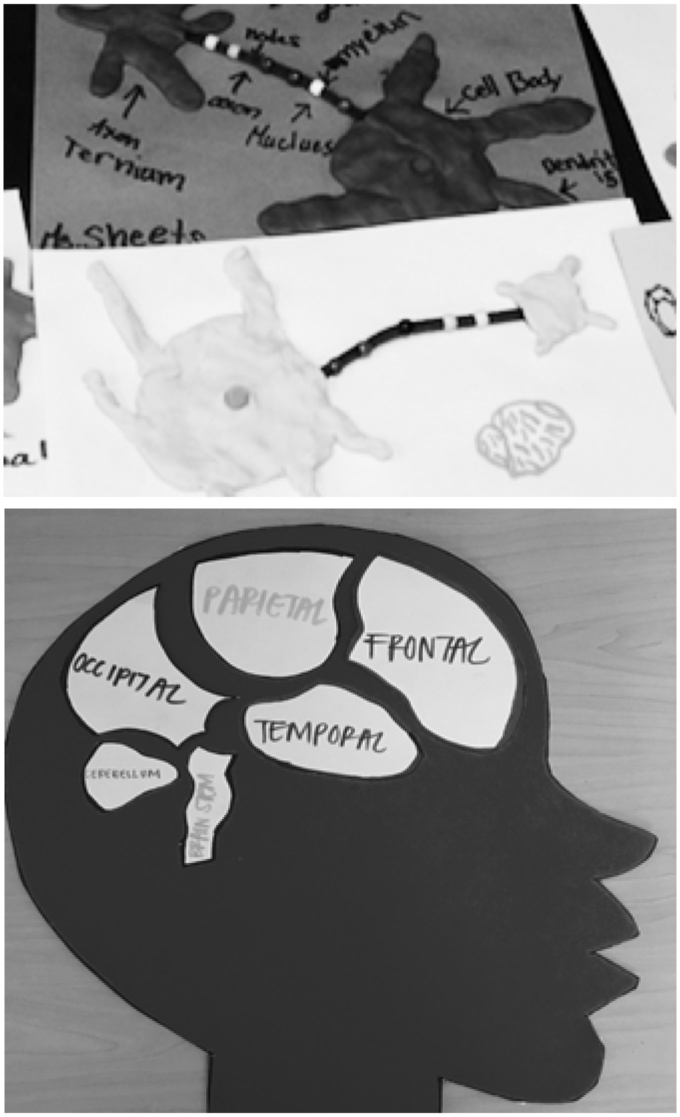

Figure 1. Top panel. Build a Neuron Activity: To teach parts of a neuron: soma and axon terminals (play doh), nucleus (cotton balls), myelin sheath (plastic beads), axon (pipe cleaner). *Bottom panel.* Brain Anatomy Puzzle: Using cut-out silhouettes, students solved a brain structure puzzle: and learned about Functions of Cerebral Lobes (Frontal, Temporal, Parietal, and Occipital), Cerebellum, and Brainstem.

that "connectedness" between the high school mentors and fifth-grade mentees fostered academic achievement (Karcher et al., 2002). In the present study, we examined whether supplementary science education, especially that taught by college students, could improve elementary school students' academics and desire to attend school.

Focus on Neuroscience

Neuroscience focuses on the structure and function of the brain, how organisms decipher information from the external world, as well as homeostasis of the body (autonomic nervous system function). With the popularity of TV shows such as "Brain Games," national celebrations of "Brain Awareness Week" promoted by the Society for Neuroscience, and successful grade school outreach efforts promoted by neuroscience-promoting organizations like The Dana Foundation (http://www.dana.org), it is evident that young people have substantial interest in neuroscience. Research suggests that supplementary neuroscience education can positively affect young people's science knowledge and education attitudes. Fitzakerley and colleagues (2013) demonstrated that Brain Awareness presentations to fourth to sixth grade students increased positive attitudes toward science and learning by using the "Science-in-the-Classroom" approach. Their intervention resulted in 88% of students showing positive shifts for 10 out of the 18 survey questions, such as "I am good at science" and "I can get smarter." The intervention proved to be the most beneficial for schools in less affluent areas. Furthermore, potential benefits of early exposure to neuroscience include learning how to acquire empirical evidence and evaluate research findings, understanding neurological disorders and drug-use effects, and deepening the desire to study neuroscience in the future (Cameron and Chudler, 2003). Other studies indicate that university students can be effective implementers of neuroscience to elementary school students (National Research Council, 1997; Foy et al., 2006).

A review of the current textbook used in the California sixth-grade curriculum revealed that there is limited coverage of life sciences, including neuroscience (Bell, 2008). However, other science topics, such as ecology and earth systems, are adequately covered. In 2013, the California Department of Education adopted new standards to revitalize and upgrade the science curriculum (State Board of Education, 2013). These new standards require that teachers in grade six cover various areas of science, including neuroscience; these standards have not been fully implemented into California classrooms in part because of a lack of instructional materials aligned to the new standards.

Supplementary Neuroscience Workshops Designed by Undergraduate Students for Riverside County Elementary Students

In January of 2017, four neuroscience undergraduates from the University of California, Riverside formed an organization, "UCNeuro" to perform outreach that improves neuroscience content knowledge, to cultivate greater interest in science, and to promote college attendance in Riverside County's underprivileged K-12 schools. This student-run organization has provided neuroscience outreach to over 5,000 students and roughly 35 teachers in local K-12 schools and after-school programs. The students began by starting a year-long intervention at Van Buren Elementary School where they taught basic neuroscience topics to 4th, 5th and 6th grade elementary students bi-weekly, using hands-on lesson plans and interventions. After gaining experience in teaching elementary school students, UCNeuro members and its faculty mentor, a neuroscience professor, proposed a project to quantitatively observe the effects of supplementary neuroscience instruction on neuroscience knowledge and education attitudes in sixth-grade students. The project was designed to deliver neuroscience workshops using tiered, interactive lessons in order to teach difficult concepts and increase the understanding of neuroscience in sixth-grade students in

UC Neuro Workshop	Society For Neuroscience Core Concept
1- Introduction to Neurons – Building Blocks of the Brain (Neuroscience Knowledge Measure Q#8, 10)	**1- The brain is the body's most complex organ:** There are around 86 billion neurons in the human brain, all of which are in use. Each neuron communicates with many other neurons to form circuits and share information.
2 - Neuron to Neuron Communication – Chemical Signals (Q#9)	**1- The brain is the body's most complex organ:** Each neuron communicates with many other neurons to form circuits and share information. **2 - Neurons communicate using both electrical and chemical signals:** Synapses are chemical or electrical junctions that allow electrical signals to pass from neurons to other cells
3 - Brain Structure - Puzzle and Sheep Brain Model (Q#11, 12)	**1 - The brain is the body's most complex organ:** Humans have a complex nervous system that evolved from a simpler one. **3 - Genetically determined circuits are the foundation of the nervous system**: Sensory circuits (sight, touch, hearing, smell, taste) bring information to the nervous system, whereas motor circuits send information to muscles and glands.
4 - Autonomic Nervous Function (Q#13)	**1- The brain is the body's most complex organ:** The nervous system influences and is influenced by all other body systems (e.g., cardiovascular, endocrine, gastrointestinal and immune systems).
5 – Drug Effects (Q#14)	**2 - Neurons communicate using both electrical and chemical signals:** Communication between neurons is strengthened or weakened by an individual's activities, such as exercise, stress, and drug use. 4 - **Life experience changes the nervous system:** Some injuries harm nerve cells, but the brain often recovers from stress, damage, or disease.

Table 1. Correspondence between UCNeuro Workshop Themes and Society for Neuroscience Core Concepts.

Riverside County. A series of tiered workshops using a hands-on/interactive teaching approach was implemented to teach difficult concepts and allow students to think critically by observing, manipulating or experimenting with a specific process (Sadi and Cakiroglu, 2011). If the workshops were found to be effective, they could potentially become instructional materials used by teachers to implement the newly adopted California science standards.

These workshops were also used to study whether educational supplementation could address common barriers faced by racial/ethnic minority students, i.e., those hindering higher educational expectations and greater difficulty adjusting to the collegiate environment (Terenzini et al., 1994; Terenzini, 1993). We examined whether students' interest in neuroscience could be leveraged to develop more positive attitudes toward science and academics, while also normalizing the possibility of pursuing a higher education. In particular, student self-efficacy has been shown to be a steady indicator of academic achievement, while influencing the processes of motivation, self-regulation, self-perception, expectancy of results, and the choices and interests of students (Cassia et al, 2009). According to the self-efficacy theory of behavioral change, a person's perceived self-efficacy can shape their adult situation (Bandura and Adams, 1977). An important factor was that the undergraduate workshop implementers themselves belong to racial/ethnic minorities and/or are first generation college students to whom the student subjects could relate.

Lastly, given the established gender differences in mathematics and science achievement (Halpern et al., 2007), we decided to analyze the workshop outcomes by gender in order to better understand any potential differential effects on boys vs. girls in neuroscience knowledge and education attitudes.

MATERIALS AND METHODS

Study Design

The study employed a one-group, pre-intervention/post-intervention survey design (heretofore designated as pre-test/post-test). Data was collected via pencil-and-paper surveys. This study was approved by the Institutional Review Board (IRB) at UCR. Neither the school nor district had its own IRB requiring approval of the study.

Sample and Recruitment

Sixth grade was chosen for this study because students in that grade had been introduced to the five senses in fifth grade and thus, had a very basic introduction to neuroscience on which the workshops could build. After gaining experience working with elementary school students across multiple grade levels and consulting with the principal of the target school, we determined that sixth graders had enough motivation and science background to understand neuroscience concepts, making them an ideal target for the workshops.

The research project was approved by the school principal, in consultation with the teachers, at Glen Avon Elementary School in the Jurupa Unified School District, which serves students from a socioeconomically disadvantaged area in Riverside County. We presented the study to the entire sixth grade (3 classes, 90 students total) and distributed parental consent forms and student assent forms, requiring their return in seven days. The assent form emphasized that the students' grades would not be affected if they did or did not assent to participate in the study. Seventy-eight students provided both signed forms. Participating students had to attend 4 of the 5 workshops and be present for both the pre- and post-test to be included in the analysis. The final sample included 77 students.

Intervention

Hour-long neuroscience workshops were implemented weekly over five consecutive weeks between January and February of 2018, constituting 5 total hours of neuroscience instruction and activity. Three classes of sixth graders participated: Class 1: 24 students (12 girls, 12 boys), Class 2: 27 students (11 girls, 16 boys), and Class 3: 27 students (10 girls, 17 boys). Upon arriving to the class each week, students randomly sat in one of four groups, each taught by one of the four undergraduate implementers. The implementers consisted of a Latino male, Latina female, Indian female, and Persian female. The first workshop began with an overview to the entire class of the material to which the students would be exposed, and students were encouraged to share anything they already knew about the brain. After the first workshop, each subsequent workshop began with a short review of the previous workshop's material, followed by a question-and-answer period.

The workshops employed interactive methods, such as hands-on interaction with brain models, construction of a neuron out of various materials, and educational games. The methods also included simplifying complex lessons using terms and analogies that children could understand. This form of interactive teaching as a whole has been shown to promote a greater understanding of information with an easier application to real world situations (Pascarella and Terenzini, 1991; National Research Council [NRC], 1996). It has also been shown to be effective when teaching neuroscience to young students (Foy et al., 2006; Cameron and Chudler, 2003). Each workshop addressed one or more core concepts promoted by the Society for Neuroscience (https://www.sfn.org) which provided guidance to meet the new California standards – see Table 1.

Workshop #1: Introduction to Neurons - Building Blocks of the Brain

This initial session focused on Core Concept #1 (Table 1), that neurons are the basic units of the nervous system which communicate with one another neurons to form circuits and share information. Students were given play doh, construction paper, pipe cleaners, colored beads, markers, and small, colored cotton balls to build a model neuron and learn about the different functional parts of neurons. Students followed instructions to shape the soma and terminals with play doh, using a cotton ball as the nucleus, a pipe cleaner as the axon, and beads over the pipe cleaner to represent the myelin sheath (Figure 1, top panel). The implementers explained the name and function of each structure and asked the students to label the parts on their

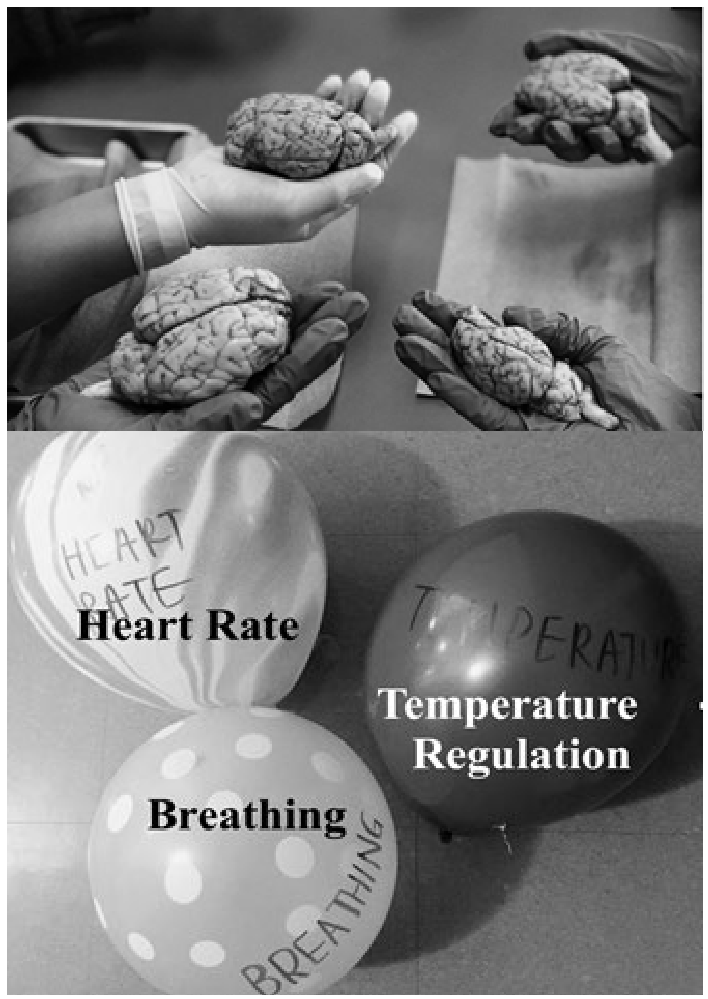

Figure 2. Top panel. Demonstration of Anatomy of Sheep Brain: Sheep brain specimens used to point out anatomical location of cerebral lobes, spinal cord, brainstem and cerebellum in animal model. *Bottom panel.* Juggling balloon Exercise to Highlight Autonomic Nervous System Functions: Ball toss with balloons representing conscious breathing, heart rate monitoring, and temperature regulation.

construction paper. Each student could take their projects home with them and were encouraged to review it.

Workshop #2: Neuron-to-Neuron Communication - Chemical Signaling
Students were taught, through an outdoor ball-toss game, how each neuron communicates with others to share information. The concept of the chemical messengers called neurotransmitters, was delivered inside the classroom with visual aids (drawing neurons on whiteboards) to show how one neuron releases a chemical neurotransmitter(s) to send signals to a neighboring neuron while also recycling the released neurotransmitters to end the signals. Students went outside the classroom for the "Neurotransmitter Ball Toss game." Students were divided into 2 groups representing presynaptic neurons ("sending" neuron 1) and postsynaptic neurons ("receiving" neuron 2). Members of the neuron 1 group were given a ball that represented a neurotransmitter. The students were grouped into pairs, where the student representing neuron 1 would toss the ball to their partner who represented a neurotransmitter receptor on neuron 2. Students competed to see which pair caught the most balls in one minute. The pair with the highest tally received a prize sticker.

To emphasize neurotransmitter recycling, after tossing the ball to their partner, students representing neuron 1 had to run around their partner and retrieve their ball before being able to toss the ball again. Once the winning group was determined, transmitter release and recycling were reviewed in the classroom to address Core Concepts #1 and #2 (Table 1).

Workshop #3: Brain Structure - Lobe Functions Puzzle and Sheep Brain Model
This workshop consisted of an introduction to the complex anatomical structure of the brain using a large puzzle (Figure 1, bottom panel) in which different colors corresponded to cerebral lobes and other anatomical brain structures including: occipital lobe (red), parietal lobe (yellow), frontal lobe (blue), temporal lobe (green), cerebellum (purple), and brainstem (orange). A large cut-out made of construction paper, representing a silhouette profile view of a human head, was placed on the classroom tables and the different anatomical components of the brain were labeled. The implementers taught and reviewed functions of the major brain areas, emphasizing that the occipital lobe controls vision, the frontal lobe controls movement, the parietal lobe controls somatosensation (touch), the temporal lobe controls hearing, the cerebellum helps with balance and coordination of muscle activity, and the brainstem controls autonomic motor functions. The students worked in teams to reassemble the "brain puzzle". Once the pieces were correctly positioned, the students were asked about what potential deficits would arise if different parts of the brain were injured or damaged.

The second part of this workshop utilized sheep brain specimens (Figure 2, top panel). Students received personal protective equipment (gloves, goggles, and napkins). If desired, students held and analyzed the specimens. Students were encouraged to feel the surface of the cerebrum and cerebellum and were oriented to the top (dorsal) and bottom (ventral) surfaces of the brain. They were also shown the location of the brainstem and spinal cord. This workshop workshop addressed Core Concepts #1 and #3 (Table 1).

Workshop #4: Autonomic Nervous Function
Brainstem function was demonstrated through an activity that simulated life without a brainstem. The implementers taught the students about the main homeostatic functions controlled by the brainstem including breathing, heart rate, and body temperature regulation which corresponded with Core Concept #1 (Table 1). The students were split up into four groups (one group per implementer) and completed a simple addition/subtraction test on paper, while juggling 3 balloons in the air that represented breathing, heart rate, and body temperature, trying to prevent the balloons from hitting the floor (Figure 2, bottom panel). The object of the game was to show how vital (autonomic) processes are handled involuntarily by the brainstem while executive centers of the brain consciously engage in problem solving activities such as addition/subtraction.

Workshop #5: Drugs and Your Brain - How the Damage is Done
This session described how drugs affect communication between neurons and harm nerve cells which aligned with Core Concepts #2 and #4 (Table 1). To explain how drugs mimic/inhibit the binding of natural neurotransmitters, we presented a slideshow accompanied by a simplified reenactment of the process. We explained mechanisms by which drugs act on the brain, like agonists which we called "pretend drugs", antagonists which we called "block drugs" and reuptake inhibitors which we called "recycle blockers". Since students were already aware of the importance of neurotransmitters from workshop 2, learning these specific mechanisms better emphasized the danger of drugs.

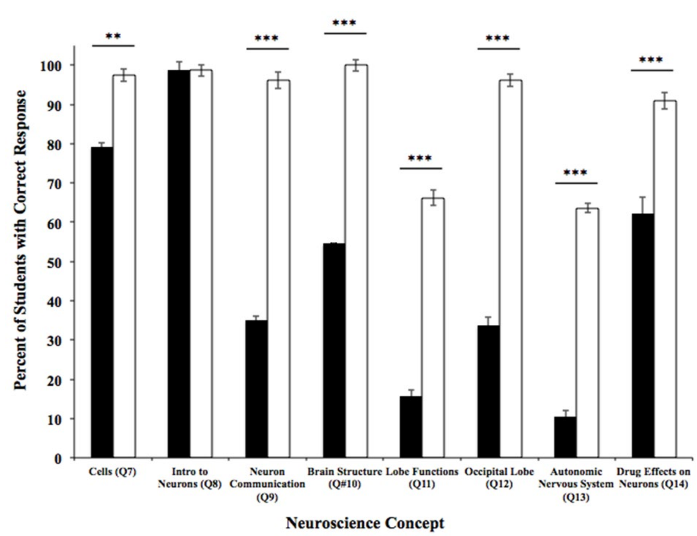

Figure 3. Pre-test (black bars) and post-test (open bars) percent of participants with correct answers on neuroscience knowledge questions. Asterisks indicate statistically different from pre-test at p< 0.05 (*) or p< 0.01 (**).

A small football represented a normal neurotransmitter and a small traffic cone was used to represent the receptor. The football fit perfectly into the traffic cone, which we explained allows for normal brain function. A small soccer ball was used to represent drug molecules that enter your brain. We placed the soccer ball into the cone, explaining that the drug can mimic or block the response to a normal neurotransmitter binding to its receptor. Drugs such as heroin, methamphetamine, and nicotine, were called "pretend drugs" to describe their roles as receptor agonists mimicking the role of endogenous neurotransmitters, such as endorphins, dopamine and acetylcholine, respectively. The implementers explained that these drugs were not only harmful acutely, but could harm neurons permanently. Next, the implementer covered "block drugs" including alcohol and Xanax and how they reduce neuronal activity. Students learned how this reduction is accomplished, in part, by the potentiation of the inhibitory neurotransmitter, GABA. Finally students were introduced to how "recycle blockers" such as cocaine operate.

DATA COLLECTION

Participating students were given a pre-test one week prior to the first workshop and a post-test on the day of the last workshop, immediately after instruction had ended. The students had 15 minutes to complete the surveys and ask any questions of the research team. To allow for pre- and post-test matching, participants were assigned a unique two-digit identification number.

The survey had three parts: the first part collected data on students' gender, and the second part collected data on students' education attitudes (Appendix 1 - Education Attitudes) including desire to attend school, excitement about learning science, assessment of own knowledge, likelihood of attending college, perception of school as providing cool opportunities to learn, and confidence in achieving goals. The third part of the survey collected data, via eight multiple choice questions, on the students' neuroscience knowledge aligned to Core Concepts designated in Table 1 (see Appendix 1 -Neuroscience Knowledge). The students' answers to the questions were coded as either correct or incorrect. The answers were then combined to determine a student's total number of correct with higher values indicating greater neuroscience knowledge. We anticipated that students would know at the pre-test the answer to the first question, about the definition of a cell, based on our knowledge that this material was already covered in the existing lesson plans. We included it in the pre- and post-tests to assess background knowledge on which the workshops built.

ANALYSIS

Using the full sample, we conducted McNemar tests of paired proportions for each neuroscience knowledge question to determine whether the proportion of students who got each question correct improved from pre-test to post-test. We then ran a paired samples t-test to determine whether the mean neuroscience knowledge (number of correctly answered questions) at post-test was statistically different than the mean at pre-test. We also ran paired samples t-tests to determine whether the mean scores of the education attitudes at post-test were statistically different than the scores at pre-test.

Using gender sub-samples, we repeated the analyses of overall neuroscience knowledge and education attitudes to determine whether the patterns of pre- to post-test differences varied by gender. We then constructed pre-post mean difference scores for each variable and used independent samples t-tests to determine the effect of gender. We expected a statistically significant effect of the intervention represented as greater mean post- than pre-test neuroscience knowledge scores and as more pro-education attitudes at post- than at pre-test.

RESULTS

The intervention was successfully implemented. The implementers were faithful to the design of the intervention and were able to execute the workshops without deviation from the lesson plans. As planned, the implementers had the full-hour session for 5 consecutive weeks with no adverse effects noted in any one of the workshops and no interruptions from school teachers or behavioral problems among students. Additionally, implementers reported a high level of interest from participating students as indicated by their engagement with the material and clarification questions that showed both enthusiasm and understanding. Support from school teachers and the school principal was shown through their introduction of the implementation team to the students, and expression of their gratitude to the implementers and the faculty advisor. The principal has requested that the team return to the school for additional interventions.

Additionally, the UC Neuro implementers anecdotally reported that they themselves benefitted from the experience. They perceived that they had enhanced their communication skills, deepened their knowledge of neuroscience and research, fostered their professional and leadership skills, expanded their network with the community, and felt a sense of accomplishment. They described the experience as being rewarding and beneficial to their careers. The implementers demonstrated their leadership potential and commitment to science literacy, while working on their career aspirations.. Lastly, UC Neuro serves as an unofficial ambassador program for UCR, helping to enhance the reach of the university to the community and aid in the recruitment of future college students.

Neuroscience Knowledge

To assess participant outcomes, we first examined each of the 8 neuroscience knowledge questions separately using the entire sample data which included both sexes. (questions 7-14; Appendix 1). We compared the proportion of students who answered each question correctly at pre-test to that at post-test. Figure 3 shows that mean post-test scores in 7 of the 8 tested areas were significantly greater at post-test. Students' knowledge of a neuron based on the question "What are the cells of the brain called?" did not change from pre-test to post-test.

We then examined overall neuroscience knowledge

Educational Attitudes (data from both sexes)	Pre	Post	Diff.
Looks forward to coming to school	3.17 ± 0.77	3.32 ± 0.64*	0.16 ± 0.65
	t = -2.10, df = 76, p = 0.04		
Excitement about learning new science material	4.48 ± 0.72	4.60 ± 0.63	0.12 ± 0.65
	t = -1.58, df = 76, p = 0.12		
Students' perceived own knowledge compared to peers'	3.34 ± 0.75	3.79 ± 0.78***	0.45 ± 0.94
	t = -4.25, df = 76, p = 6.11E-05		
Likeliness to attend college	4.16 ± 0.86	4.38 ± 0.69*	0.22 ± 0.77
	t = -2.51, df = 76, p = 0.01		
School learning opportunities	4.35 ± 0.85	4.47 ± 0.77	0.12 ± 0.78
	t = -1.32, df = 76, p = 0.19		
Confidence in achieving one's own goals	4.03 ± 1.00	4.42 ± 0.73**	0.39 ± 1.16
	t = -2.95, df = 76, p = 0.004		

Table 2. Pre- and post-test means, standard deviations, and t-test results for education attitudes. Asterisks indicate statistical difference vs pre-test at p< .05 (*), p<.01 (**), or p < .001 (***).

using the entire participant dataset. The pre-test mean percentage of correct answers to the neuroscience knowledge questions before intervention was 44.86% (SD = 1.24). The post-test mean was 88.64% (SD = 1.09), indicating that the mean percentage of correct answers doubled after intervention. This difference was statistically significant (t = 1.99, df = 76, p = 2.92E-32). When data was separated according to sex, we found that on average, both boys and girls showed significant improvements in neuroscience knowledge from pre-test to post-test. Results of dependent samples t-tests of mean differences in overall neuroscience knowledge scores in the gender sub-samples revealed a 36.7% increase for boys (pre-test mean: 51.67 ± 1.18; post-test mean: 88.33 ± 1.14; t=2.02, df=44, p=1.06E-20). A 44.1% pre-post increase for girls was observed (pre-test mean: 44.92 ± 1.27; post-test mean: 89.06 ± 1.04; t=2.04, df=31, p=9.92E-14). Finally, we found that the boys' pre-post test mean difference was not statistically significantly different from the girls' mean difference (t= 2.00, df= 54, p=0.08).

Educational Attitudes

Our pre- and post-test educational attitudes survey contained 6 items (Appendix 1). Combined data from both sexes showed statistically significant positive changes from pre-test to post-test in 4 of 6 educational attitude survey items (Table 2) including: looking forward to coming to school, perceived own knowledge compared to peers' knowledge, likeliness of attending college, confidence in achieving their goals. No significant changes in pre- and post-test means were found for the survey items assessing excitement about learning new science material or perceived frequency of "cool opportunities" for learning at school.

Similar analyses were performed with these data separated by sex (Table 3). These additional analyses showed fewer significant differences compared to when data from both sexes where combined. Boys showed statistically significant pre- vs. post-test mean increases for 3 survey items including the extent to which they look forward to coming to school, the perceived amount of their own knowledge relative to their peers' knowledge, and the likeliness of going to college. In contrast, the girls showed statistically significant increases for 2 survey items including for the perceived amount of their own knowledge relative to their peers' knowledge and confidence in the ability to achieve one's goals. Thus, boys differed from girls in the survey item relating to likeliness to go to college. We tested for baseline sex differences to better understand the differences described above. Girls had a statistically significantly higher pre-test mean for the likeliness of going to college (t = 1.99, df = 75, p = 0.0001), but not for the extent to which they look forward to coming to school (t = 1.99, df = 74, p = 0.15) nor their confidence in ability to achieve one's goals (t = 2.00, df = 64, p = 0.79).

We found that there was no statistical sex effect in the pre- vs. post-test difference values for each education attitude (Table 3, Diff. of Diff. column). There was an apparent gender effect that did not meet statistical significance for likelihood of attending college (t = 1.68, df = 75, p = 0.098). In summary, the students, regardless of gender, increased their neuroscience knowledge and developed more positive education attitudes from pre-test to post-test, as hypothesized.

DISCUSSION

In this paper we describe the development, content, and implementation of a supplemental science intervention for California sixth graders and reported results of a test of its effects on students' neuroscience knowledge and education attitudes. The results were that the intervention was successfully implemented as designed and found to be feasible. As stated by Pascerella and Terenzini (1991), learning is "more durable and easily applied to real-world

	Question Topic											
Gender	**Looks forward to coming to school**				**Excited about learning new science material**				**Perceived own knowledge compared to peers**			
	Pre	***Post***	**Diff.**	**Diff. of Diff.**	***Pre***	***Post***	**Diff.**	**Diff. of Diff.**	***Pre***	***Post***	**Diff.**	**Diff. of Diff.**
Boys n = 45	3.07±0.84	3.29±0.66*	0.22±0.70	**-0.16**	4.31±0.79	4.44±0.69	0.13±0.69	**-0.04**	3.33±0.71	3.69±0.79**	0.36±0.91	**0.23**
	t = -2.12, df = 44, p = 0.04				t = -1.29, df = 44, p = 0.20				t = -2.63, df = 44, p = 0.012			
Girls n = 32	3.31±0.64	3.38±0.61	0.06±0.56		4.72±0.52	4.81±0.47	0.09±0.59		3.34±0.83	3.94±0.76**	0.59±0.98	
	t = -0.63, df = 31, p = 0.54				t = -0.90, df = 31, p = 0.37				t = -3.43, df = 31, p = 0.002			
Gender	**Likeliness to attend college**				**School learning opportunities**				**Confidence in achieving one's own goals**			
	Pre	***Post***	**Diff.**	**Diff. of Diff.**	***Pre***	***Post***	**Diff.**	**Diff. of Diff.**	***Pre***	***Post***	**Diff.**	**Diff. of Diff.**
Boys n = 45	3.87±0.89	4.20±0.76*	0.33±0.90	**-0.27**	4.27±0.91	4.31±0.87	0.04±0.88	**0.18**	4.00±0.98	4.29±0.79	0.29±1.12	**0.24**
	t = -2.47, df = 44, p = 0.02				t = -0.34, df = 44, p = 0.74				t = -1.73, df = 44, p = 0.09			
Girls n = 32	4.56±0.62	4.63±0.49	0.06±0.50		4.47±0.76	4.69±0.54*	0.22±0.61		4.06±1.05	4.59±0.61*	0.53±1.22	
	t = -0.70, df = 31, p = 0.49				t = -2.03, df = 31, p = 0.05				t = -2.47, df = 31, p = 0.02			

Table 3. Pre-test and post-test mean (+/-SD) scores on education attitude questions and pre-post mean difference (+/-SD) scores Diff) for each gender sub-sample. Asterisks indicate statistically different from pre-test at p < .05.

settings" when there is a focus on interactive teaching methods. These methods allow for the students to not only be more engaged in the material, but allow them to feel more comfortable to think critically. Collaborative learning helps enhance the development of critical thinking through discussion, evaluation and development of ideas (Gokhale, 1995). We developed workshops that employed interactive methods, such as games and creative activities, and the students responded enthusiastically to these methods. To add, we believe that the interactive nature of the intervention contributed to the students' learning. With regard to intervention effectiveness, there were desirable pre- to post-test changes in students' neuroscience knowledge and education attitudes. These findings provide preliminary evidence of the intervention's promise as a supplementary science intervention.

With regard to neuroscience knowledge, seven of the eight knowledge areas showed improved knowledge after the intervention. The area that showed no change, knowledge of neurons, was unexpectedly high at pre-test, perhaps due to an introduction to the topic by the teachers in anticipation of the workshops. Thus, the lack of significant change appears to be due to a ceiling effect. This result may mean that students are ready for more advanced concepts related to neurons, like those emphasized in the workshop series tailored to sixth graders (Table 1). Most of the neuroscience content questions were answered correctly by 90-100 percent of the students indicating significant knowledge gained. Two questions fared less favorably, (lobe functions and autonomic nervous system) indicating that more emphasis is needed on these topics.

Relative to the changes in neuroscience knowledge, the changes in education attitudes were smaller. However, the changes were in the desirable direction, occurring in four of the six education attitudes over time. No significant changes occurred in the students' excitement about learning new science material or perceived frequency of "cool opportunities" for learning at school. The absence of change in these two attitudes may be due to a ceiling effect, as the means were high at pre-test for both measures. These high pre-test scores may also indicate a highly curious and engaged group of sixth graders even before the intervention. Going forward, we could consider using alternative measures with more finite categories that would be able to capture even smaller changes in these two measures. Additionally, we could also revise the workshop content to try to further increase science excitement and, working with the school to increase the workshop frequency to better impact these outcomes.

We found no statistically significant gender differences in the pre- to post-test changes in the full sample. Both boys and girls showed overall improvement in their neuroscience knowledge and education attitudes as a result of the intervention. That said, analyses revealed different patterns of change based on sex. The differences in the patterns (e.g., girls gained in confidence, boys did not) may be due to issues of statistical power/sample size. After all, the pre- to post-test changes in these cases were all in the desirable direction. Alternatively, they may be due to baseline gender differences, at least in the case of the likeliness of going to college. In the sub-samples, boys improved on the likeliness of going to college, but girls did not. However, girls' pre-test means were higher than boys, suggesting a possible ceiling effect for them. These findings, taken together, suggest that if the changes over time are attributable to the intervention, there is no compelling need to tailor the intervention for gender subgroups.

The design of the intervention did not allow for a test of implementer effects, since students in any one class were exposed to all four implementers. However, in a future implementation, the design could be modified such that students have only one implementer, enabling a test of implementer effects. Prior research has documented the importance of having role models by gender and race/ethnicity for developing an interest in the fields of science, technology, engineering, and mathematics (Halpern et al., 2007). For this reason, UCNeuro chose male and female implementers from racial/ethnic and socioeconomic backgrounds that were similar to the target student population. In future research, we could survey the students about their connection to the implementers and examine how specific constellations of implementer characteristics relate to students' outcomes and to what extent an implementer-student match is important.

A significant limitation of this study is the absence of a control group and random assignment of students to treatment or control conditions. The inclusion of a control group(s) and random assignment would allow for definitive attribution of the pre-post changes to the intervention. Now that we have determined the feasibility of the intervention and found preliminary evidence of its effectiveness, we can replicate the study in the future, including both treatment and control groups and employ random assignment of students into those groups. We could also conduct multiple post-tests to examine retention of intervention effects over time. Another inquiry of interest would address how much was contributed by the unique pedagogical approach (undergraduate students versus school teachers, the student-centered and entertaining methods used.) and how much was related to neuroscience content as a possible motivating factor.

Since the start of this study, UCNeuro's membership has more than doubled, permitting the organization to expand its reach to more schools and students in Riverside County. Furthermore, the participating school has invited UCNeuro to return for additional implementation. Using these contacts, we can conduct the necessary further research to strengthen the evidence base for this intervention that stands to meet the need for supplemental science education to motivate elementary school students to study science and pursue advanced education. In the meantime, while California's new science standards are being operationalized, the UCNeuro workshops can be employed and adapted to the existing curriculum to improve knowledge in the life sciences. It has been suggested that teachers' lack of neuroscience knowledge has regrettably led to the propagation of many damaging myths about the brain (Howard-Jones, 2014). To avoid the use of our intervention by teachers merely as a script to bring about successful outcomes among their students, the undergraduate student implementers covered several topics in neuroscience as part of a tiered mini-curriculum. Topics chosen were aligned to that of the Society for Neuroscience core concepts and their undergraduate major curriculum. In future studies, we will test teachers along with the students to provide insight into their understanding of key neuroscience concepts that will allow them to become more effective science teachers.

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APPENDIX 1: MEASURES OF EDUCATION ATTITUDES AND NEUROSCIENCE KNOWLEDGE

Education Attitudes

1. Do you look forward to coming to school? Check one.
   - Yes, all of the time: especially if there are hands on activities
   - Yes, most of the time
   - Yes, some of the time
   - No, never

2. How excited are you about learning new science material? Circle one.

1= not excited at all, 3= a little excited, 5= very excited

1 2 3 4 5

3. How much do you know compared to other kids your age? Circle one.

1= a lot less, 3= about the same, 5= a lot more

1 2 3 4 5

4. How likely do you think you are to go to college? Circle one.

1= Not at all 3= I might go 5= Very likely

1 2 3 4 5

5. School gives me cool opportunities to learn about interesting material.

1= Never 3= Rarely 5= Often

1 2 3 4 5

6. I am confident that I will achieve the goals I set for myself.

*1= Does not sound like me 3= Sounds a little like me 5= Sounds a lot like me *

1 2 3 4 5

Neuroscience Knowledge (Correct answers are **bolded**)

7. Cells are…. Pick one.
   - **The smallest pieces that make up all living things**
   - Found in rocks
   - Only in the outside part of your body
   - Tiny atoms that make compounds

8. What are the cells of the brain called? Check one. (Introduction to Neurons)
   - Cerebaloos
   - Brainites
   - Encephalons
   - **Neurons**

9. How do cells in the brain “talk to” one another? Check one. (Neuron to Neuron Communication)
   - By growing and shrinking
   - **Through chemicals called neurotransmitters**
   - By direct contact between them
   - Through vibrations in the space between them

10. How many neurons make up your brain? Check one. (Introduction to Neurons)
    - 1: one
    - 10: ten
    - 10,000: ten thousand
    - **100,000,000,000: one hundred billion**

11. Match the lobe of the brain with what it is responsible for. (Write Letter in Space) (Brain Structure)
    - Temporal lobe: ___**C**___

A. Moving your body
- Parietal lobe: ___**B**___

B. Sensation of touch
- Frontal lobe: ___**A**___

C. Hearing

12. The eyes are connected to which part of the brain to help you see? Check one. (Brain Structure)
    - **Occipital lobe in the back of your head**
    - Insular lobe above your neck
    - Lobular lobe right above the eyes
    - Parietal lobe at the top of your head

13. Which of these functions is associated with the brain? Check all that apply. (Autonomic Nervous Function)
    - **Breathing**
    - **Sensation of touch**
    - **Body movement**
    - **Vision**
    - **Heart Rate**
    - **Body Temperature**

14. What effect do drugs and alcohol have on the brain? (Drug Effects)
    - They change the location of cells
    - **They change the way neurons “*communicate*” with one another**
    - They immediately kill your brain
    - They have no effect on your brain