



International Journal of Research in Academic World

Received: 06/April/2024

IJRAW: 2024; 3(5):61-64

Accepted: 11/May/2024

Nanotechnology Content in Educational Programs: Current Curriculum and Practices

*¹Manoj KS Chhangani and ²Sofia I Hussain

*^{1, 2}Professor, Department of Chemistry, Government Meera Girls' College, Udaipur, Rajasthan, India.

Abstract

Nanotechnology stands as a crucial multidisciplinary domain of research and development, recognized globally as a top priority. Its advancements at the nanoscale are pivotal for national security, economic prosperity, and the overall enhancement of living standards. Envisioned as a transformative force, nanotechnology holds the promise to reshape society profoundly. The swift and sustained progress in this field is fueling a growing demand for specialized knowledge and expertise, prompting the continuous evolution of educational curricula.

To effectively integrate nanoscale-related content into classrooms, contemporary teaching methods must be continually refined to engage learners and empower them to apply their knowledge effectively. As nanotechnology remains at the forefront of research and development, educational practices must adapt to ensure they remain the primary facilitators of its growth. The ongoing emergence of new technologies, which continually reshape society, underscores the necessity for educational systems to evolve, preparing informed and active citizens.

Utilizing tools such as three-dimensional graphics, virtual reality, modeling, and other information and communication technologies can reinforce understanding of nano-related scientific and technological concepts, offering immersive and interactive learning experiences. By embracing these innovative approaches, educators can effectively equip learners with the skills and knowledge necessary to navigate the complexities of the nanotechnology landscape.

This paper endeavors to introduce the field of nanotechnology and its significance in both societal and economic contexts, highlighting its importance as a subject of study. Additionally, it seeks to offer examples and recommendations for integrating nanotechnology into teacher-preparation programs.

Keywords: Nanotechnology, education, interdisciplinary, curriculum development, contemporary approaches, problem-based learning

Introduction

The importance of integrating high-level content addressing pressing issues through contemporary educational approaches is increasingly recognized within educational systems worldwide. Education, marked by development and innovation, plays a pivotal role in fostering a mature, skilled, and creative populace. Among emerging technologies, including medical, biotechnological, and notably nanotechnological advancements, lies a wealth of opportunities for workforce development and economic growth, making them integral to career and technical education. Forecasts indicate a future heavily influenced by the widespread adoption of nanotechnologies, with longitudinal analyses suggesting its pivotal role in a transformative societal shift (Mnyusiwalla *et al.*, 2003) [11].

Focused research and development in the realm of nanoscience and nanotechnology have yielded breakthroughs leading to the development and commercialization of marketable products and novel applications (Shelley, 2006) [16]. With increasing utilization of nanotechnologies in diverse products such as cosmetics, textiles, coatings, automotive materials, and electronics, the integration of nanotechnology

into consumer goods appears inevitable. Nanotechnology is important in lots of areas like energy, medicine, and information technology. Nanotechnology warrants significant attention not only in government and commerce but also in educational spheres (Shelley, 2006) [16]. As such, educational curricula should emphasize the relevance and implications of nanotechnology, reflecting its integral role in shaping contemporary society.

Review of Literature

According to Mnyusiwalla *et al.* (2003) [11], nanotechnology involves manipulating matter at the nanometer scale to create purposeful materials, devices, and systems, leveraging new phenomena and properties at this scale. Lakhtakia (2006) further emphasizes that nanotechnology encompasses various approaches and resources, spanning all aspects of device and system fabrication at the nanoscale. Additionally, Schank *et al.* (2007) [14] suggest that advances in nanotechnology and technology in general are blurring disciplinary boundaries in education and science.

Clark and Ernst (2005) [5] highlight nanotechnology as a multidisciplinary field, bringing together experts from

chemistry, physics, biology, materials science, and engineering to explore and apply knowledge at the nanoscale. As noted by Bayda *et al.* (2019) [3], advancements in bioengineering, instrumentation, materials science, and manufacturing are blurring the lines between scientific and technological disciplines, while Jeevanandam *et al.* (2018) [8] point out the strengthening relationships among science, technology, and society due to rapid discovery and advancement.

The critical importance of progress in science and engineering at the nanoscale for national security, economic prosperity, and societal well-being is underscored by Sudha *et al.* (2018) [18]. They note that many science, engineering, and technology disciplines converge at the nanoscale due to shared principles and investigative tools. Additionally, Gottardo *et al.* (2021) [7] predict that nano businesses will emerge as the fastest-growing industry, surpassing even telecommunications and information technology combined.

Need for Targeted Knowledge and Skill

Key areas of research and development in nanotechnology center on nano-optics and nano photonics, which hold immense promise for revolutionizing industrial and manufacturing processes and fostering environmental sustainability. While the potential benefits of nanotechnology are widely anticipated, its applications are not solely confined to the realm of the future. Presently, manufacturers are leveraging nanoproperties to produce various products, including stain repellents, water repellents, etc. The ongoing advancement in nanotechnology relies heavily on associated processes, necessitating precise utilization of instruments and chemicals to operate at increasingly smaller scales. Industrial and manufacturing applications of nanotechnologies serve as the bedrock for further exploration and innovation. These applications, spanning biology, chemistry, medicine, and fabrication, offer fertile ground for interdisciplinary education and collaborative research endeavors.

The increasing demand for specialized knowledge and skills is poised to significantly influence the educational landscape across all levels. The recognized blending of disciplines greatly informs the evolving framework of integrated systems within technology education classrooms nationwide. Shields and Rodgers (2005) [17] underscored the importance of fostering a deeper understanding of cutting-edge technologies among technology education students. Their research pinpointed key competencies, including students' capacity to discern the implications of green energy, fuel-efficient vehicles, biometrics, and nanotechnology, highlighting the interconnectedness of these areas.

Nanotechnology Education

One of the primary hurdles facing the advancement of nanotechnology is the imperative to educate and train a new cohort of proficient workers proficient in the multidisciplinary perspectives requisite for the swift evolution of this nascent technology (Roco, 2002) [13]. Analogous to the way in which the microscopic approach permeated educational systems, the concepts operating at the nanoscale-spanning atomic, molecular, and supermolecular levels-should be integrated into educational curricula. Furthermore, fostering

interdisciplinary connections that reflect the inherent unity in nature is imperative (Roco, 2002) [13].

As technological innovation continues to unveil new frontiers, there is an ongoing need to incorporate elevated subject matter and classroom experiences featuring cutting-edge methodologies into K-12 education (Sweeney, 2006) [19]. The future trajectory of progress in nanoscale science and engineering hinges significantly on the content and caliber of education provided in senior secondary school syllabi (Sweeney, 2006) [19]. Adequate preparation and support for educators, coupled with meticulously designed and captivating nanoscience curricular activities, are essential for imbuing students with a profound understanding of the fundamental principles governing particle behavior at the nanoscopic level (Schank *et al.*, 2009) [15].

Engaging curricular activities featuring real-world applications have the potential to positively influence students' perceptions of science and emerging concepts. By incorporating high-quality three-dimensional graphics and virtual reality software, students can enhance their understanding of the nanoscale (Jones *et al.*, 2003) [9]. Direct engagement with microscopy and virtual microscopy exercises allows students to grasp scale concepts at the nano level and serves as a valuable resource for conducting computer modeling experiments (Chizmeshya *et al.*, 2006) [4]. These approaches create opportunities for students to actively participate in nanoscale materials research at an age-appropriate level and with relevant content.

Understanding scale in nanotechnology can be challenging for students. Connecting nanometers to familiar units offers a basic understanding of nanoscale objects. So, just how small is 'nano'? In the International System of Units, 'nano' signifies one-billionth, or 10^{-9} ; meaning, one nanometer equals one-billionth of a meter. To visualize this scale, consider the following examples:

- A sheet of paper is roughly 100,000 nanometers thick.
- A strand of human DNA has a diameter of 2.5 nanometers.
- There are 25,400,000 nanometers in one inch.
- The thickness of a human hair ranges from approximately 60,000 to 100,000 nanometers.
- A single gold atom measures about a third of a nanometer in diameter.
- To illustrate scale, if the diameter of a marble is one nanometer, the diameter of the Earth would be about one meter.
- One nanometer is approximately the length your fingernail grows in one second.

The term 'nano' originates from the Greek word 'nanos,' meaning 'very small,' which characterizes the nanoscale (1-100 nm) appropriate for particles and materials (Bayda *et al.*, 2019) [3]. Generally, materials designated as nanomaterials fall within the range of 1-100 nm, exhibiting different or enhanced properties compared to their bulk counterparts (Babick *et al.*, 2016) [1]. Nevertheless, relating the nanoscale to visible and tangible objects can aid students' comprehension of this concept. Figure 1 (Barhoum *et al.*, 2022) [2] illustrates standardized units alongside tangible, visible, or represented objects for comparison to the nanoscale.

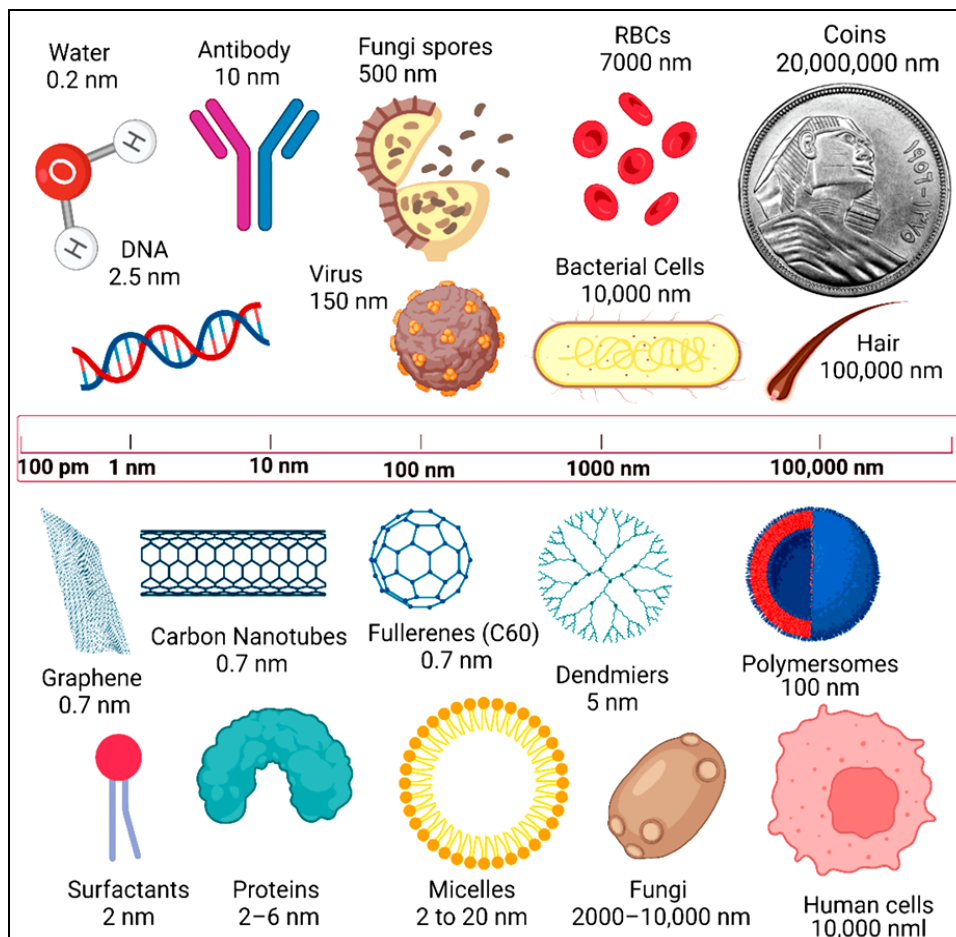


Fig 1: Size scale of objects compared with the nanoscale size regime (Barhoum *et al.*, 2022) [2]

Equipping Teachers for the Nanotech Era

Universities are integrating nanotechnology into their technology education teacher-preparation curricula, encompassing both content and practical applications. These courses offer students opportunities to delve into contemporary medical, environmental, and biotechnological subjects through various learning activities, experimentation, data collection, and modeling projects. In the medical technology sequence, students explore topics such as disease prevention and medical imaging technologies, including pasteurization, irradiation, sterilization, water treatment, sanitation, immunization, computerized axial tomography, ultrasound technology, magnetic resonance imaging, and endoscope technology.

The environmental sequence focuses on graphical weather patterns, Earth observation systems, green power, sustainability, cradle-to-cradle design, and renewable energy resources. In the biotechnology sequence, students delve into DNA technology, gene detection, enzyme replacement, cell culture, and related nanotechnologies, with a significant portion of the curriculum dedicated to nanotechnology study. Areas of study within nanotechnology include:

- **Materials Science:** Focuses on creating and understanding materials at the nanoscale, exploring their unique properties and applications.
- **Chemistry:** Involves synthesizing and manipulating molecules and atoms to create new materials and structures with specific properties.
- **Physics:** Investigates the fundamental principles governing nanoscale phenomena, such as quantum mechanics and electromagnetism.

- **Biology:** Explores the interaction between nanomaterials and biological systems, including drug delivery, imaging, and diagnostics.
- **Engineering:** Applies nanotechnology principles to design and develop new devices, sensors, and systems for various industries, from electronics to healthcare.
- **Medicine:** Focuses on using nanotechnology for medical applications, such as targeted drug delivery, imaging, and tissue engineering.
- **Environmental Science:** Examines the impact of nanomaterials on the environment and explores their potential for remediation and pollution control.
- **Computational Modeling and Simulation:** Utilizes computer simulations to predict and understand the behavior of nanomaterials and nanostructures.

An essential aspect of integrating nanotechnology into a technology education teacher-preparation program is to establish a cohesive and progressive sequence of courses. These courses should systematically build upon each other, fostering a layered understanding of content and performance-based application that aligns with identified system-based benchmarks in a coherent manner.

Moreover, incorporating visual examples and simulated real-world applications can enhance student engagement and comprehension in technology teacher education (Clark & Ernst, 2007) [6]. Utilizing problem-based and project-based learning approaches has also been demonstrated to enhance understanding of fundamental concepts and promote deep and creative learning across academic disciplines (Powers & DeWaters, 2004) [12].

By identifying connections with mathematics and science, instructional sequences can visibly reinforce the application of concepts, skills, and principles in nanotechnology education. Disciplines such as chemistry, physics, biology, materials science, and engineering all play pivotal roles in the study, experimentation, and advancement of nanotechnologies.

Conclusion

The study of nanotechnology is pivotal for the advancement of society, with implications spanning across various sectors including medicine, environment, and technology. Integrating nanotechnology into educational curricula requires contemporary approaches that engage learners effectively and empower them to apply their knowledge. By incorporating interdisciplinary perspectives, real-world applications, and problem-based learning, educators can equip students with the skills and understanding needed to navigate the complexities of the nanotechnology landscape. Furthermore, establishing a cohesive and progressive sequence of courses, supported by visual aids and simulated experiences, ensures a comprehensive and effective education in nanotechnology for future generations.

References

- Babick F, Mielke J, Wohlleben W, Weigel S, Hodoroaba VD. How reliably can a material be classified as a nanomaterial? Available particle-sizing techniques at work. *Journal of Nanoparticle Research*. 2016; 18:1-40.
- Barhoum A, Garcia-Betancourt ML, Jeevanandam J, Hussien EA, Mekki SA, Mostafa M, Omran MM, Abdalla S, Bechelany M. Review on Natural, Incidental, Bioinspired, and Engineered Nanomaterials: History, Definitions, Classifications, Synthesis, Properties, Market, Toxicities, Risks, and Regulations. *Nanomaterials*. 2022; 12(2):177. <https://doi.org/10.3390/nano12020177>
- Bayda S, Adeel M, Tuccinardi T, Cordani M, Rizzolio F. The History of Nanoscience and Nanotechnology: From Chemical-Physical Applications to Nanomedicine. *Molecules*. 2019; 25:112.
- Chizmeshya AVG, Drucker J, Sharma R, Carpenter RW. Real time nanostructure imaging for teaching nanoscience, and nanotechnology. Boston, MA: Material Research Society (0931-KK03-07), 2006.
- Clark AC, Ernst JV. Supporting technological literacy through the integration of engineering, mathematic, scientific, and technological concepts. Published Proceedings of the American Society for Engineering Education Annual Conference and Exposition, Session 146. Chicago, IL, 2005.
- Clark AC, Ernst JV. A model for the integration of science, technology, engineering, and mathematics. *The Technology Teacher*. 2007; 66(4):24-26.
- Gottardo S, Mech A, Drbohlavová J, Małyska A, Bøwadt S, Riego Sintés J, Rauscher H. Towards safe and sustainable innovation in nanotechnology: State-of-play for smart nanomaterials. *NanoImpact*. 2021; 21:100297.
- Jeevanandam J, Barhoum A, Chan YS, Dufresne A, Danquah MK. Review on nanoparticles and nanostructured materials: History, sources, toxicity and regulations. *Beilstein Journal of Nanotechnology*. 2018; 9:1050-1074.
- Jones MG, Andre T, Superfine R, Taylor R. Learning at the nanoscale: The impact of students' use of remote microscopy on concepts of viruses, scale, and microscopy. *Journal of Research in Science Teaching*. 2003; 40(3):303-322.
- Lakhtakia A. Priming pre-university education for nanotechnology. *Current Science*. 2006; 90(1):37-40.
- Mnyusiwalla A, Daar AS, Singer PA. "Mind the gap": science and ethics in nanotechnology. *Nanotechnology*. 2003; 14:R9-R13.
- Powers SE, DeWaters J. Creating project-based learning experiences university-k-12 partnerships. Published Proceedings of the American Society for Engineering Education Frontiers in Education Conference, Session F3D. Savannah, GA, 2004.
- Roco MC. Nanoscale science and engineering education activities in the United States. *Journal of Nanoparticle Research*. 2002; 4:271-274.
- Schank P, Krajcik J, Yunker M. Can nanoscience be a catalyst for educational reform?. In F. Allhoff, P. Lin, & J. Moor (Eds.), *Nanoethics: The ethical and social implications of nanotechnology*. Wiley, 2007, 277-290.
- Schank P, Wise P, Stanford T, Rosenquist A. Can high school students learn nanoscience? An evaluation of the viability and impact of the nanosense curriculum. Menlo Park, CA: SRI International, 2009.
- Shelley T. *Nanotechnology: New promises, new dangers*. New York: Zed Books, 2006.
- Shields CJ, Rodgers GE. Incorporating experimental technologies in the middle level technology education classroom. *Journal of Industrial Teacher Education*. 2005; 42(4):72-80.
- Sudha PN, Sangeetha K, Vijayalakshmi K, Barhoum A. Nanomaterials history, classification, unique properties, production and market. In A. Barhoum (Ed.), *Emerging Applications of Nanoparticles and Architectural Nanostructures: Current Prospects and Future Trends*. Elsevier Inc, 2018, 341-384.
- Sweeney AE. Teaching and learning in nanoscale science and engineering: A focus on social and ethical issues and k-16 science education. Material Research Society (0931-KK03-05). Boston, MA, 2006.