Nano-environmental Engineering for Teachers (Work in Progress)

Dr. Carolyn Aitken Nichol, Rice University

Dr. Carolyn Nichol is a Faculty Fellow in Chemistry and the Director of the Rice Office of STEM Engagement (R-STEM). R-STEM provides teacher professional development to elementary and secondary teachers in science and math content and pedagogy, while also providing STEM outreach to the Houston Community. Dr. Nichol's research interests are in science education and science policy. She received her B.S. in chemical engineering from the University of Massachusetts at Amherst, her doctorate in chemical engineering from the University of Texas (UT) at Austin, and served as a postdoctoral fellow in the College of Pharmacy at UT Austin. Prior to joining Rice University, she worked at Boehringer Ingelheim on innovative drug delivery systems and she was an Assistant Professor in Diagnostic Radiology at UT MD Anderson Cancer Center, where she conducted research on nonviral gene therapy systems. At Rice University she has developed and taught courses in The Department of Bioengineering including Numerical Methods, Pharmaceutical Engineering, Systems Physiology, Biomaterials and Advances in BioNanotechnology.

Ms. Christina Anlynette Crawford, Rice University

As Associate Director for Science and Engineering of the Rice Office of STEM Engagement, I lead the Rice Excellence in Secondary Science Teaching (RESST) biology program. In this capacity, she guides Houston area high school Life Science teachers in weekly meetings on Rice's campus to explore both biology concepts and the ways in which they can be taught using inquiry methods. I also works with the NEWT Center and leads their Nanotechnology Environmental Engineering for Teachers (NEET) and NEWT Research Experience for Teachers (RET) programs.

Jorge Loyo-Rosales, Rice University
Alice Chow

Alice Chow is an Associate Director for Research and Grants for the Rice University Office of STEM Engagement. She conducts research in K-12 STEM education on topics such as impact of teacher professional development programs on student achievement and attitudes.

Dr. Carrie Obenland, Rice University

Dr. Obenland is the Assistant Director for Outreach and Research at the Rice Office of STEM Engagement. She as her PhD in Chemistry from Rice University, as well as her Masters. Her graduate work was focused on chemical education. She earned her BS in Chemical Engineering from the University of Texas at Austin.

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An increasing number of teachers are not properly trained or prepared to effectively teach science, technology, engineering, and math (STEM) subjects [1]. Most teachers are unaware of the benefits of integrated STEM learning, which involves learning STEM content while also addressing authentic problems. One particularly effective strategy for employing integrated STEM learning is through Project-Base Learning (PBL), in which students gain real world experience in designing and leading their own STEM-focused projects.

PBL is a pedagogical teaching approach that places students at the center of learning. The role of the teacher is to help facilitate learning by guiding students to essential understandings. During effective PBL experiences, teachers set up rules and parameters that encourage students to complete a project within a specified time frame by working cooperatively with peers [2]. Students are provided ample opportunity to ask questions and conduct original, thought-provoking research. PBL allows students to cultivate and grow interpersonal, communication, organizational, and other management skills while also learning STEM content.

The engineering design process (EDP) is an important strategy that enhances the effectiveness of PBL by providing students with a framework for completing their projects [3]. The EDP begins with identifying a problem and attempting to understand what the causes are, and how, if at all, the problem is currently being addressed in society. This stage of the process consists of Internet research and learning from subject matter experts, e.g., guest speakers. After gaining sufficient background knowledge to begin to imagine viable solutions to the problem, they develop a plan to implement their solutions. Here, students must think like engineers and work collaboratively with fellow students to determine what materials and resources to utilize for a prototype to achieve maximum effectiveness and efficiency. They build and test the prototype according to their design. The final stages involve constant revision and redesign as more data becomes available through testing. By experiencing the EDP, students gain a genuine appreciation for the cyclical processes involved in research and that scientific discovery is a continuous journey.

Pilot Program Development

NanoEnvironmental Engineering for Teachers (NEET) provides a framework for introducing STEM teachers to both PBL and the EDP. NEET is a professional development program for secondary school teachers within the National Science Foundation (NSF) Engineering Research Center (ERC) Nano-Enabled Water Treatment (NEWT), an interdisciplinary and multi-institutional ERC. The goal of NEWT is to facilitate access to clean water almost anywhere in the world by developing efficient, easy to deploy, modular water treatment systems in order to provide humanitarian relief in regions facing water shortage issues. NEWT also develops systems to treat and reuse challenging industrial wastewaters in remote locations, such as oil and gas fields, to help energy production be more sustainable and cost-efficient with regard to its water footprint. Rice University, Arizona State University, Yale University, and The University of Texas-El Paso are the institutions working together in NEWT to achieve the ERC goals. Knowing the tremendous impact NEWT technology may potentially have on society’s use of water, the educational team developed a program to provide teachers an opportunity to learn about the innovative outputs of NEWT and utilize them in a meaningful way with their students. Table 1 outlines NEET's development and implementation schedule.

Table 1. NEET Development and Implementation schedule.

Time Frame	Activity	Goal	# Teachers	Student Impact*
Spring 2016	2-Day Brainstorming Session	Determine connection between our ERC and environmental science curriculum, teacher needs and understanding of the EDP	15	-
Spring 2017	NEET Yr 1- Pilot	Implement semester-long program based on brainstorming session feedback	25	3,425
Spring 2018-2020	NEET Yrs 2-4	Implement and refine program based on participant feedback; augment evaluation plan	75	10,275

**Estimated based on the average high school teacher being responsible for about 137 students each year [4]*

To develop the NEET program, NEWT's educational team hosted 15 environmental science teachers for a two-day brainstorming session to determine the educational needs of teachers and identify the ERC nanotechnology topics to be incorporated into the pilot NEET program. Teachers were selected to participate in the brainstorming session based on years of teaching experience in environmental science and teaching in a high-needs district. The session included presentations of NEWT research, instructional practices and strategies discussions, and a hands-on lesson presented by a former NSF Research Experience for Teachers (RET) participant. On day two, participants took a boat tour and performed water testing protocols at local bayous. Teachers were encouraged to provide feedback on their needs within the environmental science classroom and completed a survey of their interest in professional development on specific instructional practices. Over 90% of the participants selected PBL as an area for growth.

Pilot Program Goals

The pilot of the first full semester NEET course strived to increase the content knowledge of educators and empower them in implementing rigorous PBLs and engineering design activities in their classrooms. Using feedback from the brainstorming sessions, the program was designed to achieve these goals by providing participants with opportunities to: 1) think reflectively and critically about their current teacher practices; 2) improve understanding of advanced placement and state standards; 3) fully engage in an authentic PBL and engineering design experience on water treatment and sustainability; and 4) learn about current NEWT research being conducted at Rice University, Arizona State University, Yale University, and University of Texas-El Paso.

Pilot Program Recruitment and Participants

NEET participants were selected from local districts that had high underrepresented minority student populations. Of the 47 applications received, 25 teachers were selected for the pilot NEET program. Teachers had a wide range of teaching experience from 1 to 33 years with an average of 12 years of experience. Table 2 lists Public Education Information Management System (PEIMS) [4] data, e.g. total number (#) of students and % of economically disadvantaged students (EconDis) in the independent school district (ISD) or charter school system.

Table 2. 2017 NEET teachers and district student PEIMS data (2015-2016) (N=25).

District/Charter Schools	**Teachers**		**Students**	
	#	**%**	**#**	***% Econ Dis***
Aldine ISD	3	12	70,277	88.3
Alief ISD	2	8	47,227	80.4
Friendswood ISD	1	4	6,116	9.1
Harmony	1	4	1,103	50.5
Houston ISD	11	44	214,891	76.5
Katy ISD	2	8	72,725	28.3
Pearland ISD	1	4	21,030	26.6
Spring ISD	1	4	36,813	70.6
Yes Prep	1	4	9,514	83.2
Fort Bend ISD	2	8	72,910	33.7

Pilot Program Activities

During the course, participants interacted with NEWT faculty, researchers, and former NEWT RET interns. The interaction with the NEWT community was vital to the program because it allowed teachers to learn about current research on water treatment practices, nanotechnology, and water sustainability. In addition to presenting their research, NEWT faculty served as project mentors, providing support for teachers as they sought solutions to their problems posed as part of their PBL experience. This feedback system provided teachers with sustained and deepened connections with the ERC community and simulated the kind of support their students need to be successful in PBL.

The course incorporated different lessons from the textbook *Welcome to Nanoscience: Interdisciplinary Environmental Explorations (IEE)* [5] to increase teacher content knowledge of nanotechnology and water treatment. Each week of NEET was organized so that participants could progress stepwise through the EDP in order to successfully complete their case study-based project. Table 3 below outlines the weekly schedule for the 45-hour NEET class.

Table 3. Outline for the 3-hour weekly NEET class totaling 45 hours for 15 weeks.

Week: Topics	**Objectives**
1: Welcome to NEET	Pre-testing; What is NEWT/NEET; Why PBL and Engineering Design
2: NEWT Research	Dr. Paul Westerhoff on NEWT research conducted at Arizona State University; Titanium Dioxide Photocatalytic
3: Engineering Design	EDP; components of engineering; semester project outline
4: RET Lesson Presentation 1	RET participant share Nanotechnology lesson developed; Semester Project Case studies – Define the Problem
5: IEE	Introduction to Nanotechnology and Water pollution
6: NEWT Research	Dr. Rafael Verduzco on Captivated Deionization at Rice University; lab tour-graduate student
7: Engineering Design	Case Study Background Research
8: IEE	Bacterial transport in groundwater; nanoforces in nature
9: RET Lesson Presentation 2	RET participant share Nanotechnology lesson developed; project Brainstorming; Material selection
10: Engineering Design	Group Project Prototype construction
11: Engineering Design	Group Project Prototype testing & construction
12: NEWT Research & Engineering Design	Dr. Eva Moya, Community Engagement and sustainability, University of Texas- El Paso; Group Project Prototype testing & construction

Week: Topics	Objectives
13: RET Lesson Presentation 3	RET participant share Nanotechnology lesson developed; prototype testing
14: Engineering Design	Participant Post-testing; Group Project Prototype testing - Poster Construction
15: Presentation Night	NEET project showcase

In-class discussions were held over current events to engage and introduce the participants to possible areas of focus. Participants chose a unique case study for their projects from six areas: 1-Drinking Seawater; 2-Utilizing the Sun; 3-Clean Water After a Natural Disaster; 4-Collecting & Drinking Rain Water; 5-Low Cost Point-of-Use Water Filters; 6-Filters for Cities in Need.

In groups, participants defined their case study and determined the main issue of focus. For example, "Case Study 6: Filters for Cities in Need" focused on understanding the limitations of water use in cities such as Corpus Christi, Texas and Flint, Michigan when the water supply was limited or unavailable due to manmade issues, while "Case Study 3: Clean Water after a Natural Disaster" characterized the water supply in New Orleans after Hurricane Katrina. Each group created a list of questions to answer in order to be innovative in their solution. Through the semester, participants were engaged in the EDP via check points along the way to keep the class on track. Each group created a prototype of their solution. The NEET course will continue to add new areas of study to keep the course relevant.

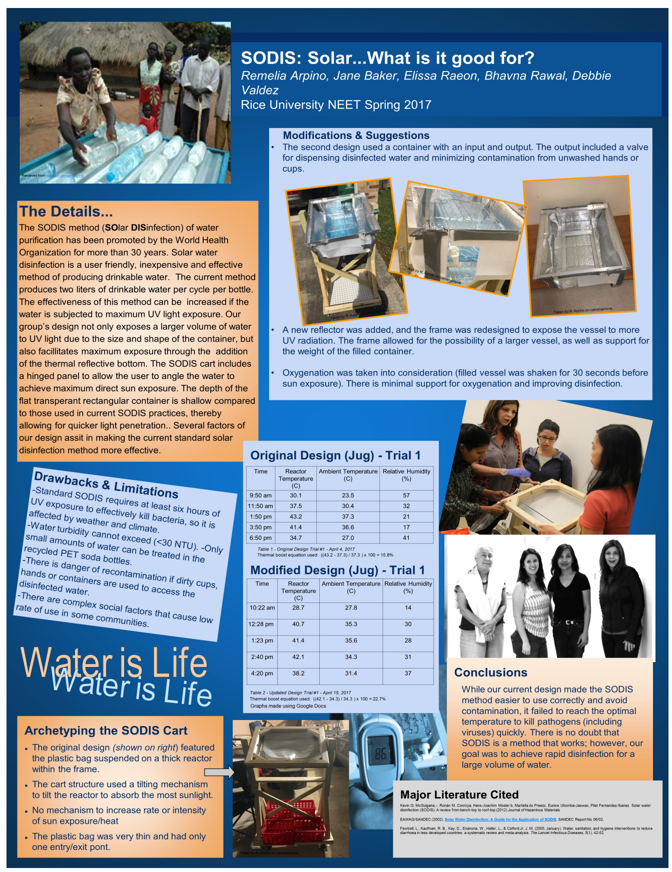

Fig. 1. NEET group poster on enhancing Solar Water Disinfection systems.

NEET culminated with an engineering design showcase which provided teachers with an opportunity to present their engineering projects to their peers, school administrators, and NEWT members. The showcase also served to help develop the teacher's scientific communication skills. Each group created a poster to excite and inspire student interest in PBL. The posters explained the problem addressed, project design, how it was tested, and possible modifications, limitations, and impact. School administrators of the NEET teachers were invited to the showcase which gave them a chance to learn about the benefits of PBL and how it is incorporated into the curriculum.

Pilot Participant Feedback

Teachers completed a feedback survey at the end of the course. When asked "How do you rate your experience in NEET as a valuable professional learning opportunity in order to grow as an Environmental Science teacher," an overwhelming majority rated the course as Excellent (54%) or Very Good (42%) with the lowest rating as Average (4%). Participants were also asked to rate the effectiveness of the NEET program in numerous areas as shown in Fig. 2. Most (85%) of the participants rated the overall course very effective or effective. Additionally, the majority of participants stated the course was very effective or effective at increasing their knowledge of NEWT technologies, critical thinking, leadership, teamwork, and communication skills.

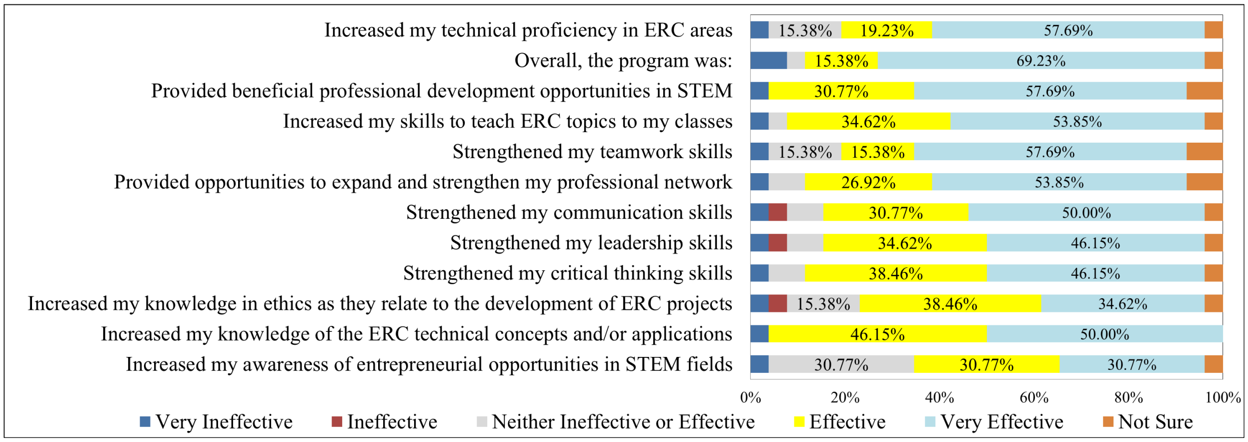

Fig. 2. Participant Feedback on the effectiveness of NEET.

Participants were asked how NEET influenced their students, with one example as follows:

- **Participant A -** *"My scholars as well as myself were benefited. I am more confident in talking and explaining the phenome of science content. My scholars earned a state 'Science Distinction' which is a huge honor. Implementing PBL, the Engineering Design and giving them the opportunity to explore and to make discoveries on their own has enriched my classroom, which is why we earned our distinction."*

Discussion/Lessons Learned

Results from the pilot program revealed preliminary evidence that teachers had advanced in skills related to science knowledge and pedagogy and that PBL was implemented in the classroom benefitting their students. The current 2018 NEET evaluation has adopted a self-efficacy assessment with questions targeted in teaching engineering. We will also be requesting feedback from teachers on their EDP use in the classroom and effect on their students.

Conclusion

This paper shares the program design of the NEET program which provides a framework for introducing both PBL and the EDP to K-12 STEM teachers, aimed to contribute to teacher confidence in implementing these strategies in the classrooms. Institutions that provide professional development opportunities to K-12 STEM educators may benefit from implementing a program similar to NEET as the course has the ability to both increase the content knowledge of educators and to empower them in facilitating rigorous PBLs and engineering design activities in their classrooms.

Acknowledgment

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