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Incorporating Engineering into the High School Chemistry Classroom

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Abstract

A unique experience is provided to pre-service and in-service teachers to participate in a research project via a grant won from the National Science Foundation. The project "Multidisciplinary Engineering Research for Rural Michigan's Future" allows pre-service and in-service science educators to participate in research project collaboration while focusing on implementing research practices into their curricula. The research experience for teachers' emphasis is on broadening student problem solving skills, communication skills, and exploratory learning. A sample of curriculum change of a high school chemistry course incorporating engineering components will be discussed.

Introduction

The Common Core and Next Generation Science Standards design is to prepare students with the knowledge and skills necessary to face upcoming problems and issues in the 21st century. The Next Generation Science Standards, which have not yet been released, intend to motivate all students to engage actively in science and engineering practices. With the focus now shifting more heavily on technology, research, technical reading and communication, classroom practices must also change to meet these needs.

> *From an inspirational standpoint, the framework [for K-12 Science Education] emphasizes the importance of technology and engineering in solving meaningful problems. From a practical standpoint, the Framework notes that engineering and technology provide opportunities for students to deepen their understanding of science by applying their developing scientific knowledge in different contexts. Both arguments converge on the powerful idea that by integrating technology and engineering into the science curriculum, teachers can enable their students to use what they learn in their everyday lives.*[1]

Science teachers have traditionally followed the textbook definition of the scientific method which consists of the following steps: define problem, make hypothesis, set up and do experiment and draw conclusion, but today's science teachers are now facing the reality of having to implement the engineering process in their instruction. The engineering process consists of these following steps: define problem; research problem; develop possible solutions; select best possible solution; construct prototype; test and evaluate; and redesign.[2]

Program Description

The overall purpose of the National Science Foundation granted project, "Multidisciplinary Engineering Research for Rural Michigan's Future", was to provide secondary education teachers the opportunity to delve into the engineering process for better teacher understanding in order to strengthen student understanding. The program was six-weeks long.

As a high school chemistry teacher, an opportunity was provided to perform simulation research to understand the interactions between a polymer Poly(N-isopropylacrylamide), also known as PNIPAM, and graphene oxide, GO[2,3,4] under different temperatures and various ultrafast electrical pulses. A snapshot of the nano-composite of PNIPAM and GO is shown in Fig. 1. Not having much computer programming experience, the teacher was trained via a tutorial to learn the Linux-based molecular dynamics software GROMACS before beginning the simulation experience. Working with an undergraduate student assistant, the teacher explored the software and learned how to do simple programming and make videos for result analysis within the first two weeks. With a general understanding of programming, the teacher did literature research on PNIPAM and Graphene Oxide, collaborating on building a molecular structure, and learned various force fields used in molecular dynamics simulation in the next two weeks. During the last two weeks, the teacher ran MD simulation of the nano-composite by GROMACS in Linux system and learned to use Visual Molecular Dynamics (VMD) to visualize molecular topologies and analyze the results, and discussed current issues and future work trends.

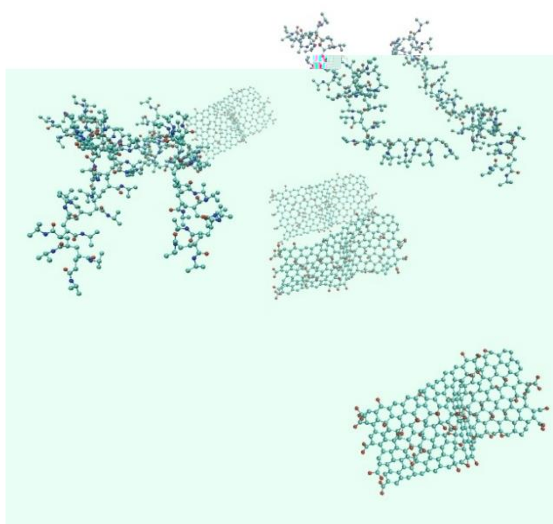

Figure 1: PNIPAM and GO (water box not shown).

The engineering process is about finding solutions to problems. Today's high school students need to think like both scientists and engineers. Scientists ask a question and follow the steps of the scientific method to answer the question. Engineers ask: Who need(s) what because why?[5] Both methods are important for students to understand and experience, but in order to do so current delivery and instruction practices require modification to provide exposure to both processes.

Results

Attention was given to both the scientific and engineering processes throughout the fall while teaching three eighty minute blocks of introductory chemistry to juniors and seniors. Three units were modified to conform to the engineering approach while others focused on the scientist approach as in the past years. These three modified units shown in Table 1 begin with a real life problem that students know something about but need to gather more information to answer the problem. Students research information, summarize and discuss their findings with others, and make predictions before beginning any laboratory experience. Students then move into the hands-on experience with guidance before given the opportunity to explore independently. Through exploration, students have options to investigate which promotes discussion and sharing of information with others. Students are asked to reflect on their findings from their laboratory or hands-on experience and make predictions about their understanding. To conclude the learning experience, students are asked to make a final product based on their newly acquired knowledge or compare their findings with standard information used in today's chemistry course.

Table 1. Proposed curriculum changes.

Scientist Units	**Engineering Units**
Introduction to Chemistry Laboratory Practices	Lewis Structures and VSEPR Theory-What's that Smell?
Chemical and Physical Changes	Chemical Reactions—Playing with Legos
Empirical Formulas and Related Calculations	Stoichiometry Introduction—Fizzy Kool-Aid
Acid Base Chemistry	--
Naming and Writing Compounds	--
Quantum Theory and Electron Configuration	--
Gas Laws and Stoichiometry	--

Discussion

It is possible to intrigue students and motivate them to be more active in their learning process when they are asked to find a solution to a problem. At the same time, it needs to be made clear that transitioning from being a scientist to an engineer requires teacher patience with students because this is as new to them as to the teacher. Students are not necessarily accustomed to reading or collaborating with others to gain knowledge or modify their procedures, so for many it is initially scary and challenging. Science teachers will need to train and guide their students to work like an engineer before expecting them to be an engineer.

Upon incorporating this approach, it was clearly evident students were accomplishing learning goals in a much more engaging manner within the same window of time. In fact, students arrived early to class to work on problem solving and had full class discussions about their thoughts without being teacher initiated or led. But, the most important and meaningful accomplishment for me as a teacher occurred when several students stated they were so interested they went home and read ahead in their textbook in order to be prepared for the next day's activity. This has been a long term goal as an educator to entice students to read, discuss with others, and think outside of classroom time because they want to understand and contribute.

Assessing student learning and understanding has to also be accounted for in our data driven educational system in order to determine the effectiveness of the changes made. Therefore, this year's students were given the same exams that were given to students in the previous school year. Upon analyzing the results, it was found the engineering approach improved student testing and understanding about 11-13% per unit.

Conclusion

There are instructional changes to be made as new expectations by the Next Generation Science Standards are being set for science teachers and students alike. Through the teacher's engineering experience, incorporating literacy strategies, and approaching the curriculum from a different perspective, the chemistry curriculum is still the same but the approach is one of problem solving and student inquiry. There will be roadblocks along the way as teachers learn how to implement this method, but the intent is to increase students' enthusiasm for science, develop problem solvers for everyday living, and prepare them to be competitive globally. As the year progresses and confidence develops for both the teacher and students in this new approach, the students are expected to exude excitement to learn, become better communicators, think and ask questions at a higher level, and above all, realize that they are successful science readers, learners and doers.

Acknowledgements

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