

Using a Mobile Laboratory to Promote College-Level Outreach and Graduate Student Engagement in Precollege STEM Literacy[†]

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This article presents a case study about the impact that our mobile laboratory, the Rutgers Science Explorer bus, has had on the professional development of graduate students and content enrichment for the middle school communities in the state of New Jersey.

INTRODUCTION

According to a 2011 National Academies report (1), to remain competitive in the global market, it is imperative to (i) increase the number of students who pursue degrees and careers in Science, Technology, Engineering and Mathematics (STEM); (ii) expand the STEM-capable workforce and increase participation of under-represented groups; and (iii) increase STEM literacy. The Next Generation Science Standards (NGSS) (<https://www.nextgenscience.org/>) describe strategies designed to improve scientific literacy and understanding of STEM best practices among the K–12 population. To implement the NGSS, K–12 teachers, STEM-education professionals, and informal educators have used a variety of approaches to design suitable curricula and provide access to state-of-the-art equipment (2, 3). These approaches support active learning environments and can include field trips, in-classroom visits, and professional development opportunities for educators; they engage students in detailed analyses, critical thinking, and problem solving independently or in groups. Public perception of STEM disciplines as being hard and “not for me” persists due to a lack of role models and an inadequate understanding about what STEM professionals do and how they do it (4). These factors may discourage many students from immersing themselves in the STEM world and/or from considering a STEM career (5). In addition, there remain misconceptions about who can do research and why research

is done, a lack of advocates for STEM in local environments, and too few meaningful experiences that demonstrate application of STEM discoveries in everyday life (5–7). In this article, we describe our approach to bring authentic STEM-related experiences to middle school students led by STEM graduate students on board a mobile laboratory. We focus on the experiences of the graduate students, ways that have been developed to increase scientific literacy, and how they have served as role models for the New Jersey middle school communities that they visited.

HISTORICAL PERSPECTIVE

In 1999, Rutgers University received a National Science Foundation GK-12 Program award to build learning communities fostering an active learning approach. The award promoted partnerships between members of Rutgers University—faculty, administrators, and students—and middle school teachers and students—grades 5 through 9—to expose the teachers to STEM best practices and increase their content knowledge. This approach was significant since nonexperts in STEM fields can teach middle school science courses (8). With this in mind, faculty, graduate students, and undergraduate students with expertise in STEM fields worked with teachers to enhance the middle school curriculum. The ideal learning community consisted of two graduate students, two undergraduate students, and four teachers. Team members participated in a two-week training institute during the summer, before in-classroom visits were conducted during the academic year. There was sustained contact with the entire group at follow-up meetings back at the university, when teams would report on their experiences. The model was successful and led to new initiatives that were the basis for the expansion and institutionalization of the learning community program at Rutgers.

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THE MOBILE LAB

In 2006, the Rutgers Science Explorer (RSE), a custom-built, 40-foot-long Blue Bird bus, was outfitted as a mobile laboratory to visit schools within a 50-mile radius of Rutgers–New Brunswick campus (Fig. 1). The new mobile model allowed for interaction among groups of 20 middle school students, one teacher, and two STEM graduate students, who each spent 90 minutes on board the RSE. During this time, graduate-student scientists worked with the middle school investigators on units that presented an interesting, relevant problem about a current STEM issue. Our STEM units reflect the expertise and research backgrounds of graduate students and have been designed to align with the NGSS. This approach helps teachers and middle school students apply the concepts that they have learned from their existing curricula, while allowing students to consider and explore the STEM career opportunities that are explained by the graduate-student scientists. By assuming the role of scientists and engineers, and guided by the graduate students, the middle school students were exposed to what scientists do on a daily basis; they were presented with a problem and, after working on a variety of activities, they applied key concepts from their school curriculum to solve the problem.



A



B

FIGURE 1. The Rutgers Science Explorer is a 40-foot-long Blue Bird bus that was custom designed to be a STEM laboratory. A) Exterior of the Rutgers Science Explorer. B) Interior of the Rutgers Science Explorer.

THE RSE CURRICULUM

The middle school curriculum units that are implemented on the RSE have been developed by teams that are comprised of the Rutgers faculty member who served as the principal investigator for the NSF awards, the current director of the RSE, who holds a PhD in a STEM discipline and was a former graduate student on the Bus, a program coordinator, who manages the logistics of visits to the middle schools, a science education specialist, and participating graduate students in relevant STEM fields. Working together, they have developed and field-tested the hands-on activities that are offered on the Bus. Activities are based on ongoing research projects of the Rutgers graduate-student scientists and target a global or local issue that is relevant and of interest to the nonspecialist community. This model fosters a sense of social responsibility among the team and the middle school students and teachers, and promotes the objective that all members of the community are part of the solution.

Since its introduction in 2006, the RSE experience has become more focused, requiring graduate students to spend less time away from the laboratory bench. During their one-year commitment with the RSE, graduate students spend over 150 contact hours (approximately two 8-hour days per month over a 10-month period) interacting with middle school students on board the RSE. In addition, they have the option of participating in special events on campus and at local libraries and museums. These opportunities expand their teaching experience to other audiences and learning environments and provide them with unique skills to communicate science, both within their field and to nonspecialists. Graduate students are also encouraged to develop an activity related to their field of expertise.

The curriculum units that are implemented on the RSE abide by the University's Laboratory Safety Guidelines and are linked to topics discussed at the middle school level. A successful RSE unit (i) lasts about 90 minutes, (ii) incorporates at least three or four hands-on activities, (iii) can be set up in 15 minutes or less, and (iv) must be inquiry based. Units developed in conjunction with the graduate students cover topics in the fields of anthropology ("Skeleton Detectives"), earth sciences ("Volcanoes"), physics ("Parallel and Series Mr. Edison"), molecular biology ("DNA Detectives"), chemistry and physics ("Matter Matters"), marine ecology ("One fish, two fish... why are there dead fish?"), geology ("Drilling into Sciences"), engineering ("Power to the People"), and microbiology ("Outbreak").

"OUTBREAK": AN EXAMPLE OF AN RSE CURRICULUM UNIT

The "Outbreak" unit (see Appendix I for details) focuses on clinical microbiology and was designed by a Rutgers graduate student in the Department of Ecology and Evolution. When the "Outbreak" unit is presented on the Bus, it begins with a PowerPoint presentation given by

a RSE graduate-student scientist. A hypothetical scenario is introduced that commissions the middle school investigators to identify the cause of a disease that is affecting members of the community. With the assistance of a microbiology guidebook specifically designed for this unit (Fig. 2A), the middle school students eliminate parasites, viruses, and fungi as the causal organisms and conclude that two different bacteria are responsible for the infections. After further studies using a series of “simulated tests,” the middle school students conclude that two different diseases are affecting the population (Fig. 2B). The final activity asks the middle school students to interpret the results of an API metabolic test strip (Fig. 2C) and record the code for the bacteria causing the diseases so that they can recommend a treatment course with antibiotics. A description of “Outbreak” and its alignment with the NGSS is included in Appendix 1.

Since this unit was introduced in 2010, it has been popular among the schools visited by the RSE. After the 2014

Ebola outbreak in West Africa, we observed a significant increase in the number of requests for “Outbreak.” Middle school teachers requested additional information about infectious diseases and other related topics. In response, we incorporated relevant discussions about microbes (viruses versus bacteria) and interactive question-and-answer sessions between the graduate students and middle school students during the RSE visits when the “Outbreak” unit was conducted. A similar increase in requests for “Outbreak” occurred in 2016, after the Zika virus epidemic in Brazil and the Caribbean. This unit can be adapted easily, and it serves as a community resource of contemporary science information. Middle school students receive this information from a graduate-student scientist who is at the forefront of new findings. This is only one example of the impact that the RSE has had in the communities that we have visited, and it reinforces the commitment that graduate students who are participating in the RSE have made to strengthen their ties with local middle school communities.

COMMUNITY IMPACT

Developing the RSE curriculum is a team effort, and the established units connect to ongoing research projects at Rutgers University. Therefore, the units give middle school students the unique opportunity to learn about a current research topic and to ask questions to a scientist who is working on that topic or in the same field. This practice encourages middle school students to develop a sense of social responsibility and promotes the idea that all members of the community can contribute to, and are part of, the solution. Another important aspect of this experience is that, while one interaction may or may not be significant enough for a student to consider a career in STEM, it can certainly spark interest and spur engagement in other extracurricular activities, such as joining a science club, or independently learning more about the topic, or participating in other science programs locally or at the University.

Since 2006, the RSE has visited 128 middle schools in 14 counties around New Jersey. In all, 45,893 middle school students have participated in RSE programs, and 51% of the schools visited have requested an additional RSE experience for their students. This demonstrates the success of the program and demonstrates the need that schools have for STEM support. A total of 80 graduate students from diverse STEM backgrounds (Fig. 3) have served as graduate-student scientists for the RSE program, allowing middle school students to identify themselves with a young and enthusiastic scientist in the flesh. Of the graduate students who have participated in the RSE program and who have completed their graduate degrees, approximately 34% occupy traditional industry and faculty positions, 20% have assumed positions related to teaching and outreach, and 37.5% continue their training in higher education (Fig. 4). This group of practicing scientists has a new perspective on how to communicate their science to the communities around them; they have a unique

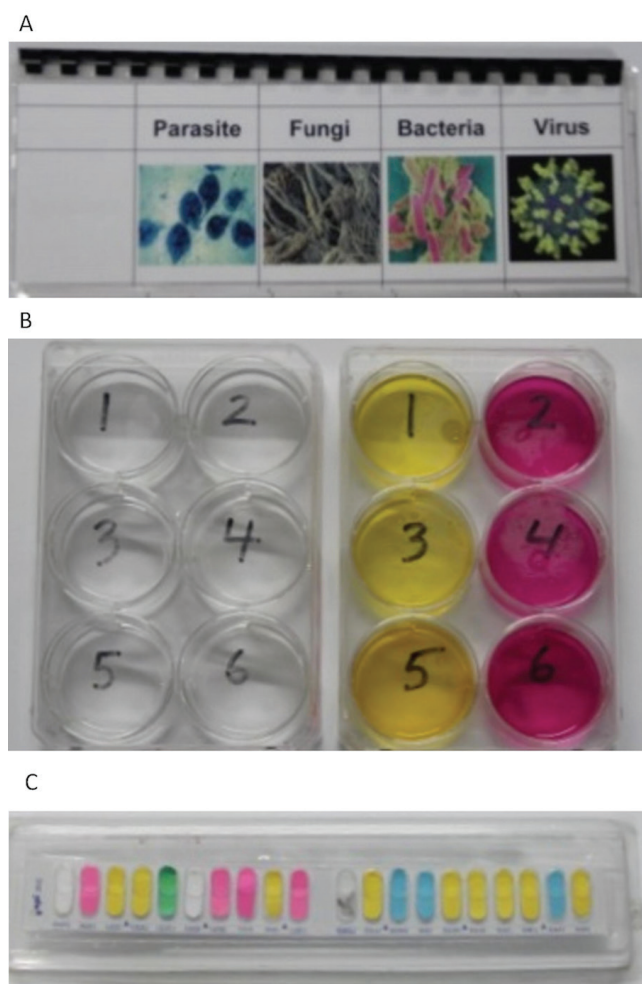


FIGURE 2. Outbreak Unit: Materials developed to conduct a clinical microbiology exploration where students identify two different bacteria causing outbreaks in the human population in New Jersey. A) Microbes guide (Appendix 2). B) A 6-well plate before test (clear) and after test (pink and yellow results are obtained by adding one drop of pH indicator). C) Paper simulation of API strip.

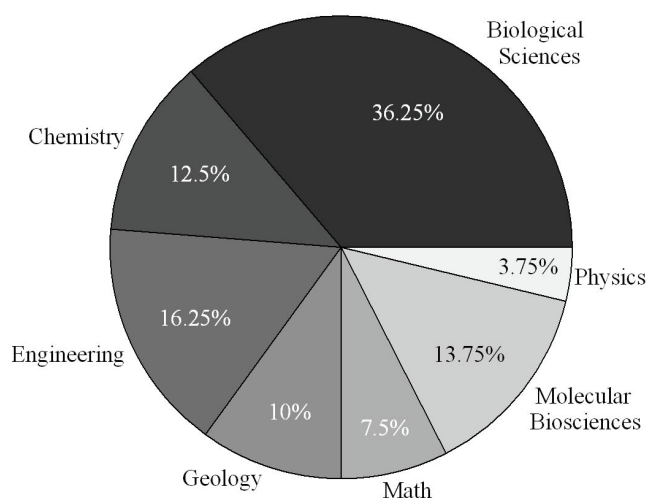


FIGURE 3. Rutgers Science Explorer graduate students by STEM discipline ($n = 80$).

skill set that encourages members of the general public to become involved with the research world. Formal program evaluations (IRB-approved) showed that the participating graduate students found the RSE experience valuable for their career, without significantly affecting their time to graduation. Graduate students report informally at monthly RSE staff meetings, giving them the opportunity to share experiences with each other and with RSE program faculty. Below are two examples of graduate students' perceptions after one year with the RSE:

Graduate student 1

Although my research at Rutgers will eventually benefit society, I look forward to my weekly 'gigs' with the bus because I receive an immediate and positive response to my work. The programs specifically designed for the bus also enable the participating middle-school students to experience an immediate and positive outcome to their experiments. To an adult, the bus may seem like a big empty vehicle with 20 stools and a large monitor; but to the middle-school students, the bus is so much more. Upon entering the bus, the bustling of the students is filled with 'wow,' 'awesome,' and 'cool.' During the lessons, I have not observed a single disinterested student. The students are curious and engaging. Upon leaving the bus, I've overheard (many times), "this was the coolest day."

Graduate student 2

The Rutgers Science Explorer helps me to develop science communication skills, which I consider one of the most important talents in a successful scientist. I feel a great satisfaction when I see students very excited about experiments you do in the lab. At the same time

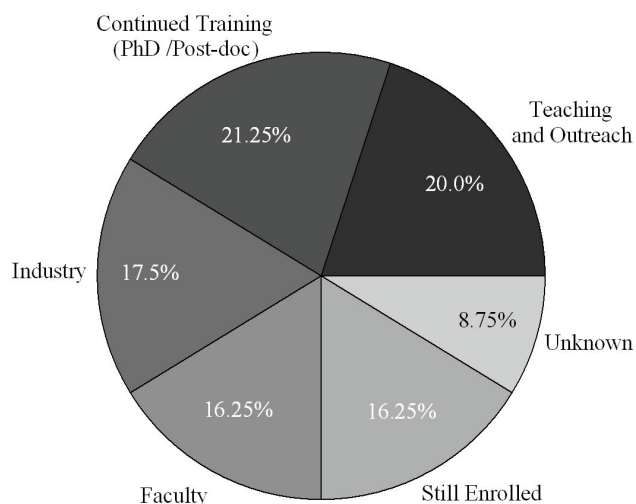


FIGURE 4. Career pathways taken by graduate students who have participated in the Rutgers Science Explorer program ($n = 80$).

you are motivating them to get involved in Science. The students motivate me to continue to learn more and teach others.

LESSONS LEARNED

Several stakeholders have contributed to the operation of the RSE. In the last 11 years, we have learned many lessons about graduate-student participation in outreach, middle school student engagement, how to establish long-lasting relationships with K–12 teachers, and how to spark interest in the STEM disciplines in all members of the community. We have overcome many physical and philosophical challenges to be able to mobilize our staff and the RSE mobile laboratory to offer middle schools an engaging curriculum. We have come to recognize the contributions made by both individuals and institutions, all of which are indispensable to keeping the RSE "on the road" (Table I).

CONCLUSIONS

STEM education is key to creating sustainable networks that could secure our future and increase our nation's economic development. Since 2006, the Rutgers Science Explorer bus, a mobile laboratory and demonstration center, has introduced many New Jersey communities to the research world by connecting STEM graduate students with middle school students, teachers, and schools. Specifically, the bus has served as a vehicle for graduate students to make meaningful contributions to precollege education without demanding significant time commitments away from their work to complete their degrees. By working together with RSE program faculty, graduate students have contributed to the development of innovative, relevant curriculum units that incorporate some of the same strategies and thinking processes that are used when they conduct research.

TABLE 1.
Rutgers Science Explorer stakeholders: challenges versus benefits.

Stakeholders	Middle School Students	Middle School Teachers	Graduate Students	Middle Schools and Local Districts	University
Challenges	<ul style="list-style-type: none"> Not understanding content or procedures Being unfamiliar with tools and equipment Disconnection between the classroom and the mobile lab (this experience occurs once a year) 	<ul style="list-style-type: none"> Integrating research discipline into existing courses Reformulating content to meet learning styles and incorporate NGSS Adjusting schedule to length of sessions (90 minutes) 	<ul style="list-style-type: none"> Time away from research Limited teaching experience Designing lessons based on research that can also be incorporated into the middle school curriculum No training in pedagogy and teaching strategies 	<ul style="list-style-type: none"> Physically accommodating the mobile lab on school premises Adjusting schedule and class sizes Cost (\$300 per day) and staff time (one teacher on the bus all day) 	<ul style="list-style-type: none"> Expense of maintaining the mobile lab Developing the administrative structure to support the program Stipend for graduate students Liability and insurance
Benefits	<ul style="list-style-type: none"> Meet, interact with, and learn from research scientists Develop their own scientific identity, while identifying with role models Learn application of sciences beyond the classroom Exposure to a new and fun learning environment 	<ul style="list-style-type: none"> Increase base knowledge by interacting with scientists Enhance existing curricula Access to state-of-the-art scientific equipment Professional development opportunities in the summer 	<ul style="list-style-type: none"> Convey STEM field of expertise to nonexperts Expand network to members of the communities and graduate students in other disciplines Experience non-expository teaching methods Exposure to new career opportunities 	<ul style="list-style-type: none"> Connect to source of knowledge (graduate students) Access new opportunities in STEM fields Establish a long-lasting relationship with the University 	<ul style="list-style-type: none"> Support for the outreach mission statement Advertisement and community exposure (Rutgers visually represented by the bus) Initial interaction with students who might apply to Rutgers in the future, and their teachers

When the graduate-student scientists present these units to precollege students around New Jersey, they engage young learners, serve as role models, and encourage them to consider future STEM careers.

SUPPLEMENTAL MATERIALS

Appendix 1: Outbreak overview and connection to the NGSS

Appendix 2: Microbes study guide

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