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Innovations in Nano Materials Education through International Collaborations

Dr. Ajit D. Kelkar, North Carolina A&T State University

Dr. Ajit D. Kelkar is a professor and chair of Nanoengineering department at Joint School of Nanoscience and Nanoengineering. He also serves as an associate director for the Center for Advanced Materials and Smart Structures. For the past twenty five years he has been working in the area of performance evaluation and modeling of polymeric composites and ceramic matrix composites. He has worked with several federal laboratories in the area of fatigue, impact and finite element modeling of woven composites including U.S. Army, U.S. Air force, NASA-Langley Research Center, National science Foundation, Office of Naval Research, and Oak Ridge National Laboratory. In addition he has collaborated with Rice University, Texas A&M University, Tuskegee University, Air Force Institute of Technology, University of Dayton, Florida State University, Prairie View A&M University, University of Delaware, Texas State University, University of Minnesota, University of California, and San Diego. His expertise are in the area of low cost fabrication and processing of woven composites using VARTM process, fatigue and impact testing of composites, analytical modeling of woven composites. Presently he is involved in the development of nano engineered multifunctional materials using XD CNTs and electro spun fiber materials. In the modeling area he is working on blast simulations for the Humvee vehicles subjected to various TNT blasts loadings and atomistic modeling of polymers embedded with CNTs and alumina nanoparticles. He is also involved in high velocity impact modeling of ceramic matrix composites and polymeric matrix composites embedded with electrospun nanofibers. He has published over two hundred papers in these areas. In addition he has edited a book in the area of Nano Engineered materials. He is member of several professional societies including ASME, SAMPE, AIAA, ASM, and ASEE.

Dr. James Gardner Ryan, Joint School of Nanoscience and Nanoengineering

Dr. James G. Ryan attended Rensselaer Polytechnic Institute in Troy, NY where he received his B.S., M.S. and Ph.D. degrees in Chemistry and an M.S. degree in Biomedical Engineering. Dr. Ryan is the Founding Dean of the Joint School of Nanoscience and Nanoengineering of North Carolina A&T State University and the University of North Carolina at Greensboro. His responsibilities include academic and administrative leadership of JSNN as well as the development of strategic partnerships with industry and government organizations. Dr. Ryan's research interests include thin film deposition, interconnect technology, semiconductor manufacturing technology and radiation hardened nanoelectronics. Dr. Ryan joined JSNN after working at the College of Nanoscale Science and Engineering (CNSE) of the University at Albany as Associate Vice President of Technology and Professor of Nanoscience from 2005 to 2008. At CNSE, he managed the cleanrooms and numerous consortia involving CNSE and its industrial partners such as IBM, TEL, AMAT, ASML and others. Dr. Ryan joined CNSE after a 25 year career with IBM. From 2003 to 2005, he was a Distinguished Engineer and Director of Advanced Materials and Process Technology Development and served as the site executive for IBM at Albany Nanotech. Prior to that assignment Dr. Ryan managed interconnect technology groups in research, development and manufacturing engineering areas at IBM. He is the author of over 100 publications and presentations, has 47 U.S. Patents and is the recipient of numerous awards including 17 IBM invention plateaus, an IBM Corporate Patent Portfolio award, an IBM Division Patent Portfolio Award, IBM Outstanding Technical Achievement Awards for Dual Damascene and for Copper technologies and the 1999 SRC Mahboob Khan Mentor Award.

Dr. Ram V Mohan, North Carolina A&T State University
Dr. Sachin Marotrao Shendokar, Bharati Vidyapeeth Deemed University

Innovations in Nano Materials Education through International Collaborations

Abstract:

The Joint School of Nanoscience and Nanoengineering (JSNN) was established as an academic collaboration between North Carolina Agricultural and Technical State University and The University of North Carolina at Greensboro. Both Universities are classified by the Carnegie Foundation as "research universities with high research activity." JSNN builds on the strengths of the two universities in the basic sciences and in engineering to offer an innovative, cross-disciplinary graduate program that will train professionals in various emerging areas of nanoscience and nanoengineering. The M.S. and Ph.D. programs in Nanoengineering feature coursework involving engineering at the nanoscale. It is designed for students with a strong background in engineering who seek additional, specialized training in order to find industrial or government positions in fields that utilize nanotechnology. The graduate program has four focus areas: Nanocomposites, Nanoelectronics, Nanobiology and Computational Nano. Further details about JSNN can be found at http://jsnn.ncat.uncg.edu

In 2010 North Carolina A&T State University and The University of North Carolina at Greensboro signed a Memorandum of Understanding on behalf of JSNN with Bharati Vidyapeeth Deemed University in Pune, India (BVDU) which involves student and faculty exchanges. As a part of this program, two faculty members received their doctoral degrees in the area of advanced nanocomposites and after their return to India in 2011, established a new M.S. degree program in nanotechnology at BVDU's College of Engineering (BVDUCOE) in India. This paper presents the details of this M.S. in nanotechnology program; highlight challenges faced and success achieved in nanomaterials education through this new collaborative M.S. program in nanotechnology between JSNN and BVDU. One measurable success of the JSNN-BVDU collaboration in nanotechnology and nanomaterials is the successful organization of an international conference (NANOCON 2010 and 2012) with researchers from 17 countries and over 300 technical presentations. The NANOCON conferences played a key role in enhancing industrial and educational program awareness of nanotechnology in India. Another success of this collaborative effort is the M.S (Nanotechnology) program at BVDU with total 17 students admitted with first two cohorts. The collaboration model has allowed four of the students from the first M.S. Nanotechnology cohort to conduct M.S. thesis research at JSNN. The major challenge to this collaborative educational program has not been technical but rather logistical, obtaining student visas for the participating students.

Genesis of International Collaboration for the M.S. in Nanotechnology degree program

Research in American universities is of paramount importance, producing innovative technologies that change our society through application-oriented research conducted by faculty

and students. Nanotechnology has already dramatically impacted our lifestyle through a variety of innovative products and technologies. Some of the recent applications of nanotechnology research are in the areas of drug delivery, advanced materials for defense and aerospace applications, improving energy efficiency, water purification and green technologies. While some of these applications are already proven, resulting in cost savings or improvements in efficiency, others are still in the research phase.

Research in nanotechnology is underway in facilities around the world. India, though a huge economy due to the size of its population is still evolving in the area of nanotechnology and continues to develop the resources required for nanotechnology-related research[1,2]. Not only is specialized research equipment required for nanotechnology limited to few institutions, faculty and students with appropriate skills in the field are also limited. New educational programs in this critical technology area are definitely needed to bridge this gap. Currently, there are approximately 31 engineering institutions in India that have recently started nanotechnology related courses and programs. This is a small percentage compared to the number of engineering institutions in India. In addition, there are about 20 renowned research laboratories/organizations including Jawaharlal Nehru Centre for Advanced Scientific Research, Indian Institute of Science (IISc), Centre for Nanotechnology & Advanced Biomaterials (CeNTAB), all campuses of Indian Institute of Technology (IIT), all campuses of National Institute of Technology (NIT), National Chemical Laboratory (NCL), Indian Institute of Sciences Education and Research (IISER), Centre for Materials for Electronics Technology (CMET), and Tata Institute of Fundamental Research (TIFR) where nanotechnology-related research is carried out. The investment in the nanotechnology research made by Indian government agencies such as Department of Science and Technology (DST), Department of Biotechnology (DBT), Department of Information Technology (DIT), Council of Scientific and Industrial Research (CSIR), Defense Research and Development Organization (DRDO), Indian Council of Medical Research (ICMR) is nearly $250 Million, and is primarily concentrated with these premier institutions. In addition, over $100 Million has been invested from several multi-national pharmaceutical, automotive, food and beverage, electronics and information technology industries. Despite these investments, the research institutes and specialized nanotechnology programs in the educational institutions are unable to obtain the number of appropriately skilled technologists required for the growing field of nanotechnology in India. Collaborative efforts with nanotechnology institutions through global partnership in the US and abroad have the potential to support and guide nanotechnology program development in institutions such as BVDU. The M.S. in Nanotechnology degree program at BVDUCOE in collaboration JSNN is a clear example of one such program and is likely to play a key role in the future of nanotechnology education in India. This paper discusses the recent development of such a program, its features and its ability to provide global research and education experience to the BVDU graduates. Some of the challenges are highlighted. The first cohort of this M.S. program in nanotechnology is expected to graduate in summer 2013 and the program is showing promise for continued success. This global partnership is contributing

both to the graduate education of nanotechnology and continuing research interactions between the two collaborating institutions.

Bharati Vidyapeeth, the parent organization of Bharati Vidyapeeth Deemed University was established in 1964 to impart quality education. Since then, it has grown many fold and incorporated graduate and post-graduate education in several fields that include Basic Sciences, Engineering, Medical Sciences, Management, Law, Arts and Commerce. Today Bharati Vidyapeeth incorporates 165 institutions. Many of the Universities in India are government operated with several institutions under its umbrella. For example, Pune University is a public university. The "Deemed to be University" are generally privately operated, but functions exactly in the same manner as a public university. A principal difference between an Indian public University and a Deemed University is that (as in the U.S.) the public University gets financial support from the government for its routine operations i.e. salary of employees, student support, etc. A Deemed University generates its own funds. Deemed Universities must be accredited by national agencies like National Accreditation and Assessment Council (NAAC) and its operations must be endorsed by the University Grants Commission (UGC), the body governing education in India. On the basis of academic excellence and potential for development, the Government of India granted the status of Deemed University to a cluster of 12 institutions under the Bharati Vidyapeeth, on the recommendations of the University Grants Commission (UGC), New Delhi on 26 April, 1996 under Section 3 of the UGC Act 1956. Today, BVDU has 29 constituent units, three research institutions and seven campuses, two in the city of Pune and one each in the cities of New Delhi, Navi, Mumbai, Kolhapur, Sangli, Karad and Solapur. The University runs academic programs in as many as 11 disciplines, including Medicine, Dentistry, Ayurveda, Homoeopathy, Nursing, Engineering, Pharmacy, Management, Law, Arts, Science and Social Science. In the 16 years since its inception as a Deemed University, there has been a continuous increase in the number of academic programs at BVDU. Presently there are 234 academic programs, 44 undergraduate, 104 post-graduate programs and the remaining are diploma and certificate programs. The University has introduced several emerging degree programs such as a B. Tech. in Biomedical, an M. Pharm. in Biotechnology and a Masters in Optometry. The continuous success of quality of the BVDU programs resulted in reaccreditation with a prestigious 'A' grade by the National Assessment and Accreditation Council (NAAC) in September 2011.

The BVDU – JSNN partnership in nanotechnology is through its College of Engineering. Bharati Vidyapeeth Deemed University's College of Engineering, Pune (BVDUCOE) was established in 1983. It is one of the oldest colleges in the Pune area and has the highest enrollment for freshman engineering in the state of Maharashtra. Over the last 28 years, the college has grown significantly, and is now acclaimed as one of the best engineering colleges in the state of Maharashtra. The popular magazine, Data Quest, has ranked BVDUCOE at 35 in the list of Best Engineering Colleges among hundreds of engineering colleges in India. In July 2000, the Government of India, on the recommendations of the UGC and All India Council of Technical Education (AICTE), included this college as a constituent unit of Bharati Vidyapeeth

Deemed University. In addition, this college has accreditation from both NAAC and National Board Accreditation (NBA) with all undergraduate programs accredited by NBA.

With its cross-functional and interdisciplinary nature, nanotechnology has a high potential for research and meeting the growing needs of the country. BVDU, College of Engineering, based on the inputs from its collaboration with JSNN, initiated the M.S. (Nanotechnology) program in 2010.

M. S. in Nanotechnology degree program at BVDUCOE - Promulgation of collaborative efforts and global partnership with JSNN

The M.S. in Nanotechnology degree program is a result of faculty exchanges established with North Carolina A&T State University (NCA&TSU) over the span of several years. The evolution of this collaboration and exchanges led to the development of the M.S. in Nanotechnology degree program at BVDUCOE. In our experience, development of such working relationships over the years is essential for global partnerships. Initial collaborations established by the Memorandum of Understanding (MOU) between JSNN and BVDU focused on faculty exchange and doctoral training. Three BVDUCOE faculty enrolled in Ph.D. programs at NCA&TSU. To ensure their continued contributions to BVDUCOE, these exchange faculty members were admitted with J1 U.S. exchange visitor visas, which mandate that the faculty member returns to India after completion of their studies at NCA&TSU. The education and experience gained in U.S. and working relationships established with faculty and administration at NCA&TSU, and their familiarity with BVDUCOE protocols of new program establishment in India greatly facilitated the process. The first faculty member who completed his Ph.D. at NCA&TSU conducted research on "Manufacturing and Characterization of Advanced Composites Interleaved with Electrospun Nanofibers". During his research, the faculty member also learned about nano-manufacturing concepts using Electrospinning, Chemical Synthesis such as Sol-gel techniques, Magnetron Sputtering, Pulse Laser Deposition and characterization techniques using Scanning Electron Microscopes, Transmission Electron Microscopes, Helium Ion Microscope, X-ray Diffraction and spectroscopy techniques for nano fibers and thin films. The global partnership made it possible for the faculty member to receive training on advanced tools and techniques that would normally be unavailable to a faculty member at BVDUCOE who was primarily focused on teaching.. This exposure and education was pivotal for the development of the syllabi and curriculum for M.S in Nanotechnology degree program at BVDUCOE. It took commitment to this collaborative partnership and an understanding of each other's cultures in order to accelerate the establishment of the BVUDUCOE's M.S. in Nanotechnology degree program. The BVDUCOE curriculum is a intermingling of JSNN's graduate program development experiences and BVDUCOE's requirements.

A key factor that led to the establishment of the BVDUCOE M. S. program in nanotechnology is the organization of the NANOCON international conferences at BVDUCOE. The first conference was held in 2010 with the second one following in 2012. The second

conference in 2012 was an outcome of the overwhelming response from participants of NANOCON 010. BVDU organized 'NANOCON 012' with the theme 'Nano Technology-Innovative Materials, Processes, Products, and Applications' (18-19 October, 2012). Eighteen international researchers from various fields of Nanotechnology from the US, Japan, Israel, Italy, Spain, France, and Australia participated at NANOCON 012. A total of 170 research papers were presented with over 500 participants. This is expected to become a regular conference held once every two years. Public exposure of BVDUCOE by these conferences served to provide awareness to prospective students for the M. S. in Nanotechnology degree program.

NANOCON 010 was conducted in association with North Carolina Agricultural and Technical State University, Greensboro, North Carolina USA, Tuskegee University, Tuskegee, Alabama, USA and the Centre for Materials for Electronics Technology (C-MET), Pune, India and the Department of Information Technology (Govt. of India). Six researchers from NCA&TSU visited and presented at NANOCON 010. This International conference enabled the deliberation of issues associated with Nanotechnology and provided researchers with a forum for interaction. Following the conference, as a part of the MOU between JSNN and BVDU, the M.S. in Nanotechnology degree program was initiated in 2011.

Each year only ten high caliber students are admitted to BVDUCOE's M.S in Nanotechnology program. The selection criteria are based on their academic performance in their undergraduate engineering program, aptitude and placement in a competitive entrance examination. Nanotechnology is inherently cross-disciplinary and hence students from any engineering discipline can be admitted to M.S (Nanotechnology) program at BVDU. Recently admitted students have Bachelor of Engineering degrees (Equivalent to US B.S.) from disciplines that included Computer Science, Electronics, Information Technology, Metallurgy (Material Science) and Production (Manufacturing) engineering. Based on their performance during the M.S. in nanotechnology program, selected students are provided an opportunity to conduct their M.S. thesis research with faculty members at JSNN. This research exposure at JSNN is expected to provide M.S. in Nanotechnology students much needed hands on experience with high-end Nanotechnology instrumentation, faculty expertise and other technical resources available at JSNN. The first cohort of such student interns are currently at JSNN and initial exposure to U.S. teaching methods and technical experiences have been beneficial to the students.

M.S. in Nanotechnology Curriculum at BVDU – Establishment and Challenges

The deemed university status of BVDU was the catalyst to quickly propel the M.S. in Nanotechnology degree program establishment proposal through the Board of Studies at BVDU and the Faculty and Academic Council. An important issue for the establishment was the syllabus structure, curriculum, and content of the M.S.in Nanotechnology courses. Comprehensive deliberations were required since no other university in the western region of India has a similar graduate degree program in nanotechnology. Though the JSNN M.S. in

Nanoengineering program provided a working model, the BVDUCOE curriculum was formulated to meet academic requirements in India. To obtain advisory input from experts in India, a specialized workshop was organized which was attended by total of 12 researchers and academicians working in the area of nanotechnology at the institutes like IIT, NCL, IISER, and DRDO. Experts from all over India were invited to formulate the M.S.in Nanotechnology Curriculum. An Indian M.S. degree program in engineering typically consists of four semesters over a span of two years. During the curriculum development workshop for the M.S. in Nanotechnology degree program, consensus was established to have twelve courses in the curriculum with four required courses in each of the first two semesters, two elective courses in the third semester and one self-study (independent study) subject in the third and fourth semesters. Since Nanotechnology is interdisciplinary in nature, a fundamental understanding of nano characteristics is needed with a specialized science orientation. Hence, the first semester was devoted to nano concepts from physics, chemistry and biology. Also included is a required course to provide an overview of nanomaterials, their synthesis and characterization and applications in nanoscience and nanotechnology. The second semester of the M.S. in Nanotechnology degree program emphasizes advanced synthesis of nanomaterials, characterization, computational modeling, energy and environment, safety and commercialization issues in nanotechnology. Two self-study and elective subjects are designed for students with undergraduate backgrounds in mechanical, electronics, computer, chemical, and electrical engineering disciplines, and also to cover specialized advanced topics such as nano-medicine.

In most Indian engineering curricula, the majority of students do not study biology beyond secondary education. Therefore, introducing nanobiology as a part of M.S. nanotechnology curriculum at BVDU posed a challenge. Considering that nano-medicine has many potential applications, the curriculum development board members were convinced to include nanobiology, nanomedicine and similar subjects in the BVDU M.S. in Nanotechnology curriculum. Self-study (independent study) courses and topic areas are meant to provide an opportunity for students to choose any specialized topic area in nanotechnology and study it with guidance from a faculty member. The seminar and thesis research are the part of the third and fourth semester. In order to make an assessment scheme consistent with global educational standards, the M.S. (Nanotechnology) was chosen to pilot the Choice-Based Credit System (CBCS). Unlike U.S. universities, a Credit System for performance evaluation is not prevalent in India. Instead, the Indian system is marks-based. BVDU has introduced the Credit System with a Choice of Subjects offered to students (Choice-Based Credit System (CBCS)).

After formulating the curriculum, the teaching faculty was composed of in-house faculty members and personnel from the local research center, CMET. The Four Faculty members associated with M.S in Nanotechnology degree program at BVDUCOE have expertise in Nanocomposites, Nanobiology, Chemical Engineering and Nanoelectronics. The faculty members have published ~45 journal articles collectively and have ~60 national and international conference publications. The most important part of this collaboration is the development of a

network of 15 renowned research organizations within India. Also, the academic program greatly benefited from the proximity of the major materials research center, CMET, and its scientists.

Enrollment for the first year of the M.S. in Nanotechnology degree program at BVDUCOE provided significant challenges. In India, demand for a particular discipline is based on the awareness, and its potential for employability. In the first year, low turnout of those seeking admissions to the M.S. in Nanotechnology degree program at BVDU was due to apprehension among the Indian engineering students about the potential for employment in nanotechnology after the completion of the academic program. Prospective students completing their undergraduate degrees had very limited exposure to nanotechnology and had not taken any courses that would introduce them to the concepts of Nanotechnology. In the recent times, an introductory elective course in nanotechnology in many U.S. universities is available to undergraduate engineering students. This resulted in only seven students admitted for the first cohort entering in 2011. However, in the second admission year (2012), 10 students were admitted. One concern raised by the students was the potential to provide sufficient job opportunities because Nanotechnology is still in its infancy stage in India. Through their interactions with the scientists and engineers at the research organizations mentioned earlier, students quickly realized the potential and the demand for engineering graduates with nanotechnology specialization. In addition, the establishment of the M.S. in Nanotechnology program at BVDU attracted the attention of companies like Reliance Industries, Tata-Technologies, Johnson and Johnson, Suzlon, etc., who are finding it difficult to get researchers, scientists and engineers with specialized nanotechnology background and have expressed interest in the graduates of the BVDU M.S. in nanotechnology program. The first cohort of M.S. in nanotechnology students is expected to graduate in summer 2013 and we anticipate good placement of the graduates. This awareness of the employment potential with a larger need but a small pool of qualified graduates has resulted in a change in the student interest in the program. The demand for the M.S. in nanotechnology program is very high with nearly 1000 participating in the most recent placement examination conducted at BVDU. The opportunity to conduct their M.S. thesis research at JSNN with an assistantship of $1000 per month and a subsequent opportunity to be admitted to JSNN's Ph.D. programs based on their performance during their M.S. thesis research and recommendation of advisor is another attraction for prospective students. In spite of the increasing demand and a large pool of applicants, admission levels have been kept to only 10 students to maintain the quality and rigor of the program.

Program Requirements and Curriculum for the M.S. in Nanotechnology degree program at BVDU:

Total hours required. - 110 credit hours (Only thesis option is available)
Theory Credits – 54,
Seminar Credits – 5,
M.S. Thesis Credits - 51

Other requirements – M.S. Thesis research is required resulting in at least one peer reviewed paper in a journal or conference. The current cohorts are on track to meet these requirements.

Core Courses (36 credits): The student will take a total of eight courses in the first and second semesters that will introduce them to fundamental concepts, methods, and discoveries in different areas of Nanotechnology. These courses include:

Subjects (Courses)	Teaching Scheme (Hrs) Hrs./Week		Examination Scheme (Credits)		Total Credits
	L	P	TH	TW/PR/OR	
Semester I					
Nanoscience and Nanotechnology	04	02	04	01	05
NanoPhysics	04	--	04	--	04
NanoChemistry	04	--	04	--	04
NanoBiology	04	02	04	01	05
Semester II					
Nano Fabrication and Advanced Synthesis Technology	04	02	04	01	05
Nano-Computing	04	--	04	--	04
Energy, Environment, Safety and Commercialization For Nanotechnology	04	--	04	--	04
Nano Characterization	04	02	04	01	05
Semester III					
Elective -I	04	02	04	01	05
Elective -II	04	02	04	01	05
Self Study Paper - I	04	--	04	--	04
Thesis Stage -I	--	07	--	21	21
Seminar	--	05	--	05	05
Semester IV					
Thesis Stage-II	00	20	--	30	30
Self Study Paper - II	04	--	04	--	04
Total	**48**	**44**	**48**	**62**	**110**

Key: L-Lecture, P/PR-Practical, TW-Term Work, OR- Oral (Verbal Examination)

Elective Courses (10 Credits): electives provide an opportunity for students to choose core domain subjects that are close to their undergrad discipline. The following electives are offered in the present curriculum. Additional elective options are expected to be introduced in the future.

ELECTIVE I:	ELECTIVE II:
a. Computational Nanoscience b. Nano Electronics c. Nano Medicine d. Nano Engineered Devices	a. Nano Photonics b. Industrial Nanotechnology c. Nano Material Science d. Nano Composites

Self-Study Subjects (08 Credits): Two independent study subject areas are decided by students in consultation with advisor. These subject areas are to be studied by students on their own. They may attend classes, lectures, seminars, and conferences offered elsewhere in other departments or even other schools. The following are the self-study subject options available to M.S.in Nanotechnology degree program students at BVDU.

Self-Study I	Self-Study II
1. Modeling and Simulation of Nanosystems 2. Synthesis and Design Nanoscale Products 3. Emerging Trends in Consumer Nano Products 4. Applications of Nanotechnology in Food and Agriculture 5. Finite Element Methods for Nanoscale Structures 6. Computer Aided Design of Nano Systems 7. MEMES/NEMES	8. Silicon Nanostructures & Carbon Nanotubes Based Nanoelectronics 9. Crystallinity and Structure of Nanomaterials 10. Nanoscale Mechanics of Materials 11. Quantum Theory of Solid 12. Economic Principles of Nanotechnology Management 13. Mechanics of Nanomaterials 14. Metrology for MEMS and NEMS

Outcome and Experiences of the BVDU M.S. Nanotechnology Program

Since the inception of the collaborative nanotechnology M.S. program and the working model for global interactions through educational, research and student exchanges between JSNN and BVDU, the following are some of the notable outcomes and experiences:

- The International Conference NANOCON 010 and 012 provided an opportunity for networking with as many as 30 nanotechnology researchers from 17 countries for BVDU faculty and students. Additionally, faculty and students associated with the M.S.in Nanotechnology program had an opportunity to participate in the international conference and publish in the special issues of the Journals.
- Four M.S. students from BVDU were selected to conduct thesis research work at JSNN. Though securing their U.S. visas posed some delays due to the sensitive nature of the technical areas and special clearance by the U.S. Department of State and U.S. consulate, students were successful in securing their visas and are at JSNN doing research under the direction of JSNN faculty members. In addition, these students are also benefiting from the JSNN graduate courses in areas that are not offered at BVDU. This is expected to provide a long term return on investment for BVDU, if the students are selected to continue for their Ph.D. program at JSNN. Any such graduate might be considered for

faculty employment by BVDU and would be a resource for introducing and offering courses at BVDU and ensuring continuing global collaboration.

- The collaborative faculty exchange with BVDU had resulted in establishment of a nanofiber fabrication facility locally at BVDU. Nanofiber manufacturing has been accomplished from Gelatin, Nylon, Di-methyl formamide, Cellulose Acetate and Chitosan. Some of the fibers have been functionalized with Curcumin for treatment of diabetic wounds. Synthesis of Fe, CdS and Gold nanoparticles and characterization using a particle size analyzer has been established.
- A Bio-Synthesis and Characterization facility has been developed at the research center for Interactive Research School in Health Affairs (IRSHA).
- The established M.S. in Nanotechnology degree program has been instrumental in funding received for BVDU's Technical Educational Quality Improvement Program (TEQIP) to procure characterization equipment like a UV-Vis spectrophotometer, FTIR, Dynamic Mechanical Analyzer, Scanning Electron Microscope and Florescence Spectrometer.
- Nano Composite manufacturing using glass molding, Nanofiber manufacturing using Electrospinning, Sol-gel synthesis, Microwave synthesis, Sputter deposition, Chemical Synthesis facilities has been established at BVDU.

All these outcomes would not have been possible without the JSNN-BVDU global partnership in establishing the M.S. in nanotechnology program at BVDU. The research and educational infrastructure is enabling the establishment of BVDUCOE as a key player in nanotechnology research and education in India.

Conclusions:

This paper presented details and experiences of the international collaborative program which was initiated as a part of Memorandum of Understanding between the Joint School of Nanoscience and Nanoengineering, USA and Bharati Vidyapeeth College of Engineering in the area of nanotechnology education. Preliminary results and outcomes clearly indicate the benefits to partnering institutions, and have established a working model for global partnership. The M.S. in Nanotechnology degree program is becoming instrumental in establishing BVDUCOE as a key player in nanotechnology research and education in India. The global partnership is also providing JSNN with a pipeline for qualified students for JSNN's doctoral programs in nanoengineering and nanoscience. We feel that this global partnership program can serve as a role model for other international collaborations. Presently JSNN is exploring the possibility of similar programs with other international universities.

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