ARTICLE

Evaluation of Changes in Ghanaian Students' Attitudes Towards Science Following Neuroscience Outreach Activities: A Means to Identify Effective Ways to Inspire Interest in Science Careers

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The scientific capacity in many African countries is low. Ghana, for example, is estimated to have approximately twenty-three researchers per a million inhabitants. In order to improve interest in science among future professionals, appropriate techniques should be developed and employed to identify barriers and correlates of science education among pre-university students. Young students' attitudes towards science may affect their future career choices. However, these attitudes may change with new experiences. It is, therefore, important to evaluate potential changes in students' attitudes towards science after their exposure to experiences such as science outreach activities. Through this, more effective means of inspiring and mentoring young students to choose science subjects can be developed. This approach would be particularly beneficial in countries such as Ghana, where: (i) documented impacts of outreach activities are lacking; and (ii) effective means to develop scientist-school educational partnerships are needed. We have established an outreach scheme, aimed at helping to improve interaction between scientists and pre-university students (and their teachers). Outreach activities are designed and implemented by undergraduate students and graduate teaching assistants, with support from faculty members and technical staff. Through this, we aim to build a team of trainee scientists and graduates who will become ambassadors of science in their future professional endeavors. Here, we describe an approach for assessing changes in junior high school students' attitudes towards science following classroom neuroscience outreach activities. We show that while students tended to agree more with questions concerning their perceptions about science learning after the delivery of outreach activities, significant improvements were obtained for only two questions, namely "I enjoy science lessons" and "I want to be a scientist in the future." Furthermore, there was a generally strong trend towards a change in attitude for questions that sought information about students' perceptions about scientists (both positive and negative perceptions). In addition, outreach providers reported that their involvement in this public engagement scheme helped them acquire several transferable skills that will be beneficial in their studies and career development. These include vital skills in project and time management, teamwork and public speaking. Altogether, our findings provide novel indications that the development of scientist-school outreach partnerships in Ghana has valuable implications for science education and capacity development.

Key words: Africa; Ghana; Science, technology, engineering and mathematics (STEM); public engagement; outreach; attitude; scientist; high school; scientific capacity

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Developing sustainable capacity for Science, Technology, Engineering and Mathematics (STEM) is a major concern for African governments and their developmental partners (African Union, 2014). It is widely believed that improvements in the quality and quantity of scientific research in Africa would require increased and sustained investments in STEM education (Irikefe et al., 2011; African Union, 2014, 2015). Such investments would have long-term benefits such as helping to: improve scientist-to-population ratios, improve the provision of the needed resources for education and research, and reduce the current dependence on international collaborations for a significant fraction of research output (The World Bank, 2014). Due to this, many African countries have put in place measures to help build the needed infrastructure and supportive academic environments to improve world-class training, especially at the pre-university level to provide good foundations for advanced training (Ghana Education Service, 2004; Federal Republic of Nigeria, 2011; UNCTAD, 2011). For example, successive governments in Ghana have introduced specific measures to improve pre-university STEM education, including the Free Compulsory Universal Basic Education system to expand nationwide access to elementary education (Akyeampong, 2009), and the establishment of science resource centers (in chemistry, biology and physics) in each district of the country to widen access to inquiry-based practical training for secondary school students (Ghana Education Service, 2004).

Surprisingly, many of Africa's STEM-development plans are silent on how the expertise of scientists can be harnessed to support local schools and teachers in developing pre-university education. Nonetheless, scientists will have key roles to play towards the achievement of STEM development goals in Africa. Scientists are often considered as role models and resourceful partners by young students and teachers respectively (Cameron and Chudler, 2003). In continents such as North America and Europe, scientist-school partnerships have led to improvements in student learning outcomes and the provision of teachers with resources for developing inquiry-based teaching exercises (MacNabb et al., 2006; Fitzakerley et al., 2013; Devonshire et al., 2014). Similarly, the combination of scientists' expertise in scientific content development and teachers' capabilities in pedagogy can be a good approach to improve STEM education in many African countries. The development and strengthening of scientist-school partnerships would help to address typical challenges, such as teachers' lack of resources for inquiry-based teaching, and students' lack of exposure to STEM careers (Yusuf et al., 2014; Karikari, 2015a, 2015b). Classroom visits by scientists has been shown in non-African settings to improve students' attitudes towards science (Fitzakerley et al., 2013). However, classroom outreach activities seem not to have been given the deserved attention as an educational intervention in many African countries. Even in places where they exist, information is lacking on how best the effectiveness of this intervention can be measured, because outreach programs are often not formally evaluated. To encourage more scientists to engage with pre-university students, and also to provide supporting evidence as to why policymakers, educational authorities and the general public should support scientist-school educational programs, more needs to be done to evaluate and report on the impacts of school-focused outreach activities.

In an attempt to provide initial data that may serve as a model for developing and evaluating scientist-school educational efforts in Africa, we measured changes in Ghanaian junior high school (JHS) students' attitudes about science and scientists, before and after the delivery of a neuroscience outreach activity. Here, we describe our simple approach for assessing shifts in these students' attitudes towards science, discuss our findings, and suggest modifications to our approach. We also describe self-reported benefits that our team of trained outreach providers (consisting of undergraduate students and graduate teaching assistants) has obtained from their involvement in designing and delivering these outreach activities.

MATERIALS AND METHODS

Program background

Our neuroscience outreach project was focused on stimulating dialogue with pre-university students about brain structure and function. The aspect of the project reported herein was specifically targeted at JHS students, although the broader project was focused on learners in the upper primary, junior high and senior high schools. These educational levels in Ghana are equivalent to Key Stages two, three and four respectively in the United Kingdom and elementary school, middle school and high school respectively in the United States. The program was motivated by the fact that although learners at these stages often undergo several physical, emotional and cognitive developments, the neuroscience aspects of such developments are not adequately covered in their syllabi (Steinberg, 2005; Blakemore and Choudhury, 2006; Blakemore, 2008; Karikari et al., 2016). Moreover, we believe that improving students' understanding of the structure and function of the brain will help them to better appreciate its importance to real-life decisions and the need to keep the brain safe (Fitzakerley et al., 2013; Deal et al., 2014). Furthermore, we sought to understand if interaction with scientists would help young students to obtain further insights into the work of scientists and also help to dispel common myths about science education. In the rest of this article, we will discuss the outreach activities that were delivered to JHS students and the outcome of these activities.

Outreach activity design and implementation

In order to engage students' interest in topics related to their own lives, we focused on teaching students about brain structure and function (Karikari et al., 2015). Previous reports have shown that these topics are engaging to students, and can help to stimulate their interest in science education (Fulop and Tanner, 2012; Marshall and Comalli, 2012; Fitzakerley et al., 2013).

By using PowerPoint presentations (with videos, pictures, diagrams, and text), a preserved mammalian brain, brain models and other teaching aids, students were introduced to anatomy of the brain and the functions of the major parts of this organ (Karikari et al., 2015). Discussions focused on three major themes: brain health, brain disease and brain safety. Regarding brain health, the neuron was introduced as a basic structural and functional unit of the brain required for many brain-related physiological processes. Participants were also made aware that there are specialized neurons (such as motor neurons, sensory neurons and interneurons) that perform specific functions in the brain (Stiles and Jernigan, 2010). This way, we sought to highlight that problems in the physiological regulations within, or performed by, these cells can lead to disease. Moreover, students were taught that there are different kinds of neuronal diseases, including neurobehavioural, neurodegenerative and neurodevelopmental diseases. Focusing on Alzheimer's and Parkinson's diseases as examples, students were introduced to some of the common early signs of dementia, the prevalence, possible causes and the need to seek early medical attention. Another theme was brain safety, aimed at raising awareness about the centrality of the brain to human actions and the need to protect it from injury. The medium of instruction for all outreach sessions was English.

In order to ensure that more budding scientists are given practical training in public engagement, the outreach activities were designed and implemented by trained undergraduate (UGS) students and graduate teaching assistants (GTAs). Through this, we sought to develop an approach to train prospective scientists and other future professionals to become ambassadors of science, helping to build sustainable public engagement efforts in Ghana. Further details about the design and implementation of the activities and the training of outreach providers have been provided elsewhere (Karikari et al., 2015). Briefly, UGS and GTAs (n = approximately 20) voluntarily expressed interest in joining the outreach scheme and were subsequently taken through a training program on how to lead outreach activities for JHS students. During this session, outreach providers were trained in how to: control a class, establish discipline and ensure a conducive working atmosphere in class, and summarize key points in simple terms. Training was facilitated by faculty members with experience in leading outreach activities. Following their training, outreach providers were tasked to develop and implement the outreach activities used in this project, with supervision from faculty members. Classroom outreach activities lasted for two hours, and they consisted of an introduction of the instructors and the purpose of the visit, pre-outreach quiz, delivery of the day's activity, the post-outreach quiz and participant feedback. Students' performance in the quiz significantly improved post-outreach. The aspect of the outreach activities focusing on evaluating performance in the pre- and post-outreach quizzes is being considered separately for publication and will, therefore, not be discussed in detail here.

Attitude towards science survey design and implementation

The early identification of students' interests and talents in STEM subjects is critical for their effective development into professionals later in life (National Science Board, 2010; Walker and Zhu, 2013). However, little is known about factors that either motivate or discourage Ghanaian pre-university students from choosing careers in STEM. We hypothesized based on previous experiences that students' attitudes towards science subjects and their perceptions about science professions affect their predisposition to science. To test this hypothesis, we designed a set of questions for outreach beneficiaries to answer, before and after the delivery of the outreach activities. These questions included myths and misconceptions commonly held in sections of the Ghanaian society about scientists and science careers. They also included questions to assess the commonly-held perception that only extremely clever or smart students do well in science, and that only these students should seek to pursue science courses at the university level. The choice of questions was to enable us to understand: (i) if common notions about science and scientists influenced students' predisposition to science, (ii) if students believed that they had the abilities to improve intellectually, and (iii) students' attitudes towards science learning and careers. Twenty-three questions were asked in total. The first fifteen questions sought to asess students' perceptions about their abilities to grow intellectually, as well as their mindsets about science learning and careers. The remaining eight questions were focused on students' perceptions about life as a scientist. The design of assessment questions was based on previous findings (Fitzakerley et al., 2013; Deal et al., 2014). Students (n = 44) were asked to indicate their agreement with questions on a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree (Table 1). These questions were answered before (referred to as the "pre-outreach survey") and after the delivery of the outreach activities (called the "post-outreach survey").

Data analysis and statistics

Survey responses were anonymous; no personally-identifiable information was reported. Statistical analysis was performed using Prism 6 (GraphPad, San Diego, CA, USA) and Microsoft Excel (Microsoft Corporation, USA). Data were reported as arithmetic mean ± standard deviation (SD) at the 95% confidence interval. The Shapiro-Wilk normality test was used to assess data distribution since survey ratings were non-parametrically distributed. Two-tailed Mann Whitney U-test was used to statistically compare corresponding mean pre- and post-outreach survey responses.

RESULTS AND DISCUSSION

Assessing pre-university students' attitudes towards science

In this study, we describe an approach to evaluate the impacts of outreach activities conducted in Ghana, regarding JHS students' attitudes to science learning and professions. Being one of the first attempts to do so, we believe our findings will provide important information to outreach providers and other educational stakeholders about the potential benefits of scientist-school educational partnerships, and future directions as to how such partnerships should be developed and evaluated.

In the pre-outreach evaluation, students tended to agree with questions concerning their perceptions about the future importance of science education, the need for hard work and appropriate understanding of lessons, and the usefulness of public engagement about science (questions 6, 9, 15 and 16; Table 1, mean rating ≥ 4.00). On the other hand, students disagreed with questions suggesting that the scientific profession is not financially rewarding (questions 19 and 20; mean rating ≤ approximately 2.00). Beneficiaries appeared indecisive (mean rating between 2.50 and 3.50) about questions such as those concerning their perceived performance in science lessons (question 3 and 11), their desire to become scientists or study science in the university (question 4 and 5) and perception about scientists' relationship with others (question 18 and 23).

In the post-outreach evaluation, students tended to agree more with nineteen out of the twenty-three questions (about 83% of all questions) (Table 1). Specifically,

Question	Pre-outreach rating (mean ± SD)*	Post-outreach rating (mean ± SD)[1]	p-value
Part A: students' perceptions about their intellectual abilities, science learning and science careers.			
1. Working as a scientist sounds fun to me	3.88 ± 1.17	3.93 ± 1.18	0.8292
2. I enjoy science lessons	3.85 ± 0.78	4.37 ± 0.61	0.0103*
3. I am good at science	3.10 ± 1.04	3.68 ± 1.14	0.0617
4. I do not want to be a scientist in the future	3.39 ± 1.13	3.36 ± 1.36	0.9245
5. I will probably study science in the university	2.93 ± 1.18	3.27 ± 1.46	0.3996
6. The science lessons I learn in class will help me in the future	4.08 ± 0.93	4.27 ± 0.94	0.2902
7. I often understand what is taught in the science class	3.64 ± 1.00	3.68 ± 0.98	0.9341
8. Learning new things can never change how clever you are	3.41 ± 1.58	3.60 ± 1.50	0.5944
9. I can become more clever if I work harder	4.48 ± 0.75	4.70 ± 0.68	0.1422
10. It is only very brilliant students who study science	2.67 ± 1.30	2.49 ± 1.28	0.5812
11. I do well in science because I'm a smart person	3.19 ± 1.27	3.25 ± 1.05	0.9108
12. I don't do well in science because I'm not a smart person	2.37 ± 1.12	3.00 ± 1.32	0.0694
13. I want to be a scientist in the future	2.42 ± 1.21	3.19±1.18	0.0159*
14. It is much more important for me to learn things in class than it is to get good grades in exams	3.77 ± 1.51	3.88 ± 1.41	0.8628
15. Understanding what is taught is always more important than to memorize them	4.07 ± 1.07	3.88 ± 1.26	0.6248
Part B: students' perceptions about scientists.			
16. Scientists need to regularly educate members of the public on important issues	4.00 ± 1.07	4.31 ± 0.74	0.2587
17. Scientists usually work as part of a team	3.52 ± 1.09	4.00 ± 0.94	0.0920
18. Scientists often relate well with members of the general public	3.48 ± 0.94	3.81 ± 1.12	0.1740
19. Scientists do not receive high salaries	2.31 ± 1.26	2.53 ± 1.39	0.5737
20. Scientists are financially poor people	2.04 ± 0.88	2.07 ± 1.24	0.6230
21. Science jobs are difficult to find	2.72 ± 1.24	3.73 ± 3.84	0.4288
22. Scientists are anti-social people	2.50 ± 1.14	2.97 ± 1.52	0.2668
23. Scientists are boring people	3.00 ± 1.47	2.46 ± 1.46	0.1546

Table 1. Assessment questions and student rating outcomes for the survey on pre-university attitudes to science (n = 44). [1]Students rated their perceptions and attitudes on a five-point Likert scale; 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree. Sample size varied from question to question. * indicates statistically significant p-value at 95% confidence interval.

improvement in agreement was recorded for questions about students' predisposition towards science careers, their abilities to grow intellectually, and the usefulness of science lessons. For example, this trend of improved agreement was observed for questions 2 ("I enjoy science lessons") and 3 ("I am good at science") (Table 1). Moreover, the students demonstrated increased appreciation of the view that science lessons will be useful to them in the future (question 6; Table 1). These results suggest that the outreach activities helped to inspire beneficiaries' interest in science education and careers.

Mixed findings were obtained regarding questions about students' perceptions about their intellectual abilities. While increased agreement was recorded for questions such as "I can become more clever if I work hard" (question 9) and "I do well in science because I'm a smart person" (question 11), the students believed that they did not do well in science subjects because they were not smart (question 12; Table 1). Importantly, reduced post-outreach agreement was recorded for question 10 ("It is only very brilliant students who study science"), suggesting that involvement in the outreach sessions helped the students to better appreciate their intellectual abilities, although these findings were not statistically significant.

Concerning scientists, the students tended to agree more with the question suggesting that scientists are good team players (question 17). They also agreed that scientists should regularly interact with members of the public (question 16). Interestingly, the question suggesting that scientists are anti-social also received increased agreement post-outreach (question 22). The perception that scientists are anti-social underscores the need for scientists in Ghana to interact more often with members of the public, especially young students. Importantly, the students disagreed more with the question suggesting that scientists are boring (question 23), suggesting that they will be receptive to educational initiatives provided by scientists. Notwithstanding the interesting trends in pre- and post-surveys reported, significant changes were recorded in only two questions that assessed students' agreement with the statements "I enjoy science lessons" and "I want to be a scientist in the future" (p = 0.0103 and 0.0159 respectively; Table 1). The results from this survey are similar to previous findings from the United States (Fitzakerley et al., 2013). In that study, while pre- and post-outreach survey data comparison showed significant increases for students who said they *enjoyed* science, non-significant changes were recorded for most other survey items. From these outcomes, we reason that short-term classroom outreach activities may not be adequate to produce significant gains in student attitudes. We, therefore, provide the following tips that may be useful regarding the use and extension of our assessment tool:

1. The approach provides a quick way of assessing changes in students' attitudes towards science, providing a means to evaluate the impact of outreach activities.
2. This approach can be used to evaluate many kinds of outreach activities, such as classroom and museum outreach visits.
3. Longer-term outreach programs may provide a better measure of changes in students' attitudes and perceptions, since such programs are likely to devote more time for interaction between outreach providers and beneficiaries.
4. Future evaluation exercises should focus on fewer questions (≤ 10) to make it easier and quicker for students to provide feedback.
5. Whenever applicable, survey questions should be adapted to society-specific factors that are believed to affect students' attitudes to, and perceptions about, science.

Impact on Outreach Providers

After identifying the impact of the outreach program on the beneficiaries, we sought to assess the benefits that our outreach providers (consisting of UGS and GTAs) derived from their involvement in the development and delivery of the outreach activities. We wanted to assess if our initial aim of training these budding scientists to lead public engagement activities was achieved. In a survey, the outreach providers reported that their roles in the outreach activities had positive impacts on themselves. For example, about 90% recounted that their teamwork skills had improved "to a very large extent" whilst nearly 80% had their intrinsic motivation to achieve set objectives also improved "to a very large extent" (Figure 1). About 70% also said that their communication and public speaking skills, confidence about discussing science with both scientists and non-scientists, and ability to develop and host outreach events, had developed "to a very large extent" (Figure 1). These responses suggest that our scientific outreach project was not only beneficial to the target audience but also to the organizers. Similar findings have been previously reported from elsewhere (McQueen et al., 2012; Brownell et al., 2013; Goldina and Weeks,

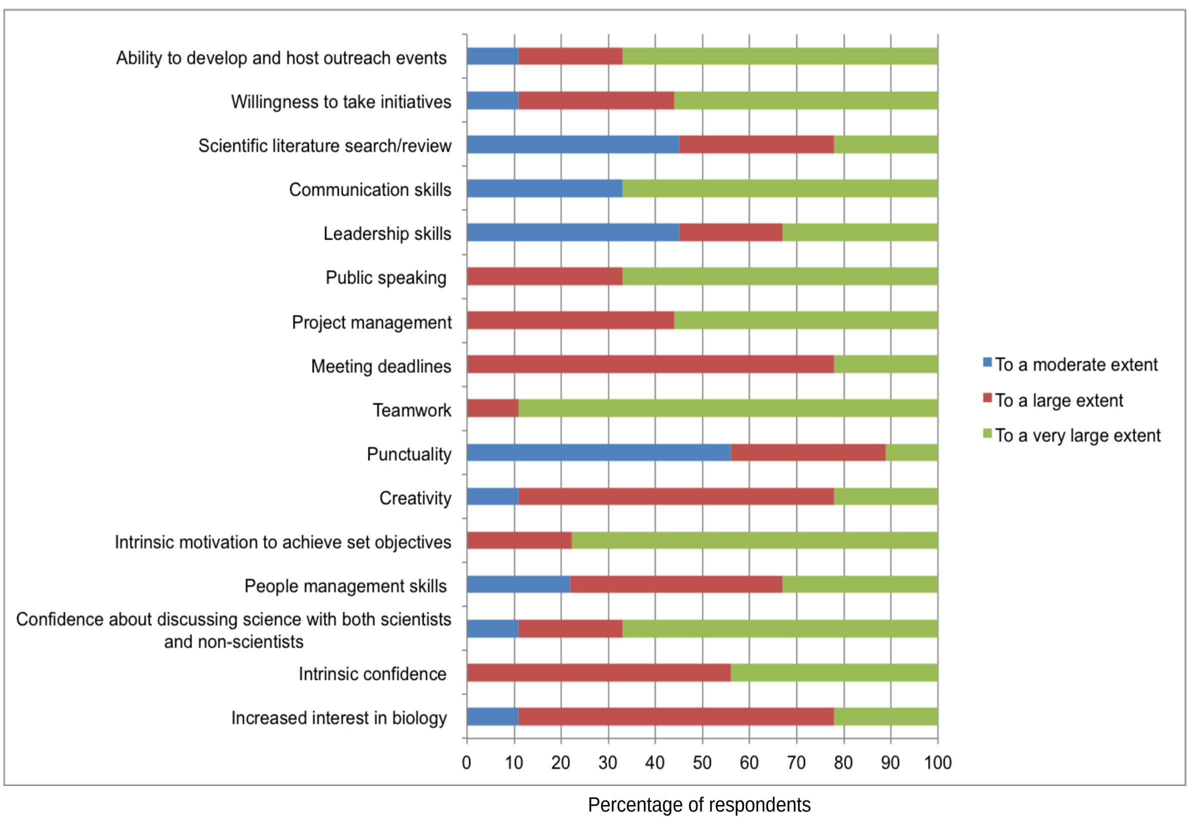

Figure 1. Responses of outreach providers regarding benefits from their involvement in designing and implementing outreach activities (n= 12). Data represent the percent of responses in each category of the five-point scale: 1 = Not at all, 2 = Very little, 3 = To a moderate extent, 4 = To a large extent, and 5 = To a very large extent. Note that response options 1 and 2 (indicating the least benefits from the outreach activities) were never selected for any of the questions.

2014). While engaging with young students, outreach providers develop important transferrable skills that are critical for their professional growth and future careers. For instance, cultivating the skills to communicate effectively with both scientists and non-scientists is a vital resource for academic writing. Moreover, the outreach providers benefit from the unique experiences of teaching high school students, which is a rare opportunity for research scientists. Instructors also acquire skills in lesson planning, development, delivery, evaluation and improvement. Such skills are often absent from standard teaching assistantship roles; developing them early could contribute to a fulfilling scientific career (McQueen et al., 2012).

CONCLUSION

We developed and piloted an assessment tool to evaluate potential changes in pre-university students' attitudes to science following science outreach activities in Ghana. The outcome suggested that exposing students to outreach activities lead to changes in their perceptions about science learning and also about scientific professions. However, short-term outreach activities (such as occasional classroom visits by scientists) may not be sufficient to cause statistically significant (and possibly long-term) changes in students' behaviors towards, and interest in, science. We, therefore, recommend that, as part of measures to improve the image of the scientific profession in Ghana (and elsewhere in Africa), appropriate measures should be put in place to promote the development of long-term educational partnerships between scientists and local schools. This would help to further identify and nurture the interests and talents of young students in STEM, supporting the development of future scientific workforce to support Africa's quest for accelerated economic growth through improved investment in scientific and industrial research. Moreover, our outreach activities were entirely delivered by undergraduate students and graduate teaching assistants. At the end of the program, survey responses from these outreach providers showed that their involvement in this project helped them to acquire key transferrable skills that are rarely obtained in the research training process. This outcome supports our long-held opinion that undergraduate and graduate students should be better involved in the development and delivery of public engagement activities in Ghana and elsewhere in the developing world. As public engagement should be the business of every scientist, this approach would help to ensure that more budding scientists are adequately prepared to engage with the public about science using diverse and effective techniques. In order to ensure that public engagement training is made more accessible to trainee scientists in Africa, we recommend that more higher education institutions should develop and offer programs in this area to their students.

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