

An integrated approach to teaching and learning nanotechnology: the Omni Nano model

The Omni
Nano model

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Abstract

Purpose – The purpose of this commentary is to describe how Omni Nano has designed and implemented a model for teaching Nanotechnology to high school students.

Design/methodology/approach – This commentary describes the Omni Nano program and the approach taken to support high school science teachers to include Nanotechnology education in their STEM programs.

Findings – The program findings are determined from qualitative teacher and student program surveys and informal interviews. The strong positive comments indicate that Omni Nano is successful at sparking students' interest in nanotechnology and teaching nanotechnology concepts effectively.

Practical implications – The Omni Nano model demonstrates how complex STEM topics such as Nanotechnology can be designed and implemented effectively to promote student learning.

Originality/value – As the field of nanotechnology continues to evolve, high schools will need to provide additional coursework to scaffold student development and meet the demand for nanotech careers. Omni Nano has developed the first nanotechnology curriculum for high school students.

Keywords Nanotechnology, High school STEM education, STEM curriculum

Paper type Viewpoint

One of the preeminent challenges faced by today's STEM industries is a shortage of experts and innovators to fill the next generation of STEM careers. Although it is forecasted that over 3.5 million new STEM jobs will be created in the USA alone by 2025, as many as 2 million of these positions could remain unfilled due to a lack of available professionals (Radu, 2018). Recent statistics show that US universities are expected to produce only 29% of the required number of grads (National Math and Science Initiative, 2014).

Some of the challenges to effective STEM education include a lack of access to resources, poor teacher training, and a vast disconnect between the science curricula being instructed in secondary schools and the STEM skills required for careers of the future. According to the National Math and Science Initiative (2014), only 36% of all American high school graduates are ready to take a collegiate science course. One survey found that 70% of students and parents felt science teachers did not have adequate resources to teach STEM education (Radu, 2018).

Research has shown that 80% of students studying STEM in college decided to do so while in high school or earlier (Harris Interactive, 2011). Furthermore, over two-thirds of today's children will take up careers that do not yet exist (World Economic Forum, 2016).

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However, despite the importance of cutting-edge science and technology in our everyday and future lives, high school graduates are typically unaware of the myriad opportunities that STEM careers offer. This is especially true in underprivileged and underrepresented communities, where funding for education is typically insufficient or limited. The need to scaffold STEM education in Pk-12 for the next generation of careers is more apparent than ever.

Nanotechnology is a relatively new, highly interdisciplinary STEM field that is foundational for all sector of the economy (Roco, 2016). Already influencing leading research and technologies, nanotechnology has the potential to turn the physical world into a programmable medium, making it one of the most powerful engines of modern innovation. Nanotechnology is a convergence science, integrating concepts from chemistry, engineering, physics, biology, computer science and more (Herr *et al.*, 2019). Nanotechnology has a wide range of practical applications, from enabling the next generation of most consumer goods to powering high-tech solutions for the most urgent global issues. These factors combine to make nanotechnology an ideal “umbrella” subject to demonstrate the creative and explorative opportunities afforded by STEM careers. However, there are no commercially available, standardized educational resources, such as digital textbooks and assessment materials, suitable for instructing nanotechnology at the secondary or early post-secondary levels (Sweeney, 2008).

Omni Nano was founded in 2012 as a non-profit organization with the mission to educate and inspire today’s youth to become tomorrow’s scientists, engineers and entrepreneurs of nanotechnology. Omni Nano believes that by learning nanotechnology as early as high school, students around the world will be better prepared for their professional careers in the globalized, high-tech economy of the 21st century. Omni Nano wants to ensure that all students understand the opportunities they have for their future and are properly prepared for the work environment they will graduate into – so that they may be ready to solve the world’s biggest problems.

To fulfill its mission, Omni Nano has developed a unique methodology for introducing the fundamentals of nanotechnology to high school and undergraduate college students. The Omni Nano approach begins with providing “Discover Nanotechnology” workshops to schools, after-school programs and youth conferences. If there is interest from teachers and students, as well as administrative support, the school district can request to access the digital curriculum to offer selected lessons and even a two-semester long course. This paper outlines Omni Nano’s process implemented to deliver approximately 250 Discover Nanotechnology workshops to 10,000 students at about 80 institutions and to offer the curriculum to dozens of schools, enrolling hundreds of students (as of February 2020).

The Omni Nano model

Introductory workshops

Omni Nano’s Discover Nanotechnology workshops are designed to provide students with a hands-on, motivational overview of the problems being solved and the technologies being utilized by contemporary scientists and engineers, with a focus on solutions enabled by nanomaterials and nanotechnology. Students are drawn to the endless possibilities for future development and are inspired to pursue further education and professional careers in a diverse variety of STEM fields.

These workshops can be offered both in-person and online and are structured as multimedia slide presentations lasting one class period, typically 45–90 min. Prior to attending the workshop, students first take a pre-workshop survey to determine their baseline knowledge of nanotechnology and to gauge their general interest in STEM.

These surveys are used to help tailor the presentations to the students' level of knowledge and are part of a pre-post assessment measure to determine the effectiveness of the workshop.

The workshops are structured in different sections. The first section of slides is designed to grab students' attention by relating nanotechnology to pop culture (e.g. science fiction, superheroes) and revealing the nanotechnology-enabled products in which they are already familiar (e.g. cell phones, cosmetics, household toiletries). The second section introduces nanotechnology as a convergence science that produces new materials (nanomaterials), which fuel the 21st-century Industrial Revolution. The third section relates the nanoscale to other dimensional scales through comparisons and visualizations. Because the US uses the imperial system, most American students must first be familiarized with the metric system and powers of 10 in order to grasp the concept of "nano" and understand the size of common nanomaterials compared to other "small" materials. The fourth section introduces some of the unique characteristics and properties of nanomaterials (i.e. materials confined to the nanoscale) compared to the same materials at the macroscale. To better make a point of how the unique properties of these novel materials can be exploited, students are provided with a sample of superhydrophobic cloth and a lab wash bottle of water. Students understand from experience that textiles naturally absorb water, but then witness the nanotechnology-enabled cloth remaining dry as the water beads on its surface. A discussion of the scientific concepts underlying this "miracle" follows. The fifth section provides a multimedia overview of goals, products and services for which nanotechnology is making or could potentially make a difference. This is the most customizable section, with a large selection of popular topics to choose from, including advanced materials (e.g. "invisibility cloaks"), next-generation electronics (e.g. flexible displays), environmental cleanup (e.g. air and water purification), renewable energy, healthcare (e.g. antibacterial treatments, cures for blindness, treatments for cancer) and personalized medicine (e.g. instant diagnostic devices, targeted drug delivery). The sixth section discusses the future job market and how today's students fit into that landscape. A map of educational paths that can lead students to the STEM career of their dreams is discussed. Emphasis is placed on the fact that there are opportunities at every level, whether students choose to pursue an associate's, bachelor's, or graduate/professional degree.

Students are incentivized with extra credit to complete a post-workshop quiz and survey and to provide feedback about their experience. By analyzing and comparing the pre- and post-workshop surveys, Omni Nano data analysts can quantify the impact that Discover Nanotechnology workshops have on students' knowledge, interests and level of motivation.

These results fuel continuous revisions to the content and structure of the workshops in order to maximize its effectiveness as an educational and motivational tool. The qualitative success of Omni Nano's Discover Nanotechnology workshops can be gleaned from the survey comments received by both hosting instructors and participating students.

Nanotechnology curriculum

The introductory workshops serve as a springboard into nanotechnology and other STEM lessons. Following the *Discover Nanotechnology* workshops, instructors often express interest in offering more nanotechnology lessons to their students, even semester-long courses. To satisfy these requests, Omni Nano developed a digital textbook and assessment materials suitable for introducing high school and community college students to the fundamentals of nanotechnology. In addition, Omni Nano established connections with local universities and industries while creating and pilot testing the curriculum. These relationships resulted in

much needed technology resources, which allowed science teachers to design problem-based lessons similar to those that are being worked on in the field.

Omni Nano's digital textbook and curriculum is the first and only comprehensive educational package suitable for introducing high school and undergraduate students to nanotechnology. This package includes everything students need to maximize their learning, including an e-textbook and hundreds of automatically graded assessment materials with personalized feedback. The package is electronically delivered to the educational institutions, which import the package into their learning management system (LMS).

This nanotechnology curriculum is comprehensive, student-centered, teacher-approved, fully digital, mobile-friendly, user-friendly and it is the first and only of-its-kind in the world! Omni Nano's resources are carefully designed so a student who has never heard the word "nanotechnology" can now take this class, and by the end of it, this student will know a lot more about this new field of science and engineering and will feel inspired to learn even more.

The course is also designed in such a way that any science teacher can easily teach this course. The course is aligned with the Next Generation Science Standards (NGSS), the newest framework that defines the science concept that must be taught in high school.

Conclusion

Currently, nanotechnology is predominantly taught at post-secondary institutions as a multidisciplinary natural science field. However, given the enormous economic and future technological impact of nanotechnology, it is essential to prepare students at the elementary and secondary levels with the necessary skills to tackle new challenges in nanoscience. By scaffolding nanotechnology education, The Omni Nano model has shown that the nanotechnology curriculum can be effectively integrated into current curricular practices or as a separate supplemental curriculum. Instructors can utilize Omni Nano's Discover Nanotechnology workshops to introduce their students to nanotechnology in advance of nanotechnology-related lessons. Then, through partnerships with schools, business and community resources, students gain access to equipment, experts, and other resources that assist teachers in developing and deliver high-quality instruction and curriculum. The final component of the model is to provide access to a complete and current nanotechnology curriculum that has expert content to support teachers and students.

Through open-source content, community partnerships and collaboration with experts working in the field, students and teachers can enrich the teaching and learning experience, improve academic achievement, and better prepare the next generation of scientists and innovators. Both the workshop content and the nanotechnology e-textbook are available to educators at no cost and can be delivered virtually. The Omni Nano model can serve as a basis to further nanotechnology education efforts both nationally and internationally.

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