Graduate Programs on Nanotechnology in Pharmaceutical Sciences

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ABSTRACT

Nanotechnology is a multidisciplinary field of discovery. Scientists working in many disciplines, including physics, chemistry, material sciences, electrical engineering, electronics, computer sciences, biosciences and pharmaceutical sciences, are contributing significantly to the development of nanotechnology at large. Nano is really too big. Nanotechnology is a developing science and it has innumerable applications. Every day new and newer applications are being discovered. No field in the sciences will be left untouched by nanotechnology. Our previous study presented at NIST conference in 2008 showed that there are very few pharmacy schools in United States who offer courses in nanotechnology even at undergraduate levels. There is a significant need for developing graduate programs in pharmaceutical sciences for nanotechnology and its applications in pharmaceutical sciences. There is a significant need for nano workforce, especially in the field of nano drug delivery systems, and other related areas in pharmaceutical sciences. It is expected that by 2015 the total workforce needed for nano technology industries will be more than 2 million people. A major chunk of this will also be employed by the pharmaceutical industry. Nanotechnology has developed many new vistas in pharmaceutical researches and a large number of researchers will be needed to pursue and develop this area of research. This paper discusses the need for the graduate program on nanotechnology in pharmaceutical sciences and provides guidelines in developing this program. We envisage that there can be specialization in various fields such as nanoparticulate drug delivery systems, nano characterization and nano formulations, nano toxicology, and nano safety.

Key Words: **nanotechnology, pharmacy education, graduate programs**

1 INTRODUCTION

The nanotechnology and related development in sciences has lead to technological revolution in many branches of biomedical sciences. Even though the nano particles have been in nature since time immemorial, the importance of utilizing this technology has escalated significantly in the last two decades. It has enormous potential to influence our lives and has been employed in many areas, including electronics, defense, consumer products, pharmaceuticals, environment, medicine, and many more. In United States, Japan, India, Europe and many countries, several initiatives have been undertaken and members of the private as well as public sectors are intensifying their researches in this field. It is also a novel way to create intellectual properties for the private sectors [1]. Several new techniques are being introduced in the field of drug delivery systems, targeting the drug, prosthetics, to overcome the blood brain barriers in drug treatments, and many other fields in health sciences, including the diagnostics and analytical techniques.

The area of Nanomedicine is developing very fast. Nanomedicine is an emerging field of medicine with novel applications. Nanomedicine is a subset of nanotechnology, which uses tiny particles that are less than one-millionth of an inch in size. In nanomedicine, these particles are much smaller than the living cell. Because of this, nanomedicine presents many revolutionary opportunities in the fight against all types of cancer, neurodegenerative disorders, and other diseases. Recently, scientists have successfully demonstrated in vitro iRNA delivery using quantam diots, chitosan and polylactide/glycolic acid conjugated nano particles which hold tremendous promise against the diseases mentioned above. These multiple impacts are creating a challenge to the academic community in the field of pharmaceutical sciences to educate the students with necessary knowledge, understanding, and skills to interact and provide leadership in the emerging field of nanotechnology [2].

1.1 Pharmaceutical Education and Nanotechnology

Pharmaceutical education throughout the Americas is responsible for preparing students to begin the practice of pharmacy as vital members of the health care team, or to assume other roles where pharmacists' knowledge and skills are required. Pharmaceutical education prepares students to become informed citizens in a changing health care environment. It is responsible for generating and disseminating new knowledge about Pharmaceuticals and pharmaceutical services, and about the role of the pharmacist in the unique health care system. Pharmaceutical education provides students with the values necessary to serve society as caring, ethical, learning professionals, and enlightened citizens. It provides students with scientific fundamentals and fosters attitudes necessary to adapt their careers to changes in health care needs over a lifetime. It also encourages students prior to and after graduation to take active leadership roles in shaping policies, practices and future directions of the Profession and national health priorities. Pharmaceutical education both at the professional and graduate level should provide new insights about pharmaceuticals. Pharmaceutical products and cutting edge drug delivery technologies through didactic and hands-on, practical courses need to be emphasized. The concept of nanotechnology, which is basically nested in bench work research, does not find practical relevance in the clinical practice settings of Pharm.D. professionals. Nanotechnology has more applications in areas of science that deals with proven and time tested drug delivery concepts and related to therapeutic applications.

1.2 Graduate Programs in Nanotechnology

However, from a research angle, this promising new therapeutic technology is finding increased predominance in many graduate (Masters and Ph.D.) pharmacy curriculum across the country. In fact, our previous studies indicate many universities and institutions like University of Nebraska Health Center, Stanford University, Cornell University, Penn State University, Rice University, University of Notre Dame, University of Washington, University of Texas-Austin, University of Buffalo, and Steven 's Institute for Research offer courses on Nanomedicine, as a part of graduate degree requirements in biomedical sciences. However, it should be noted that this trend, though encouraging, falls short of producing enough nano workforce that will be needed in pharmaceutical industry by 2015. Hence, there is an urgent need to reform the graduate curriculums of pharmacy or other basic sciences programs to offer exclusive graduate level programs in Nanomedicine and bring more institutions in tune with this idea. In order to implement a comprehensive graduate program in Nanomedicine, the schools could use the guidelines provided by IGERT as a reference. In this article, it is our endeavor to offer insights into specialized topics in nanotechnology that can range from nanoparticulate drug delivery systems, nano characterization and nano formulations, and nano toxicology to nano safety

2 METHODS

We used two techniques to get the information for this research. We developed a small questionnaire and sent it to all the Deans of the Colleges of Pharmacy (106) using survey monkey in the United States. We received 20 responses while more than 25 e mails were bounced back as the dean's e mail accounts were not receiving the unsolicited e mails. The second method was to visit the website of each college and look at their course and curriculum and look for the nanotechnology courses being offered or incorporated in any of the courses being taught at Pharm. D. level.

3 OBSERVATION AND RESULTS

3.1 Current Status of Nanotechnology in Pharmaceutical Education in USA

Some of the observation we saw from the results are:

1. In general, the academic community in Pharmaceutical education in USA is reacting slowly to prepare the work force for the emerging opportunities for the students.
2. At a graduate-level scenario, around 15% of the programs have been offering courses in nanotechnology/ nanomedicne. The titles of the courses that were taught at masters or Ph.D. levels were Application of Nanotechnology in Drug Delivery Systems, Protein and Peptide Drug Delivery Systems with Reference to Nanotechnology and its Application in this Field, Controlled Release, Introduction to Nanotechnology, Nano Crystal Technology and Polymeric Nano Particle Synthesis, Biotechnology-Based Drug Dosage Forms, and Advanced Drug Delivery Systems.
3. Graduate level courses also offered Elective projects in nanotechnology, elements of nano science and nano technology, seminars in nano science, and seminars in antibody mediated drug delivery systems based on nanotechnology.
4. A good number of universities were offering research opportunities at master's and Ph.D level in nanotechnology and its applications in

Pharmaceutical sciences. But there were no structured courses in the curriculum per say.

3.2 Current status of Nanotechnology Education world wide

Currently there are very few universities worldwide imparting specialized education in nanotechnology. The web search provided the following countries with courses and degrees offered in nanotechnology. The numbers in brackets show the number of universities offering the nanotechnology education programs leading to full degrees. These countries include: Brazil (2), Mexico (2), Czech Republic (2), Denmark (40), France (10), Germany (4), Israel (1), Italy (1), Netherlands (2), Norway (1), Spain (1), Sweden (20), Switzerland (1), United Kingdom (8), Turkey (1), United States (30), Australia/New Zealand (13), Canada (4), India (17), Singapore (1), and Thailand (2).

The primary mission of these universities is to conduct research and develop in the area of nanotechnology and nano science; even today there is less focus on nanotechnology education.

Some research centers are supporting associate and certificate programs as part of their activities in conjunction with other degrees they are offering.

The most interesting part all over the world is the faculty members in this area are supporting their laboratories and researches through their grant funding and encouraging the graduate students to get involved in this type of research.

3.3 Suggested Courses for Nanotechnology

Some of the suggested courses for the Colleges of Pharmacy in USA, as well as worldwide, for Nanotechnology can include:

1. Generic Methodologies for the Nanotechnologies
2. Nanoscale Magnetic Materials and Their Applications in Medicines and Devices
3. Processing, Properties, and Characterization of Inorganic Nano Materials
4. Macromolecule Delivery Using Nanotechnology
5. Bio Nanotechnology
6. Nanotoxicology
7. Bio Nanomaterials
8. Nano Polymeric Products for pharmaceutical applications
9. Techniques to manipulate interfaces and surfaces at nano level.
10. Self assembling nanostructures and its applications in Pharmacy
11. Nanostructures for pharmaceutical applications like aerogels, carbon nano tubes, dendrimers, magnetic molecules, metallic nano particles, nano clays, nano crystals, quantum corrals, nano wires
12. Fabrication of nanostructures
13. Characterization techniques for nano structures
14. Nano Applications in Biosciences
15. Nanoparticulate drug delivery systems

These courses can be offered as certificate course for Pharm.D. students with at least 15 credit hours. The courses can be taken while studying for their professional degree. There can be four courses to be taken to complete the certificate course with a Masters level as specialization in nanotechnology. Or, there can be eight courses offered for a Ph.D. level graduate program in Nanotechnology in Pharmaceutical sciences

Graduate programs can be designed with stress on:

1. Nanoparticulate Drug Delivery Systems
2. Nanofabrication/Nanocharacterization/ Nanoformulations
3. Nano Toxcity/ Nano Safety
4. Nanodiagnostics/nano medicine

3.4 Constraints for Implementation

Some of the major constraints for implementing nanotechnology in pharmaceutical education include:

1. Lack of resources and materials, especially in teaching nanotechnology at undergraduate and professional level
2. Applied aspect needs to be well documented and resources need to be developed to incorporate the recent advances in the field
3. As the focus of the total pharmaceutical education is Pharmacy practice based, we need to develop courses with application in practice and understanding the importance of these techniques in practice settings
4. Majority of the universities do not have facilities for the research as the equipments involved in manufacturing and characterizing are very expensive, hence they would need to develop courses where these need not be used.
5. There is a need for educating the educators at various levels about nanotechnology and also creating interests in students about nanotechnology.

4. CONCLUSIONS

Nanotechnology has a great future in pharmaceutical education, as the science behind will be more and more applied; the courses will appear in the curriculum. The

pharmaceutical education will have to gear up for the growing needs of the society in this area by incorporating topics appropriately and not missing the boat.

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