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ARTICLE

Neuroscience and Education Colleagues Collaborate to Design and Assess Effective Brain Outreach for Preschoolers

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Neuroscience outreach efforts are currently aimed at older elementary or high school children and have not traditionally assessed effectiveness. Additionally, programs are often initiated by either neuroscientists or educators alone, with few combined instances of these groups working together. Considering the wide range of benefits that accompany interdisciplinary collaborations for outreach, this study sought to develop a neuroscience curriculum for preschool students via collaborations between neuroscience and education departments. Six neuroscience lessons addressing various functions of the brain were taught to preschool students in consecutive weeks. The first lesson was given to the entire class, after which a baseline pre-assessment was performed. Students were then divided into groups, after which only half of the class received further neuroscience instruction. A post-assessment measured for increases in neuroscience knowledge in the students. Results showed that students who received the neuroscience lessons had a greater understanding of content-specific material compared to the group who did not receive neuroscience lessons. The undergraduates involved also reported great benefits from participation in this program. This work addresses the gap in interdisciplinary science programming targeting young elementary aged students, and also provides a framework for improved design and assessment of such programs to continue to better scientific outreach efforts.

Key words: outreach; neuroscience; preschool

Science outreach has a wide range of benefits, underscored by the national efforts from various disciplines to implement effective and exciting programs to engage the public (Stieben et al., 2017). In fact, many have recently called for scientists to expand public outreach and education (Cameron and Chudler, 2003; Frantz et al., 2009; "Encouraging science outreach", 2009; McNerney, et al., 2009; Chudler and Bergsman, 2014) and have presented valuable resources for doing so (McNerney et al., 2009, Chudler and Bergsman, 2014). While outreach efforts and programs have grown substantially for elementary-aged and high school students, there remains room for further improvement, especially with preschool-aged students. Creating purposeful collaborations between scientists and educators could improve design, reach, and assessment of outreach programs.

Neuroscience outreach is most often performed by graduate and undergraduate science students in a variety of settings that include local secondary and elementary schools, museums, or on-campus visitation events. While the scientific expertise of these students is likely more than sufficient to inform the content of such programs, these students receive little instruction in their science curricula regarding how to communicate complex neuroscience concepts to school-aged children in an exciting and engaging manner. This also may be a poorly developed skill set for faculty overseeing such projects, as evidenced by sources that report few research scientists engage in communication training (Besley and Tanner, 2011) despite agreeing that it is important (Leshner, 2007; Besley and Tanner, 2011). Recent calls urge training for scientists in such matters (Leshner, 2007; Trench and Miller, 2012). Collaborating with colleagues with extensive K-12 classroom expertise can greatly enhance outreach efforts and productivity (Carr, 2002; Patel et al., 2017). Early childhood education students and professionals receive extensive instruction related to lesson planning, instruction, and guiding a classroom (Buettner et al., 2016) that is often absent or underdeveloped in the curriculum provided to the average science student (Brownell et al., 2013). Efforts to approximate this training have been made, including a practice run of the outreach lesson to ensure appropriate volume of voice and verbiage for the expected age of students in the classroom (Romero-Caldéron et al., 2012). Regardless, even these thoughtful efforts cannot match the skills of trained educational professionals, particularly when working with a younger population such as early elementary aged children. In fact, experts state that scientists must move beyond classroom visits to become active participants in professional development courses for teachers (Melvin et al., 2006), suggesting collaborative efforts may produce bidirectional benefits. Such advice has prompted the design of scientist-teacher partnership programs (Cameron and Chudler, 2003; deLacalle and Petruso, 2012; Romero-Caldéron et al., 2012; Deal et al., 2014; Patel et al., 2017) which aim to address these very issues. Yet identifying school teachers with the interest and time available for such programs, and coordinating schedules for planning and implementation present additional challenges (Tanner et al., 2017). Further, the lack of standards-aligned, research-based curricula and pedagogical practices available to teachers who are motivated to engage students in neuroscience concepts makes this a challenging endeavor.

If undergraduate neuroscience students often engage in outreach efforts, it seems a logical collaboration to include undergraduate education majors as viable partners in such programming. These students have the background necessary to provide insight into whether educational approaches are grade and age appropriate. Further, their physical proximity and the connections they have to local schools should not be overlooked. Initiating programs that are devised by individuals immersed in two distinctive educational philosophies, cultures, and styles enhances the delivery of the program from the start (Carr, 2002). In fact, keeping university academic-specific and educational departments isolated from one another may be detrimental to both groups (Newton et al., 2010). Studies also suggest that increasing content knowledge of teachers will have great benefits for the education of undergraduates as well (Deal et al., 2014).

While the expansion of science outreach programs is likely to provide great benefit, minimal guidance exists for the implementation of lessons that are age appropriate for the youngest generations of students, particularly Pre-K through 3rd grade. Science education, in general, is often not emphasized in children younger than middle school (Marshall and Comalli, 2012), and many outreach efforts target 3rd graders as the youngest population (Romero-Caldéron et al., 2012). Indeed, calls for expanded educational outreach commonly describe programs directed at the K-12 population or teachers at those grade levels. This may stem from the fact that children are assumed to be unequipped to manage and synthesize a great deal of material at a younger age, but also could arise from a lack of educators trained in the science curriculum (Carr, 2002). The value of engaging science curricula for younger children is well established. One outreach program from UCLA cites that the youngest students in 3rd-5th grade are the ones who show the greatest amount of enthusiasm and curiosity about the field of neuroscience, suggesting that targeting even younger populations could be a way to stimulate interest in this field (Romero-Caldéron et al., 2012). The benefits of outreach in young students spans from capitalizing on their peak levels of student curiosity, promoting protective behaviors such as helmet wearing which develop into life-long neuro-protective behaviors, and increasing the number of individuals pursuing science careers upon graduation (Marshall and Comalli, 2012; Romero-Caldéron et al., 2012; Stieben et al., 2017). Targeting students as young as pre-K to harness the enthusiasm, curiosity, and immense ability to learn quickly that is often seen in the youngest children in school (Schotland and Littman, 2012) could improve educational outreach. Yet, upon design of pre-K programming, the most convincing way to demonstrate whether pre-K outreach efforts are effective is to implement assessment.

Scientists have begun attempts to measure whether outreach programming is effective in recent years. Yet despite progress, existing efforts at evaluation often use the perceptions of undergraduate students or the teachers in the classrooms as a proxy for the success of the program (Stieben et al., 2017). Some studies do aim to directly assess the impact of outreach on the recipient students through the use of standardized tests (deLacalle and Petruso, 2012). Yet programs are often provided in settings like museums or science fairs where obtaining written consent for assessment is challenging. Further, the targets of outreach are often under the age of 18, which would require guardian consent (Stieben et al., 2017). Still, attempts at assessment, particularly in scenarios where guardian consent is easier to obtain (such as classroom activities that can be planned in advance), can aid in determining which programs and activities are most effective.

As the need for outreach efforts increases, and evidence mounts that introducing science material to young students is beneficial, we sought to explore whether or not preschool students were an appropriate target population for neuroscience outreach. Our collaborative program was designed by an interdisciplinary team of undergraduate students and faculty who had expertise in both neuroscience and elementary/special education. Our program focused on the brain as the central command center of the body and controller of behavior. Six lessons that focused on different aspects of brain function were introduced to the students to convey these concepts. To measure whether or not preschool students' neuroscience knowledge was impacted by our outreach instruction, we assessed student knowledge before and after the program implementation. Inter-disciplinary collaborations such as this one are likely to engage children with content through instruction that is developmentally and pedagogically appropriate.

MATERIALS AND METHODS

This outreach program was initiated when the neuroscience faculty member, who had a desire to provide educational outreach in the college-associated preschool, reached out to an Education colleague that had performed math-based outreach programming in the same preschool the year prior. Both faculty agreed to collaborate in this initiative, and identified undergraduates that might be well suited for such an opportunity. The goal was to have a student with an education background and a student with a neuroscience background collaborate to design and implement the program. Two such students (both female, junior status, Caucasian) who had recently completed a course in Behavioral Neuroscience with the neuroscience faculty member as part of major requirements were identified as good candidates by the faculty. Both had sufficient neuroscience background to communicate regarding program content, and experience and interest in working with preschool aged children. The education student had worked in the preschool the year prior and had multiple other educational experiences, and the neuroscience student had less formal training but experience with younger siblings and through work as a babysitter.

After an initial consultation with faculty advisors about the major goals for the program (between subjects design, an initial introductory lesson, interview assessment conducted by faculty, programming completed within one semester, basic neuroscience topics), the students independently developed six neuroscience lessons for presentation in the preschool during six consecutive weeks (once per week). Using the foundation acquired in the Behavioral Neuroscience course, which had 5 main blocks (brain and neuron anatomy, sensation, motor behavior, motivated behavior, and cognitive behavior), the students collaborated to identify five objectives for the individual lessons. The Neuroscience student offered more thorough background on what may be considered “fundamental” lessons on brain structure and function, having completed more coursework in neuroscience. The education student’s expertise on what five-year-old children would be capable of comprehending was also critical at this step. Practical considerations also dictated topic choice; concepts needed to easily translate into brief, focused lessons that allowed for repetition and simplicity of language. The undergraduates ultimately settled on an overall goal to convey the structure - function relationship of the brain and nervous system, emphasizing the brain’s main role as a control center for bodily function. To teach this, lessons aimed to teach brain lobes and functions, the brain’s control over executive and autonomic functioning, the brain’s ability to learn and remember, and the brain’s role in interpreting sensory stimuli. Such lessons exploited the fact that 4-5 year olds are aware that they can run, taste things, see, and (perhaps to a lesser degree) think and remember. Abstract concepts such as neural transmission, emotions, and disorders, though potentially “foundational,” were avoided, as they were less concrete and more difficult to translate into things that could be seen, heard, or experienced.

Once topics were chosen, the two undergraduates worked as a team, independent from faculty oversight, to develop lessons prior to the first introductory lesson in the preschool. The education student’s prior experience in the preschool ensured familiarity with the typical structure of lessons and the general knowledge level of students. Furthermore, the education student had courses through the Education Department, which provided classroom visits at local elementary schools. Together, these experiences provided knowledge of age-appropriate content for the collaboration. The education undergraduate was also familiar with the preschool’s dogma of play-based teaching, which served as a key aspect of lesson development. Rather than instructing with pencil and paper, the lessons that were constructed aimed to engage the students with some form of engaging, interactive learning.

Upon solidifying the lesson deliverables and confirming them as appropriate with faculty advisors, the undergraduate students collaborated on how to engage the preschool students in the primary goal of each lesson. While both students were competent in understanding the content of each lesson, special emphasis was given to the word choice and presentation of each lesson, which was informed by the education student’s training. For instance, the word “neuron” or “axon” was not used in lessons, but rather replaced with words like “connections” to emphasize the communication between the brain and the body’s functions. Additionally, the education major recommended repetition of the same phrase as often as possible for each lesson. The goal when teaching was to limit jargon and rather substitute words that were accurate yet simple. Word choice was also dictated by language that could be supported with visualization and concrete experiences (i.e., a “message” that could move from brain to target). Materials that were inexpensive and easy to create were used to support lessons in order to provide items the students could interact with; the education student had previous experience in the creation of such items. The Education student emphasized the likelihood of limited attention span in this age group, so lessons were brief (7-10 minutes).

All lessons were led by either the neuroscience student or the education student based on scheduling availability, except for the introductory lesson and the final lesson (on sensation), which were co-taught. A few days prior to lesson delivery, the undergraduates met to review the lesson objective, use age-appropriate words, timing, and lesson progression. The expertise of the education undergraduate was invaluable for this collaboration, as the neuroscience undergraduate had little experience in formally teaching preschool aged children. Rehearsing the lesson and foreseeing potential pitfalls was essential to the success of each lesson. Acknowledgement of challenges with strategies and solutions were also discussed (example: how to gently redirect students towards the topic at hand while affirming their enthusiasm if they brought up unrelated information). Again, the Neuroscience student had a range of less formal experience with young children, yet thinking through instructional strategies and lesson delivery was an important component of this collaboration. Further, the co-teaching of the initial lesson allowed the education student to model level and tone of voice, word choice, classroom management strategies, and redirection within the classroom so the Neuroscience student could “see them” in action. Finally, the Neuroscience and education students could discuss issues or problems as they conducted lessons to adjust as needed (though such adjustments were unnecessary).

The preschool class consisted of eighteen children between the ages of 5-6 at the time of the lessons. Ten were male; eight were female; all were Caucasian. These students attended the nondenominational preschool affiliated with Westminster College in northwestern Pennsylvania. Classes were held on Mondays, Wednesdays, and Fridays from 8:45am-11:40am. None of the students had received any brain specific programming as part of the preschool curriculum prior to these lessons. Four of these students were children of faculty at Westminster College- three male, one female.

Permission was sought, and given, from the preschool teachers at the Westminster College Preschool that allowed undergraduate students and faculty to enter the preschool and interact with students for lessons, activities, and assessment. All activities and assessments were approved by the Westminster College Institutional Review Board. Prior to preschool entry and program initiation, the faculty advisors collected informed consents from the parents or guardians of each student in the class as well. All parents and guardians gave consent, so all students were included in the program.

The entire class (18 students) received an introductory neuroscience lesson during their typical group “circle time”, which often involved educational programming and occurred from approximately 9:15am-9:50am. This lesson was jointly delivered by the education and neuroscience undergraduates. It introduced the word “brain” to all students as a group, and provided a brief background on brain function to ensure all students could at least identify and understand the word "brain" in the initial and final interview questions that were used to assess program effectiveness. In this lesson, a black felt silhouette of the human body was displayed, and each student was given either a body part (example: heart) or a piece of yarn. Students holding body parts were asked, "What does the _______ do?" and gave a response ("beats"). Children then placed the part on the felt person. Children with strings were then asked, "What controls the _______ (heart)?" If the response, "brain," was provided, the lesson continued; if not, "brain" was provided as the correct answer. Children with yarn then connected the brain (referred to as "brain" but also "command center") and body part on the felt person. This introductory lesson also served to familiarize the preschool students with the undergraduates, who would be in the classroom on future visits, and as a way for the education undergraduate to model appropriate lesson delivery to the neuroscience undergraduate.

After the initial lesson, all preschool students were individually interviewed by a neuroscience or education faculty member. During this interview, students were asked three questions:

Q1. What is the brain?
Q2. Where is the brain?
Q3. What does the brain do?

The answers to these questions were then used to place preschool students into the subsequent brain lesson and control groups to ensure similar levels of background knowledge and eliminate preexisting between-group differences. Students were ranked based on average score across all three questions and then assigned to each group in an alternating fashion. T-tests were used to ensure similar background knowledge before proceeding. Students in one group then received five weeks of neuroscience lessons, while students in the other group engaged in lessons on art, reading, math, or music given by the preschool aides. Students that were the children of college faculty (4 total) were distributed evenly across the brain and control groups. Each subsequent lesson was administered either to the entire test group or to the individual students within the group as noted below. The group lessons occupied 15 minutes of time, while the individual lessons ranged from 7-10 minutes per student. At the end of the project, all of the tools and supplies used to teach lessons were left in the classroom for equal access for all students.

The first lesson, taught by the neuroscience undergraduate, was a foam puzzle with 4 lobes of the brain and the cerebellum (Figure 1). The preschool had a "puzzle corner" in the classroom; therefore, the undergraduates could be confident that this format would be familiar and accessible to the students. This also enabled use of a concrete object with which the preschool students could interact. Each area had an image drawn on it that symbolized a main function. Students were told, "The brain is divided into many different parts, and each part has a specific job. Let's build this puzzle together to learn about the different jobs of the brain." As they chose each piece, the undergraduate said, "This is the ___ lobe. Look at the picture and guess what its job is." Students guessed, and conversed about that part of the brain and its role before adding it to the puzzle. This gave students the ability to interact with the puzzle and contribute to the lesson, which helped to keep them engaged.

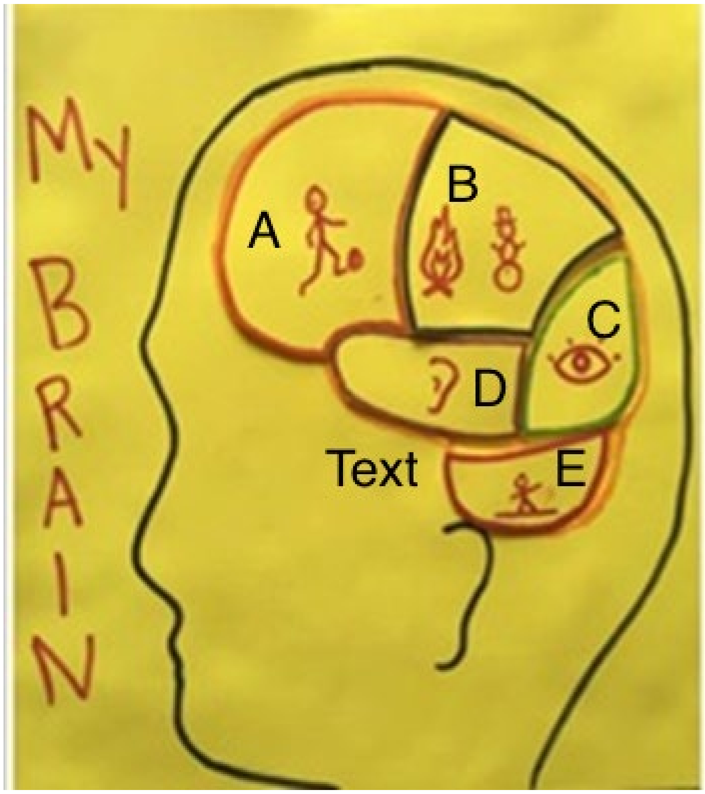

Figure 1. Brain puzzle emphasizing a function of each lobe. Examples shown include A) frontal lobe – executive functioning, B) parietal lobe – understanding sensory information, C) occipital lobe – sight, D) temporal lobe – hearing, and E) cerebellum – balance.

The second lesson, taught by the neuroscience undergraduate, was given individually and emphasized brain control of sensory and motor functions of the face (Figure 2). A large head containing a brain with strings that connected to the eyes, ears, mouth, and nose was prepared. Students were shown this picture, and then shown a picture of a child listening to music. The undergraduate would ask, "What part of the body do you use to do this activity?" and the student responded, "Ears!" The facilitator would then ask, "And what tells your ears to listen to music?" If the student did not guess brain, discussion about how the brain controls these functions followed. The student would move the picture from the brain to the ear. This was repeated for smell, sight, and taste. This lesson format was used due to the success of the introductory circle time lesson, and the students controlled the lesson. They selected the cards they wanted to explore and were only guided by the neuroscience undergraduate. This format matched with the lessons that students had previously seen and lined up with the play-based structure of the class. It also again provided a concrete set of materials with which the students could interact.

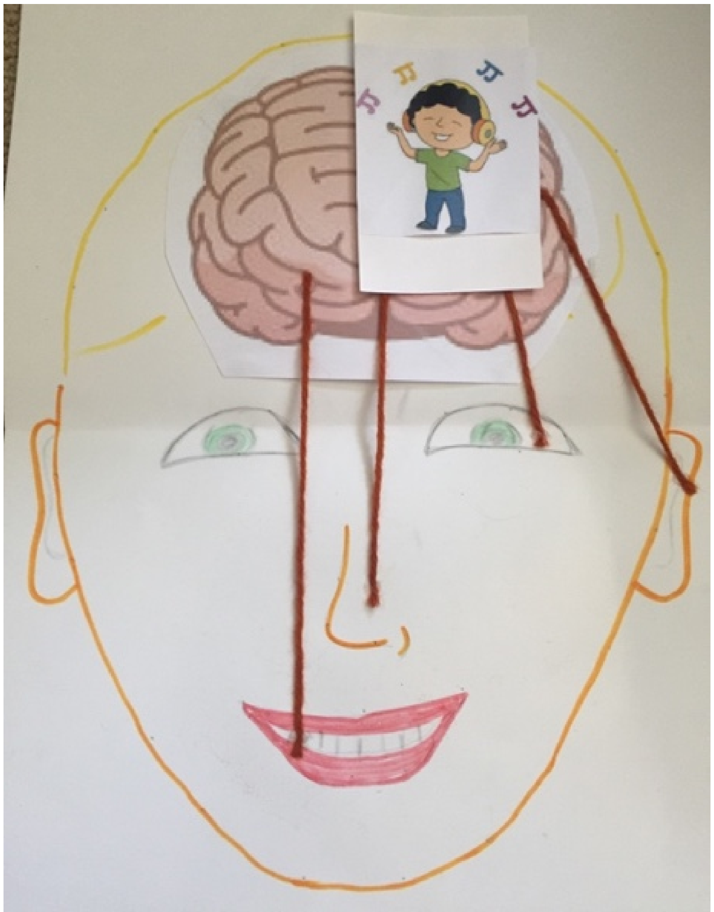

Figure 2. Lesson on the role of the brain as command center for a wide range of activities. Students matched the command card (right) with the facial feature responsible for that job.

The third lesson, taught by the education undergraduate in a group format, focused on the concept that as the students' bodies grow and change, so do their brains. Portions of the book, *Your Fantastic Elastic Brain: Stretch It, Shape It*, by Dr. JoAnn Deak (2010) were read to all of the students in the brain activities group together. The selected passages focused specifically on the changes that occur in the brain as a person learns. To put this concept into practice, the children were then taught an unfamiliar song "Brain of Mine", to the tune of "Twinkle Twinkle Little Star". The lyrics came from Dr. Eric Chudler's website, which offers other tools for teaching students neuroscience (Chudler, Brain Songs). The use of this song increased the comfort level of the pre-school students because everyone knew the initial song and could participate and they could focus on the learning of new lyrics. The children rehearsed the song until it was memorized. The lesson concluded with the reminder that, since the students were able to learn and memorize a new song, their brains had changed. This lesson format was selected because it was familiar to both the preschool students and the undergraduate education student from her previous experiences in the preschool, and had effectively been used to convey other concepts.

The fourth lesson built off the second lesson*'s* emphasis on the brain as the control center for functions like hearing. The education undergraduate instructed students in pairs to notice their heart beating, when they blinked, or the sensation of breathing. To demonstrate how the brain controls these functions without conscious thought, the pairs *were assigned one of two roles.* One student was asked to sing the ABCs while the other student was asked to count how many times they observed their partner blink or breathe. The students then shared their counts and the leaders emphasized how the brain contributes to involuntary functions. This lesson was highly interactive, used a very familiar song to help with participation, provided the opportunity for students to work with their classmates, and allowed them control over portions of the lesson.

The final lesson explored the senses and was given by both the neuroscience and education undergraduates. Individual students were asked how they taste candy or hear sounds. Many said, "ears," or, "tongue," which provided a familiar starting point through which the students could become engaged in the lesson as it moved forward. It was explained that while ears are responsible for hearing, the brain understands those sounds. Children were then asked if it would be okay to blindfold them. All children agreed. They were then asked to use their senses to explore an object and guess what it was. The first object was a cup of apple juice (their daily snack time drink). They could smell and taste the juice before saying what they thought it was. The second object was an orange, which they felt and smelled. The third object was an Easter egg filled with candy. They held the egg and listened to the noise it made when shaken. Once the students guessed, they were asked how they knew; discussion focused on how the brain took all of the sensory information and allowed them to make a guess about the object. Again, this lesson gave the control to the preschool students and allowed them to learn through exploration. The objects used were selected based on convenience, familiarity, and ease of recognition by the students, which was anticipated by the education undergraduate due to her familiarity with the classroom.

Upon completion of all five neuroscience or control lessons, the neuroscience and education faculty advisors did post-program interviews with each student individually. Students were divided at random between the neuroscience

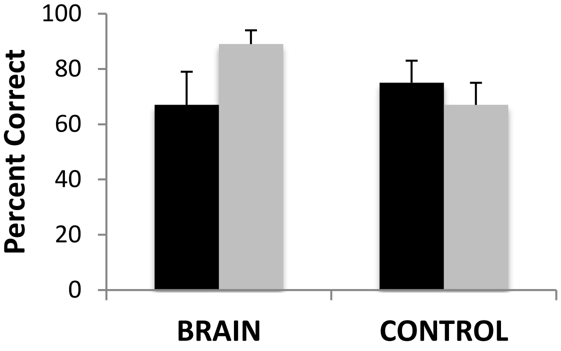

Figure 3. Average percent correct for Q1-Q3 on the pre- and post-assessment for the brain and control groups. Error bars represent SEM. Black bars represent pre-assessment average percent correct and gray bars are post-assessment average percent correct. No significant differences were noted.

and education faculty member. This post-assessment occurred 3 days after the final lesson. Faculty first asked the same three questions from the baseline assessment, but also included additional questions that were relevant to the objectives of each lesson. These questions were asked in the same order of all students from beginning to end. After Q1-Q3, the additional questions included all of the following:

Q4a. Do all parts of the brain do the same thing?
Q4b. What does (point to frontal lobe) that part help you do?
Q5a. Are there any jobs that your brain is doing all the time?
Q5b. Can you tell me about one?
Q6a. If you want to kick a ball, what tells the leg to kick?
Q6b. Where does the message start?
Q6c. Then where does it go?
Q7a. What is your teacher's name?
Q7b. How old are you?
Q7c. Do you know how you remembered the answers to those questions?
Q8a. What color is the sky?
Q8b. Is a table where you eat snacks hard or soft?
Q8c. How do you know (if they say something like I feel it with my hand or see it with my eye- ask – is your eye the only part that tells you that?)?"

It should be noted that questions 7a, 7b, 8a, and 8b were not included for analysis, as they did not contain lesson relevant material.

Assessment

Three primary analyses were performed from the assessment data. The first tested for significant differences in percent correct between the students in the neuroscience lesson group and the students in the control group on the first three assessment questions (Q1-Q3) asked before and after the program (two-way ANOVA, time and group factors). The second examined significant differences in percent correct between groups by calculating the average percent correct on lesson-specific questions Q4-Q8 and comparing those values between the brain and control groups (t-test). The third examined significant differences in percent correct by calculating the percent correct for each student on Q4-Q8 and comparing those values between the brain lesson and control groups (t-test).

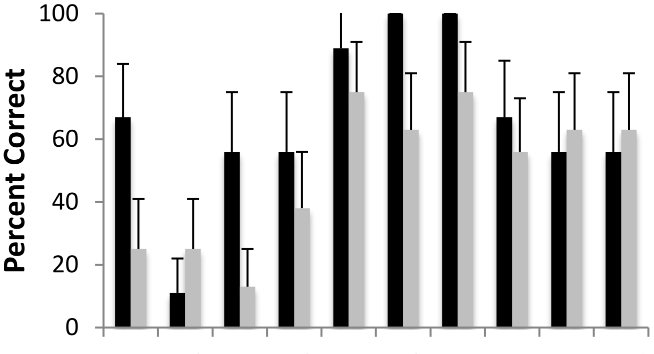

Figure 4. Average percent correct across nine of the additional post-assessment questions for the brain lesson (black) and control lesson (gray) groups. Error bars represent SEM. A significant main effect of group (brain vs. control) across all questions was noted.

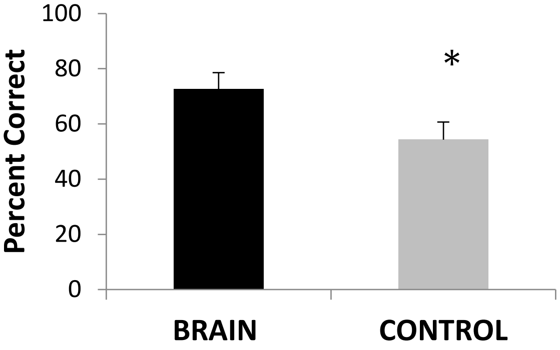

Figure 5. Average percent correct for the lesson specific questions on the post-assessment for the brain and control groups. Error bars represent SEM. Significant difference between brain and control groups is indicated by the *.

RESULTS

There was no significant difference in percent correct on the pre-test versus post-test on assessment Q1-Q3 ($F_{(1,33)}$=1.28, p=0.27, Figure 3). There was also no significant difference in percent correct between the brain lesson and control lesson groups on assessment Q1-Q3 ($F_{(1,33)}$=1.39, p=0.27), and no significant interactions between test and group in percent correct on assessment Q1-Q3 ($F_{(2,33)}$=1.48, p=0.23). The groups showed statistically similar levels of understanding of content related to the introductory lesson (which all students received) at both time points.

There was a significant difference between the brain lesson and control groups in percent correct as measured for each question ($t_{(15)}$= 2.36, p=0.03, Figure 4) on Q4-Q8, which intended to examine knowledge covered in the five additional neuroscience lessons. Percent correct on each question was higher for students that received the brain lesson content when compared to the control content. Please note- to provide additional information on the question specific responses, the data in Figure 4 are shown as percent correct between groups for each assessment question, rather than collapsed as an average percent correct. Yet the significant differences were found when comparing across questions for each group.

There was also a significant difference between groups in percent correct for each student during post-assessment Q4-Q8, which asked about the neuroscience lesson specific content. Students that received the neuroscience content in the additional five lessons showed a higher percent correct across Q4-Q8 compared to the students that received control educational lessons ($t_{(15)}$= 2.18, p=0.04, Figure 5).

DISCUSSION

Preschool students who received neuroscience outreach lessons did show a significant increase in performance on lesson specific post-assessment test questions compared to control students, which suggests that this age group is capable of learning about the basic functions of the brain. It also supports the idea that this outreach program, designed through interdisciplinary efforts between neuroscience and education colleagues, was successful in imparting basic knowledge about the brain, and demonstrates how simple assessment can help evaluate the effectiveness of such programs.

It was beneficial to have the advisors perform the assessment to eliminate a potential association between the student facilitators and the content of the assessment, yet there was room for improvement in the wording of the assessment. In some interviews, students realized the answer was often "the brain" and may have supplied this answer due to pattern recognition rather than due to comprehension of presented material. This patter, however, occurred in both groups so it is unlikely that it was a contributor to the between group differences. In replicating the post-test aspect of this study, re-wording the assessment questions so that the answer is not consistently "the brain" would be beneficial. Moving forward, questions could be written to assess knowledge of the content of each lesson without repetition of a given response. For example, for the brain lobe puzzle, questions could be, "Does the brain have different parts?" or "Can you tell me one of the jobs of one of the brain's areas?" There is also a chance that the novelty of the undergraduates in the classroom contributed to the results. Ideally, undergraduates would have provided control lessons as well. A more complete control group could also be achieved by matching the brain lessons to the control lessons in a more specific and direct way. Time constraints and the need to provide other instruction limited the ability to do this. It would have been nice to write more extensive assessment questions, yet it was important to keep the assessment within a reasonable time frame given the limited attention span of this age group. Finally, it would also be beneficial to have more time to go back into the classroom and provide the content to all students. Having recognized a benefit to implementing a neuroscience-centered curriculum to such young children, and seeing the ability of these students to grasp at least some of the concepts, motivated the researchers to want to ensure equal benefit to all students.

The degree to which these results might generalize to other populations is unclear. A few of the students in the preschool class were children of STEM professors working at the undergraduate institution. These students might be more likely to live in an environment that involves academic enrichment. Furthermore, students in this preschool often received supplemental educational programming, as other academic departments implement enrichment activities. While this helped to eliminate potential barriers to starting this program, it also means the demographics and previous experience of these students may not reflect those of all preschool students. This is apparent in the uniform nature of the demographics of the preschool students as well.

Overall, this education program was effective in teaching preschool students basic neuroscience concepts, though not all lessons had equal impact. The students did tend to perform best on questions centered on the brain contributing to behaviors and the brain "controlling" or communicating with other parts of the body for sensory and motor behaviors. This concept was presented more than once (introductory lesson, and lessons 1, 2 and 5) and was reinforced with varied examples. Not surprisingly, scores on these questions (Q1-3, 6a-c, 8c&d) were high in the lesson group, but also higher for the control group that received the single, introductory lesson compared to the other questions (though these were observed differences and not statistically different). Students in the brain group seemed to understand that the brain can have different jobs, but scores were generally lower across groups on the question that tried to address localization of function (Q4a), despite specific instruction to this end. More abstract concepts such as influence on autonomic function (Q5a&b) was particularly poor in the control group, and even brain group students provided answers regarding involuntary function that were not entirely accurate (eating, walking, talking, thinking). Students in the control group, when asked about jobs of the brain, often answered "thinking", consistent with previous literature (Marshall and Comalli, 2012). Students often did not notice functions like breathing or blinking during the actual lesson; they seemed very focused on the song. These results suggest that thought should be given to the material content as well as the level of material presented to this age. Repetition also appears beneficial for retention in this age group.

This program used two undergraduates; therefore, the ability to quantitatively assess the impact of this program on undergraduates was limited. Both undergraduates enthusiastically endorsed this collaborative project as beneficial, as revealed by their open responses to how they felt about this program:

> "The opportunity to collaborate with a Neuroscience major on this project resulted in an educational program that was not only developmentally appropriate, but scientifically accurate. I was able to draw on my counterpart's depth of neuroscience expertise to ensure that the terminology we used in the lessons fostered conceptual understandings and that the ideas we covered were of high priority. As a result, I am better informed about how to implement a similar program in my future teaching."

The education undergraduate also gained additional STEM-related certifications upon graduation; this outreach program improved her qualifications as an educator by giving her experience in a STEM educational setting.

The neuroscience undergraduate also found the program to be a valuable experience:

> "Curriculum development was completely foreign to me prior to this collaboration. It was so rewarding to implement the science content at an appropriate level without diminishing the truth of the science. This would certainly have not been possible without the inter-disciplinary cooperation. Furthermore, I've always been relatively certain that I would work with children. As a current medical student, I frequently reflect on this

> project for ways in which other related outreach programs can be brought to my future practice. It was also inspiring to see a new generation of children grow an interest in neuroscience and to help them explore those aspects of their lives further."

This program could easily include additional undergraduate students. Many outreach programs engage students in designing single lessons; this could be done in a cooperative session between students in a neuroscience course and students in an elementary education course. These lessons could be performed in a variety of outreach settings. Research teams with access to university or college lab schools could utilize that setting, or those without access to such programs could perform outreach during STEAM programming in local schools. However, considerations would need to be made to ensure consistency in lesson presentation and whether or not familiarity of the school students with the undergraduates is an important part of program. Training a large number of students would require additional time and effort, yet such efforts are likely worthwhile. Further, a range of existing outreach programs have created tools for assessing the impact of outreach on the undergraduate student. Larger scale outreach programs tend to implement surveys that assess for increased confidence in public speaking and presenting scientific concepts (Clark et al., 2016), as well as enhancements in their own understandings of the relevant content (deLacalle, 2012; Deal et al., 2014). Alternatively, interviewing could provide an additional means of assessing undergraduate impact (Carpenter, 2015). Previous research has demonstrated that outreach participation as an undergraduate improves commitment to outreach in future careers and increases confidence in students' ability to teach and interact with students (Page et al., 2011); Carpenter, 2015). Increasing communication between science and education students might lead to more inclusion of scientific content in the elementary classroom both by science students, but also by future teachers.

Teachers interested in implementing brain concepts in the classroom may feel challenged to find practical and research-based instructional practices. Yet recently researched practices in education that emphasize the connection between learning and the brain do exist. Carol Dweck (2006) describes the concept of a growth mindset, in which students learn that their brains are malleable and can grow from practice and repetition. This demonstrates how a simple concept of "learning changes the brain", which was emphasized in one of the lessons of the described preschool program, could be expanded. Indeed, research shows that students that adopt this growth mindset increase school achievement and help to close achievement gaps for minority students (Boaler, 2013). Such work demonstrates that the incorporation of neuroscience concepts in the classroom may even increase school performance. The earlier these potential benefits can be made available, the better. Neuroscientists, and scientist-educator collaborations, can encourage such practices through their outreach efforts towards students and teachers.

The potential challenges present in the classroom and the shortcomings of the specific lessons presented in this study confirm the essentiality of scientist-educator collaboration in outreach. For science outreach to be successful, it is clear that consideration of curriculum development and the pedagogy, which are the expertise of educators (Patel et al., 2017), are important. Throughout this specific program, the benefits of collaborating with education department members were innumerable, as evidenced by the quotes provided by the participating undergraduates. When constructing curricular materials, familiarity with artistic presentation and skills in creativity enabled useful curricular materials despite financial limitations. Further, the guidance regarding verbiage changes, time management, and complexity of lesson objectives was critical in this collaborative effort. Scientists alone are unlikely to be able to intuit the nuances of the classroom (Tanner et al., 2017). Consequently, we join others in emphasizing the need for long-term partnerships between scientists hoping to implement outreach and the teachers in the recipient classrooms (Patel et al., 2017), or perhaps, even better, teachers-in-training. Without such efforts, science outreach may stagnate.

To embrace the call for expanded scientific outreach, this study sought to design a preschool neuroscience outreach program that integrated the knowledge base of a neuroscience student with the classroom expertise of an education student. In doing so, we hoped to generate a curriculum that targeted an age range often ignored in outreach. We also performed a basic assessment of the program. It appears these efforts were productive and effective, given the significant gains in the preschool students that received neuroscience outreach. Future outreach programs might benefit from involving individuals with educational training in their planning and execution. Further, more frequent use of even basic assessment of such programs that extends beyond the outreach providers would help scientists tailor their activities to those that are likely to have the most impact. While demands for increased outreach are certainly warranted (Cameron and Chudler, 2003; Frantz et al., 2009; "Encouraging science outreach", 2009; McNerney, et al., 2009; Chudler and Bergsman, 2014), improved outreach seems equally important.

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