Science Outreach: Six Examples of Programs that Enrich the Learning Environments of Students and Educators

David P. Cook, MSc[1], Kevin Steed, PhD[2], Chloe Read, MSc[3], Renée Baysarowich, MSc[4], Tyler Redway, MSc[5], Pascale Robineau-Charette, BSc[6], Jacqueline Carnegie, PhD, MEd[6]

[1]Cancer Therapeutics Program, Ottawa Hospital Research Institute, 501 Smyth Road, Ottawa, ON. K1H 8L6.

[2] Biomedical Education Department at California Health Sciences University – College of Osteopathic Medicine, 2500 Alluvial Ave, Clovis, CA 93611

[3] Spectrum Academy, 575 Cutler Dr, North Salt Lake, Utah 84054

[4] Biologic and Radiopharmaceutical Drugs Directorate at Health Canada, 100 Eglantine Driveway, Tunney's Pasture, Ottawa, ON. K1A 0K9

[5] Department of Biomedical Education and Anatomy Division of Anatomy at Ohio State University, 281 W Lane Ave, Columbus, OH 43210

[6] Department of Cellular & Molecular Medicine, University of Ottawa, 451 Smyth Road Ottawa, ON. K1H 8M5, Canada

Abstract

STEM-related educational outreach offers students enriching opportunities to become more familiar with science, in terms of how it relates to their daily lives and with respect to possible career paths that they might want to follow. At the same time, graduate student trainees providing that outreach act as important resources for elementary and high school teachers while they hone their teaching skills and build confidence in the classroom. In this paper, six graduate students and recent graduates share their experiences with a variety of outreach programs that link young people with science in both Canada and the United States.
https://doi.org/10.21692/haps.2020.107

Key words: outreach, education, active learning, aboriginal, autism

Introduction

Educational outreach to K-12 students is increasingly becoming a responsibility welcomed by Canadian and American colleges and universities involved in providing STEM programs (science, technology, engineering and mathematics) at the undergraduate and graduate levels (Cao et al. 2019; Stieben et al. 2017). Outreach can take a variety of forms; it can be conducted by faculty and/or trainees and it has been linked to advantages, not only for the recipients of those educational opportunities, but also for their teachers and for the university personnel who are providing the enriched learning experiences (Laursen et al. 2007; Eng and Febria 2011; Clark et al. 2016; Stieben et al. 2017; Kumar et al. 2020).

One important goal of educational outreach programs that has been cited by those involved in its design and provision e.g. organizers of The Science Squad (Laursen 2007) and PhUn Week (Stieben et al. 2017)) is to familiarize young students with science. This is done not only by allowing them to become more aware of ways in which science links to almost everything in their everyday life but also by introducing them to scientific disciplines such as engineering and physiology as possible career goals. Some programs, such as Shadow a Scientist (Clark et al. 2016) and DiscoverE (Cao et al. 2019), encourage faculty to improve their ability to communicate complex scientific concepts at a level suitable for the lay public.

Other programs, for example, Let's Talk Science (Eng and Febria 2011), PhUn Week (Stieben et al. 2017), and Present your PhD thesis to a 12-year-old (Clark et al. 2016), provide important opportunities for graduate students to build their communication skills and develop confidence as they plan interactive projects for their focus audiences, answer student questions, and/or enjoy the welcome experience of having these young people regard them as experts and potential role models. A final valuable component that should not be ignored are the benefits for the teachers of these young students. Networking with scientists and graduate trainees via outreach programs provides important opportunities for professional development and allows them to make long-lasting links with individuals in their communities who are involved in scientific research and/or education at the college or university level (Laursen et al. 2007; Stieben et al. 2017; Cao et al. 2019).

This paper will introduce the inner workings of six different outreach programs given by graduate students and recent graduates to young people in Canada and the United States, as described in their own words. These descriptions of

continued on next page

educational outreach were initially planned to be a special update session at the 2020 Annual Conference of the Human Anatomy and Physiology Society. Since the conference was cancelled due to COVID 19, information pertaining to these programs is now being shared via this manuscript that forms part of the Special HAPS 2020 Conference Edition of the HAPS Educator. These programs have different goals, different target audiences and different STEM disciplines of focus [Table 1], but they share the common features of creating a welcoming and enthusiastic environment where students can learn by doing and where participation, be it as a learner or a teacher, provides important rewards.

Kevin Steed: Developing Service Learning to Develop Ourselves

Education has, at its heart, a profound potential to enact growth and change in both the student learner and the teacher. Many traditional teaching cognitive frameworks, such as Bloom's Taxonomy, have mediated this change in students through a hierarchical ordering of learning categories (Bloom 1965; Anderson and Krathwohl 2001) that generally translate into pedagogical techniques and best practices. Building upon Bloom's taxonomy, L. Dee Fink (2013) established a new paradigm (Figure 1) describing taxonomies of significant learning experiences that incorporate cognitive frameworks of human dimension ("why learning impacts my life") and caring ("why my learning affects others"). Based on paradigms of active and significant learning, Anatomy Academy was established to address the public health concern of childhood obesity in 5th and 6th grade student populations (mentees). Through the service-learning platform, volunteer college student teachers (mentors) were given a unique opportunity to develop teaching skills such as content delivery, student engagement, classroom management and professionalism. It became apparent early on, however, that mentees experienced something more impactful than originally anticipated, which, in turn, inspired growth, and introspection within the mentors, leading to newfound career and life trajectories.

Author	Outreach Program	Context	Location	Mentors	Mentees
Kevin Steed	Anatomy Academy (Nutrition)	Childhood Obesity	California, USA	College Student Teachers	Students in Grades 5 and 6
Chloe Read	Anatomy Academy (Autism Community)	Enrich Learning of Students on the Spectrum	Utah, USA	College Student Teachers	High School Students on the Autism Spectrum
Renée Baysarowich	Let's Talk Science	Bring STEM to Remote Communities	Northern Ontario, Quebec and Nunavut, Canada	University Graduate and Upper Level Undergraduate Students	Indigenous Elementary, Middle and High School Students
Tyler Redway	Anatomy in Action	Promote STEM Research Possibilities	Ohio, USA	Center of Science and Industry Staff	Middle and High School Students
Pascale Robineau-Charette	Let's Talk Science	Promote Interest in Biomedical Research	Ontario, Canada	University Graduate Students	High School Students
David Cook	Let's Talk Science	Experience a Biomedical Research Lab	Ontario, Canada	University Graduate Students	High School Students

Table 1. *Summary of Outreach Programs.*

continued on next page

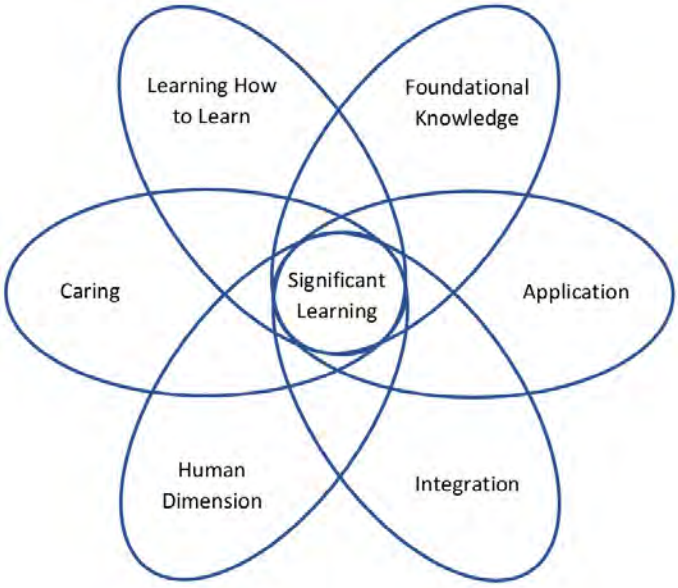

Figure 1. *This schematic combines elements from Bloom's taxonomy with select personal components (human dimension, caring, and learning how to learn) and links them to a central focus of education, a significant learning experience. This arrangement highlights that learning in each of these categories is possible during the same significant experience. (adapted from Fink, 2013)*

Figure 2. *Students from Mana Academy Charter School enjoy the results of practicing their healthy cooking skills learned during Cooking Academy. All youth present in this photo had media releases signed by their parents or legal guardians. Mentors also provided signed media releases.*

Laying the Groundwork

The service-learning program, Anatomy Academy, was developed by several public health and public policy agencies and medical graduate students under the direction of medical faculty, which gave the program a strong foundation in theory and research. With this foundation, pairs of mentors were given basic lesson plans covering anatomical and physiological systems of the body, which they expanded into active small group didactic sessions that consisted of four to eight students meeting for 20-25 minutes. This was followed by large group activities in which principles that were just learned could be applied in engaging and active games or tasks. The large groups consisted of 20-35 students meeting for 20-25 minutes. Lessons and activities took place in the mentee classrooms under supervision of their elementary school teachers (Figure 2).

The Anatomy Academy curriculum and workflow is flexible, affording the opportunity for hundreds of mentors from three local universities to tailor the provided lesson plans toward the specific and unique needs of two to three dozen elementary school sites each semester. As a result, a profound social impact was accomplished with thousands of mentees guided through the program since 2012. Survey responses were collected from mentees during and after the program. In their responses, mentees described changed behavior and an improved frame of mind concerning personal health, eating habits and choices, and activity levels. The mentors also experienced a significant impact, realizing their ability to make a difference in the world, understanding the importance of listening to students, and realizing that lives can change with "a little bit of love", in accordance with Fink's human dimension and caring taxonomies (Fink 2013).

Expanding and Changing

The benefit of a profoundly impactful program on the lives of mentors was their devotion to the teaching and learning philosophy in Anatomy Academy and investment in mediating social change through education. This was also evident in the large number of returning mentors, semester after semester, often assuming leadership and administrative roles as session leaders helping the program continue to grow and expand the service-learning opportunities for peers at their universities.

Additionally, based on their unique interactions and experiences with the mentees, some mentors saw gaps in the basic Anatomy Academy curriculum and worked to innovate the curriculum to include niche clusters of students with specialized interests. These interests included: developing a curriculum specifically for students on the autism spectrum (see Chloe Read: Anatomy Academy in the Autism Community), focusing a curriculum on the health and activity needs of dancers (Dance Academy), helping Pacific Islander families to prepare healthy meal options (Cooking Academy; Figure 2), and, devoting an entire semester

continued on next page

to the musculoskeletal system with advanced mentees (Musculoskeletal System Anatomy Academy). Each of these expansions of the original program was developed because a mentor learned something new about themselves through their interactions with their mentees. In many cases, that realization caused a career trajectory shift in the mentor, whether toward medical sciences or toward a related field in education, because they had helped spark a flame of change in someone else, igniting a passion that they did not recognize before.

Chloe Read: Anatomy Academy in the Autism Community

K-12 students on the autism spectrum face challenges every day. These include learning challenges, health challenges such as obesity and food aversions, and socializing challenges such as difficulty making friends and behavior management. Educational outreach through the Anatomy Academy program helps address each of these challenges. The program empowers young students with autism in a unique and undeniably personal way. I have spent time both as a mentor in the Anatomy Academy program and as a high school science teacher inviting Anatomy Academy into my own classroom. Because I have these two perspectives of the program, I can attest that the benefits of Anatomy Academy are potent and enduring, not only for young students but also for the mentors for two reasons: mentors and mentees benefit from the formation of personal relationships and from sensory-rich, engaging learning experiences.

Personal Relationships

The true power behind Anatomy Academy's success with children on the autism spectrum lies in personal relationships. Typically, children with autism struggle socially, and Anatomy Academy provides a safe environment for children on the spectrum to develop crucial interpersonal skills. It is of utmost importance for mentors to foster a sense of trust and friendship before any sort of lesson is presented. Day one of Anatomy Academy is entirely devoted to getting-to-know-you conversations. This is done in a variety of ways, but the most successful strategy that I have observed in my classroom is a "speed-dating" set up, where mentors have five minutes with a student to chat, joke around, draw pictures, or whatever else the student is inclined to do. Once the five minutes is up, mentors rotate to a new student. This way, students get one-on-one time with each mentor without going through the stress of changing locations. Later, the mentors discuss which student they formed the best connection with and will then partner off with that particular student for all of the following weeks. Ideally, there is a 1:1 ratio of mentors to students in an autism classroom.

The bonds that are formed during Anatomy Academy are strong. For example, one of my past students had selective mutism: she had a very difficult time talking to anyone other than her own family members. When our class began Anatomy Academy, she was completely silent during the "speed-dating" rotations. The mentors tried their best to engage with her without getting much in return. One mentor, though, noticed doodles in her notebook. The mentor took out a piece of paper and started drawing her own pictures, and after a while the student drew more pictures in response. The mentor and the student silently doodled back and forth to each other, and kept at it even after the five minutes were up. The "speed-dating" continued around them, but the student and the mentor were engaged in their doodles until the end of class. This mentor continued to work with the selectively mute student week after week, and the doodles continued. This is how the mentor taught the heart valves and chambers, the mechanisms of breathing, the major muscle groups, and brain anatomy. Doodles eventually transitioned to origami, and they built 3D versions of the organs about which they had learned. They even created origami cats and speculated about how feline anatomy compared and contrasted with human anatomy.

This selectively-mute student learned more with her mentor during Anatomy Academy than I could teach her as a classroom teacher. She learned so much, but I consider the real win to be when she quietly spoke out loud to her mentor. Shockingly, by the time Anatomy Academy ended, the student was smiling, talking, and even laughing with her mentor. The relationship formed between the mentor and student proved to be powerful to the student's learning, social skills, and confidence. Relationships are crucial for educational outreach to be as successful as possible. As shown in this example, friendship with a mentor can encourage students to engage, learn, and improve both academically and socially.

Sensory-Rich Engaged Learning Experiences

Active learning is important in all types of classrooms, but I would argue that active learning is absolutely crucial in autism classrooms. Many students on the spectrum require elevated levels of sensory input in order to focus. Sensory input can come in many forms: pacing, fidgeting with a small object, chewing gum, sitting on a yoga ball or "wobble chair," or even just standing up can be sufficient to help students focus on the lesson. In the classroom, an example would be students completing a worksheet or a group activity while toying with a fidget spinner under the desk. However, the ideal scenario happens when the sensory input relates directly to the lesson and students can learn as they are getting their sensory input (Figure 3). This scenario would have students learning about the aortic valve as they are putting on gloves and poking their fingers into the aortic valve and watching as their finger comes out through the ascending aorta on a real heart specimen.

continued on next page

From my informal classroom observations, when sensory input is directly tied to the lesson, there is more engagement from students with autism. This is exactly what Anatomy Academy does. In my experience, Anatomy Academy mentors have never taught a lesson to kids on the spectrum without sensory input that is directly associated with the concept they are teaching.

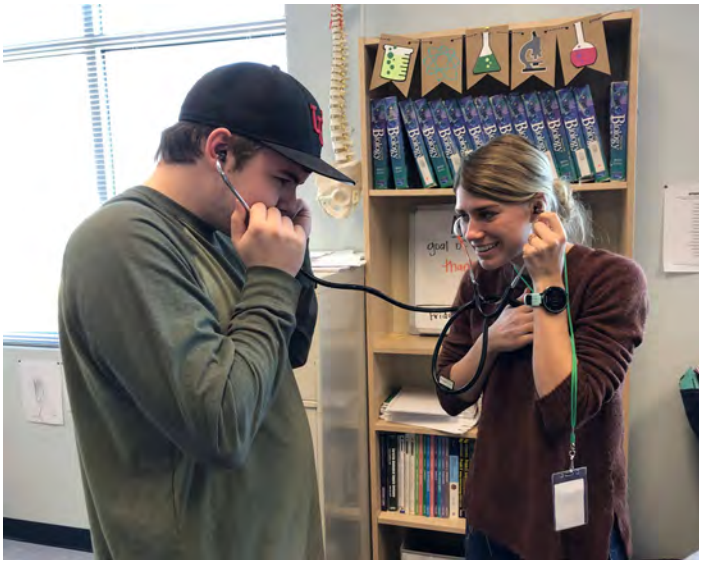

Figure 3. *Anatomy Academy at Spectrum Academy Charter School in Pleasant Grove, UT. A student with autism learns about heart anatomy and physiology by listening to his mentor's heart sounds through a stethoscope. Appropriate media releases were obtained for both the student and the mentor.*

A great example of a sensory-rich active learning experience is one that Anatomy Academy uses to teach the digestive system. This activity is also used in neurotypical classrooms, but I think it is especially useful in autism classrooms. The mentor presents the student with a plastic sandwich bag, a variety of food (bananas, graham crackers, oatmeal, and orange juice are some favorites), and pantyhose with a hole cut in the bottom. The mentors explain that these objects represent the digestive system as food passes through, and will then encourage the students to place the food into the bag and grind and churn it up, just as the mouth and stomach do. The mentor will then encourage the students to pour the now-mushy food into the pantyhose and push it through, imitating peristalsis in the intestines. The activity engages the students and provides sensory input that is directly related to the learning, meaning that the students are able to focus on both their sensory input and their learning, because they are one in the same.

Overall Benefits

Educational outreach through Anatomy Academy reaches students with autism in a truly unique way. The 1:1 mentor to student ratio that encourages friendship and the sensory-rich engagement in the activities prove invaluable in the classroom. In an autism classroom, the personal relationships between mentor and student help students progress socially and gain confidence. These relationships also aid in encouraging a student to regulate their behavior. Students are less likely to act out in front of their Anatomy Academy mentor, and as a result, there tends to be fewer negative or dangerous behaviors during Anatomy Academy, based on informal classroom observation. Furthermore, Anatomy Academy mentors do a great job at encouraging students on the autism spectrum to learn at their own pace and in their own way. For a student with learning disabilities, this type of encouragement is both empowering and necessary.

Take it from a high school teacher, educational outreach provides experiences that a single teacher cannot provide. As much as I would love to, I cannot provide the one-on-one setting or the friendship that a mentor brings. Nor can I give my students sensory-rich engaged learning activities during every class period the way Anatomy Academy can. This is what makes educational outreach so special. It provides students with opportunities that their normal classroom teachers cannot consistently provide.

Renée Baysarowich: Bringing STEM to Indigenous and Remote Communities

Over the past five years, indigenous and remote outreach programs conducted by the science outreach program Let's Talk Science at the University of Ottawa have reached over 10,000 students across Ontario, Quebec and Nunavut through two main programs: (1) week-long outreach trips to remote and indigenous communities and (2) a year-long mentorship program for indigenous high school students. During my time as both a volunteer and outreach coordinator, I have learned many strategies to ensure a successful STEM educational experience for all students and these approaches have been summarized into two main categories.

The first category involves *breaking down barriers* to make STEM inclusive, relevant, and meaningful. Students' attitudes towards STEM subjects are often negative because of their past experiences in school where there is a lot of emphasis placed on memorization of difficult concepts and achieving high test results/grades. These attitudes lead to an overall lack of interest in pursuing careers or post-secondary education in STEM fields, especially in Northern Ontario communities where there is a lack of STEM-related opportunities available. Taking these views and attitudes into consideration, our outreach focuses on making our STEM outreach hands-on and engaging, easy to learn, fun, and able to boost self-confidence.

continued on next page

Our lesson plans are structured in a way that allows for a brief introduction to the subject material to ensure students have some basic knowledge of the topic at hand, followed by a hands-on activity/experiment, which is the primary focus of the lesson. As the students are progressing through the workshop, we further their learning by making observations as a group and problem solving together.

One of our post popular activities involves extracting DNA from fruit, a topic that is relevant to everyone, since our cells also contain DNA and that DNA helps explain our differences and similarities. Students get to complete the extraction process from start to finish and often feel a great sense of accomplishment at the end. Even if a student feels that they do not excel in biology, this activity is always very well received. This workshop is a great example of taking a difficult STEM topic and breaking it down to a level where all of the students can understand its importance and relevance in our world and gain the self-confidence to conduct an experiment in its entirety, something they may have never done before.

Taking into consideration the culture and environment of the specific community is also important when aiming to make our outreach meaningful. Understanding the landscape and incorporating it into activities, when appropriate, shows students that we care about their community, value their culture, and want to help be a part of the solution. In the past, our team visited a community in Northern Ontario whose river system, which the community relies upon for food and water, had been contaminated with mercury for decades, resulting in many devastating health effects in the community. Our team developed a hands-on STEM activity where students learned how water samples are collected and analyzed and went into the field to collect samples of their own. They learned about the chemistry of mercury and how it negatively affects human health. Students also had the opportunity to handle different samples of rocks and minerals. Not only were the students engaged in the workshop, but we also had teachers and members of the community interested in participating as well.

The second category of approaches to ensure successful STEM educational experience encompasses *optimizing existing resources* to provide long-lasting changes. Northern Ontario communities are sometimes equipped with some of the physical resources (i.e. 3D printers, microscopes) to complement their lessons but lack the educator expertise and confidence to utilize this equipment in the classroom. When specific gaps are identified, educators reach out to our program and we are able to find an expert in the field who can teach them how to use the equipment and how to integrate it into hands-on learning. Some isolated communities do not have this type of equipment and in these instances, we are able to provide the training to utilize resources that are easily available to engage students in hands-on activities in addition to bringing some of the equipment to them so they can experience the technology for themselves. After this experience, educators and school administrators are often in a better position to request funding for equipment since they have experienced its capabilities and benefits.

In the past, our program had identified a need for an engineering program in Northern Ontario and Quebec and we developed a week-long outreach initiative in collaboration with the Faculty of Engineering to address those needs. Our volunteers brought 3D printers, programming kits, and solar powered mini cars to these communities and taught students about the practical applications of these technologies and how they could be used in their community. Students were able to design and build their own creations using the 3D printer, learned how to code, built solar powered cars, and were also challenged to create a plan to integrate these technologies in their community. A few communities already had 3D printers of their own, however they were not being used as there were no educators familiar with the technology. Our volunteers taught both the educators and students how to use the 3D printer, showed them how it could be used to make spare parts for members in the community, and also taught them how to troubleshoot any issues that may arise during use. After the workshops, educators reported feeling more confidence in utilizing their resources in their lesson plans and students were interested in learning more about engineering practices and experimenting with these technologies.

STEM education in remote and indigenous communities presents unique challenges but with the right approach, students and educators can greatly benefit long-term from outreach workshops and programs.

Tyler Redway: Anatomy in Action – OSU x COSI

As children we spend each day full of wonder, our young brains eager to learn new and exciting ideas as our imaginations run wild with the possibilities of the world around us. What if we hand a student a stethoscope and explain that the sounds we hear when using it are due to blood turbulence as the valves close to prevent blood backflow? What if we taught an entire class how to use a microscope and how to read an x-ray film? What if we started teaching elementary and middle school students how to be anatomists at a younger age and sparked an interest in the human body that could define a whole generation? Can we begin to build the bridge between the basic and clinical sciences earlier for the new generation?

continued on next page

When a local science center, the Centre for Science and Industry (COSI), contacted the Division of Anatomy at Ohio State University (OSU) College of Medicine to help redesign a classroom experience for middle to high school students, we had all of these questions and more. We wanted to forge a new hands-on experience that students would never forget while making a subconscious connection between the basic and clinical sciences. Filled with excitement and ideas we came to the unanimous conclusion that the students needed to be the ones running the activities we constructed. We could have easily handed students stethoscopes and taught them how to listen to their heartbeats and how that relates to the heart and cardiovascular system, but we wanted to take it further. Instead, we gave students a lab coat and a medical chart and allowed them to learn by becoming a physician themselves. Through hands-on stations students were able to see up close the inner workings of the body systems to a deeper level than traditional education typically allows. They were also able to explore different injuries and conditions that can plague the human body.

Most children know fairly early in life that we have bones that give our bodies support, a heart that pumps blood, lungs that breathe in air, and a brain that controls thoughts and emotions. To take this further, our program explains topics within these body systems that many do not get the opportunity to appreciate until much later in life. Students may recognize that a heart attack is bad without knowing what it actually means, and that is exactly what we wanted students to take away from this experience. Through this program students are able to learn firsthand what a broken bone looks like on an x-ray, what cancer looks like under a microscope, how air is inhaled and then exhaled, in addition to the different types of medical professionals who diagnose and treat conditions in all the different systems. A true integration of anatomy, physiology, histology, pathology and the implications they have on the field of medicine is the goal we set for ourselves to reach. Not every student is going to come out of this program and become a doctor or an anatomist, but if we can inspire just a handful of students with the marvel of anatomy, and science in general, we believe that we have done a good job.

The best way to learn anatomy is to see it in action, and that is precisely what we are trying to achieve through our efforts to compose a new style of anatomy education and outreach.

Pascale Robineau-Charette: Experiencing the Process: A Minds-on Approach to Research Outreach

Every year, through the science outreach program Let's Talk Science, I have the privilege of meeting hundreds of high school students who already have a keen interest in biology, medicine, and disease. I believe that, too often, they are made to believe that medical school is the only worthy career path for smart, driven students. This could be due to a simple lack of exposure to other careers that require the same qualities. I believe that introducing students to the process of scientific research, through discovery-based outreach activities, is part of the solution and that the opportunity to experience the *process* of research, rather than advanced theoretical knowledge, will keep them coming back for more.

We designed lab-based activities in which the students are intentionally given very little background information on either basic biology or the specific techniques they will be using. Groups of two to three students are given a document that contains one of three different "research projects". In our case, they were human-disease-focused projects (muscular dystrophy, breast cancer, and diabetes) with elements of genetics, genomics, and molecular biology, although the same concept could be applied to any field of STEM where experimental research is common. A very short introduction summarizes the pathophysiology of the disease and identifies the field-specific problem that their project will tackle e.g., contribution of a risk factor, generation of an animal model, or evaluating a possible therapeutic. Their projects guide them through rounds of experiments and data interpretation, eventually leading to an answer to their research question. Several technical tasks routinely executed in a molecular biology lab have to be completed in order to obtain a piece of data for interpretation e.g., pipetting, loading an agarose gel, or determining confluence of cell cultures using a microscope. With no explanation of, for example, how a polymerase chain reaction (PCR) reaction works at the molecular level, but only a one-sentence summary of what can be obtained with it, the students are left to rely solely on their curiosity and data interpretation skills to advance through the project.

We have observed various outcomes using this method. Some students are quick to make decisions and conclusions based on the evidence they have, unafraid to try an approach without the guarantee that it will work. Some students tend to discuss at length all possible conclusions, doubting every approach and wanting to make every step optimal. Both of these processes represent valuable experience of scientific thinking.

In our experience, this kind of lab-based outreach activity has numerous advantages. There will be plenty of time for students to catch up on scientific knowledge while they are pursuing an undergraduate degree. The scientific method, which the students have undoubtedly heard of, takes on much more meaning when it is experienced.

Our approach is meant to break student over-reliance on a strict protocol where the goal is to always get the right answer. Instead, focus is shifted towards asking the right questions and interpreting data to get to an answer that usually is not "black-and-white". Conveyed with enthusiasm by volunteers who

continued on next page

provide help by asking the students questions and guiding them through a thought process, this approach helps them picture themselves as eventual researchers. Taking the focus away from topic-specific knowledge leads students to the realization that it is the process that counts. This is, we believe, highly beneficial to them, while it minimizes the elitism often associated with medical sciences. After experiencing these activities, some students start seeing research as a viable career option. Even students who are not convinced that a career in research is a viable option tend to leave with a strong appreciation for the process of research and its importance to society.

David Cook: Opening the doors to cancer research

What are the goals of high school and undergraduate science labs? For most, it seems that they are designed to introduce some methodology that can be used in a well-controlled experiment to reinforce concepts taught in the classroom. A benefit of this is that it shows students that the "facts" they learn in class can actually be corroborated by observations in the real world. But what is the lasting impression these labs leave about what it means to do science? I suspect if you asked students what they remember from science labs they had previously taken, you would get answers along the lines of "we dissected a frog", "we measured color changes during chemical reactions", or even "we lit different things on fire!". Because of the need to be standardized, these labs become painfully focused on methodology, designed as rigid recipes of steps that consistently lead to desired end points. This teaches how experiments are done, but perhaps misses the most exciting part of science: being able to ask questions about the unknown and develop creative solutions to illuminate its depths. Methodologies are just the tools used towards this end; not the end itself. I certainly doubt many professional chefs would say the most exciting part of their job is following a recipe.

In order to inspire more students to pursue a career in science, we need to do a better job of exposing them to the realities of doing science. One way to accomplish this is modifying lab curricula to incorporate more problem-based learning as well as exercises in hypothesis generation and experimental design. This, however, will not be my focus here. Rather, I would like to argue that the association of many post-secondary institutes with academic research labs provides the opportunity to help with this issue through organized outreach to students of all levels.

During the final year of my undergraduate studies in 2014, I began volunteering with a national science outreach organization called Let's Talk Science, providing interactive activities to local classrooms on a wide range of topics. Soon after joining, I had the opportunity to help develop outreach targeted towards high school students focused on cancer research, which I had begun studying for my PhD. This was an interesting challenge as most high school students have only a vague understanding of how scientific research works and many of the topics actively being researched are beyond the core high school curriculum. It was clear early on that it was more important to show students how we approach cancer research rather than the specific details of what we are researching. One of the most effective ways we have found to do this is to simply open up the doors to our labs and invite students in. Since beginning this outreach only four years ago, we have brought over 1000 high school students from across Canada into our cancer research labs at the Ottawa Hospital Research Institute (OHRI) for tours and interactive workshops. Along the way, I am continually surprised by the impact that this simple act can have.

Perhaps a student's first reaction walking into a lab is the realization that scientists are not exclusively old white men carefully examining a beaker of colorful liquid. While breaking this stereotype may seem like a minor detail, I think it is incredibly important. Science is not without systemic biases that need to be addressed urgently, but given its international scope, its workforce can be surprisingly diverse. It can bring together individuals from a wide array of cultural and socioeconomic backgrounds. Further, science is actually quite energetic and youthful with PhD students and postdoctoral fellows comprising the majority of the workforce. Exposing students to this reality early in their academic career reveals that the divide between themselves and professional scientists is much smaller than they had probably believed. This makes it feel much more relatable and attainable.

Another benefit of bringing students into real research labs is that it gives the opportunity to talk to them about open questions being actively researched. Although the specific details of these topics may be well-beyond the scope of the students' education, most research can be explained in ways that are understandable. I have found that students are energized by discussing open questions in the field and the impact that answering these questions would have. If encouraged to do so, they may even offer up suggestions on how a question or hypothesis could be tested. Sure, the suggestion may be relatively vague e.g., "If you get rid of that protein, maybe the immune cells could kill the cancer", but I believe that coming up with those ideas is what science truly is; the implementation of the ideas is shaped by the available technology of the time. Ultimately, it is critical for students in any biomedical field to know that *doing* science is nothing like learning about it. Scientists spend our days asking questions that no one has answers to. There are points in time where we are the only people in the world with certain knowledge. To me, this is what makes science special.

continued on next page

Implementing such outreach may be perceived as difficult, and certainly every institute will have its own loops to jump through, but in my experience, it is fairly straightforward and non-disruptive to bring high school and undergraduate students into the lab. For high school students, local grades 11-12 biology classes are usually thrilled to have a class trip to a research institute, and many undergraduate students would jump at the opportunity to tour a lab if offered the chance. At the OHRI, we coordinate interactive tours for 25-30 students approximately once a month throughout the school year. Each tour lasts two hours and is run by three graduate students. After a general introduction, we divide participants into three groups of five to ten students and cycle them through three stations in our lab. Each station is focused on a different topic/methodology that they may be familiar with, such as DNA, *in vitro* culture systems or histology. At each station, we introduce the topic, but spend the majority of the time discussing how these topics apply to problems we are actively working on in the lab. This also provides the opportunity to show real data/samples from those projects. To keep participants engaged, we ensure that each station has a hands-on component. I have found that participants have really enjoyed having the opportunity to interact with graduate students and ask questions in a small group setting.

Exposing high school and undergraduate students to the realities of scientific research could attract those students who thrive at problem solving but were scared away from science because they could not memorize the Krebs cycle for an exam. Similarly, it could deter students who will spend years pursuing the career only to find they despise the field's intrinsic uncertainty. As scientists and educators, it is up to us to reform science education and work with local research groups to improve the visibility of these realities.

Summary and Conclusions

These examples of educational outreach reveal the enthusiasm with which graduate students and post-doctoral trainees embrace opportunities to share their love of science and scientific discovery with young people. These programs can enrich the learning experiences of students who are isolated, geographically or socially, and provide them with examples of potential career paths they might want to follow. All of these outreach programs draw on the creative abilities of the tutors to design engaging and active learning adventures for their students. Teachers in elementary and secondary schools are provided with insight into the postsecondary world of science and exposed to novel processes and tools they can use to animate the basic science curriculum. Finally, the tutors themselves build confidence and hone their teaching skills while reaping the rewards of being role models for future young scientists. Outreach fills gaps in educational curricula and provides important ways to excite students about science and how it might fit into their lives and career plans.

About the Authors

David Cook, MSc, is a PhD candidate in the Department of Cellular and Molecular Medicine at the University of Ottawa. His research focuses on cancer cell plasticity and he served as a cancer outreach coordinator for Let's Talk Science in Ottawa for four years.

Kevin S. Steed, PhD, Is an Assistant Professor in the Biomedical Education Department at California Health Sciences University – College of Osteopathic Medicine. He was the lead coordinator for Anatomy Academy for 6 years as an undergraduate and graduate student at Brigham Young University. His research interests include; neuroscience, mental and physical wellbeing, and virtual and augmented reality applications in education.

Chloe Read is a high school anatomy and physiology teacher at Spectrum Academy. She recently completed her Master's degree in curriculum and instruction from Western Govenor's University in March 2020, and has been affiliated with the program Anatomy Academy for six years.

Renee Baysarowich, MSc, is a policy analyst in the Biologic and Radiopharmaceutical Drugs Directorate at Health Canada. Her research focused on the neuroelectrophysiology of substance use disorder and she served as the indigenous outreach coordinator for Let's Talk Science in Ottawa for three years.

Tyler Redway, MS, is a PhD student in the Department of Biomedical Education and Anatomy Division of Anatomy at Ohio State University. His research focuses on human anatomy education and outreach and serves as the Graduate Student Outreach Coordinator for the Division of Anatomy and the President of the Fellowship of Student Anatomists (FOSA).

Pascale Robineau-Charette is a PhD candidate in Cellular and Molecular Medicine at the University of Ottawa, her research focusing on reproductive biology and placental dysfunctions. She is passionate about research advocacy and outreach and has been a volunteer and a coordinator for Let's Talk Science in Ottawa for five years.

Jacqueline Carnegie, PhD, MEd, is an Associate Professor in the Department of Cellular and Molecular Medicine at the University of Ottawa. She teaches anatomy, physiology and pathophysiology to undergraduate students in the Faculties of Medicine, Health Sciences and Science. Her research focuses on developing learning and self-testing tools for these student populations.

continued on next page

Literature Cited

Anderson LW, Krathwohl DR. 2001. A Taxonomy for Learning, Teaching, and Assessing: a Revision of Bloom's Taxonomy of Educational Objectives. New York: Longman.

Bloom BS. 1965. The Taxonomy of Educational Objectives: Handbook 1, 1st Edition. New York: Longman Higher Education.

Cao Y, Goh SC, Rteil A, Roberts D, Golovin K. 2019. DiscoverE: An outreach program at the School of Engineering. Proc. 2019 Canadian Engineering Education Association Conference. Paper 089: 1-6.

Clark G, Russell J, Enyeart P, Gracia B, Wessel A, et al. 2016. Science educational outreach programs that benefit students and scientists. PLoS Biol. 14(2):e1002368. https://doi.org/10.1371/journal.pbio.1002368.

Diaz MM, Ojukwu K, Padilla J, Steed K, Schmalz, et al. 2019. Who is the teacher and who is the student? The dual service- and engaged-learning pedagogical model of Anatomy Academy. J. Med. Educ. Curric. Dev. 6: 2382120519883271. https://doi.org/10.1177/2382120519883271.

Eng E, Febria C. 2011. Utilizing science outreach to foster professional skills development in university students. Creative Teaching and Learning: Exploring, Shaping, Knowing. 4:58-67.

Fink LD. 2013. Creating significant learning experiences: an integrated approach to designing college courses. San Francisco (CA): Jossey-Bass.

Kumar VP, Zuercher J, Gopalan C. 2020. An outreach activity teaching cub scouts about the human body. HAPS Educator. 24(1):59-65.

Laursen S, Liston C, Thiry H, Graf J. 2007. What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K-12 classrooms. CBE-Life Sci. Educ. 6:49-64 https://www.lifescied.org/doi/full/10.1187/cbe.06-05-0165.

Stieben M, Halpin PA, Matyas ML. 2017. Developing a nationwide K-12 outreach model: Physiology Understanding (PhUn) Week 10 years later. Adv. Physiol. Educ. 41:357-362. https://doi.org/10.1152/advan.00005.2017.

Back to TOC