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Aishwarya S. Patil, Gajanan V. Parishwad, Sonali K. Kale and
Aveshemad S. N. Husainy

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Modern Ethical and Societal Implications of Nanotechnology

Aishwarya S. Patil¹, Gajanan V. Parishwad², Sonali K. Kale³,
Aveshemad S. N. Husainy⁴

¹M.Tech Research Scholar, Department of Technology, SPPU, Maharashtra, India

²Principal, Pimpri Chinchwad College of Engineering, Pune, Maharashtra, India

³Assistant Professor, Department of First Year Engineering, Pimpri Chinchwad College of Engineering, Pune, Maharashtra, India

⁴Ph.D. Research Scholar, Shivaji University, Kolhapur, Maharashtra, India
aishwarya94.ap@gmail.com, parishwad@rediffmail.com,
sonalikale6@gmail.com, avesahemad@gmail.com

Abstract. Advancement in nanotechnology in multidisciplinary areas of health, cosmetics, automobiles, electronics, food and agriculture is established. The researchers started to study and debate the social and ethical aspects in terms of benefits and risks. The study of nanotechnology starts with proper definition of its purpose and its scope. Since nanotechnology is at an emerging stage, study of ethics is needed and society revolving around this technology has to grow. **This study will help the growth and future predictions about nanotechnology and its implications which can then be communicated to wider audience which will build confidence and will give them the right to choose.** Acceptance of advanced technology by the society is very first milestone for a longer run.

Keywords: Nanotechnology, ethical and societal implications.

1 Introduction

When an advanced technology emerges, the questions of its suitability and implications arise. Even in the century of genetic engineering, biotechnology and information technology these problems arise. Controversies bring up the need to prove the technology scientifically with the help of a detailed and deep research. Such controversies addressed in case of biotechnology [1] when genetic modification was done in food which directly affected human health as a result it was rejected by public and technology was questioned but with nanotechnology no such issues are addressed till now, it has served its purpose well. Learning from implications of biotechnology, nanotechnology's ethical, societal and health aspects are to be studied well because a technology can sustain only when it is accepted at large scale [2]. Innovation in technologies has become a race where technologies are improving at rapid pace to better the life of people and ease their efforts. This is where the need of nanotechnology emerged which gives all benefits of compactness, newest technologies, and suitability to varied fields. Nanotechnology knowledge is used in

various fields like medicine, space, automobiles, agriculture, cosmetics and electronics. When nanotechnology will grow along with consideration of society and values, it will be beneficial for human race only with improved health, better environment, improved economic growth, improved quality of life, social trust and enhanced human capabilities which will make countries flourish in an effective way.

2 Literature Survey

Baran et al. [2] shows that Nanotechnology has multidisciplinary aspects in which it is being implemented in various fields such as robotics, biotechnology, electronics, genomics, neuroscience, pharmaceuticals and information technologies. These fields are needed at International Corporation level and risk regulation authorities. Ethical issues of transparency, responsibility research public trust, potential risks, and environmental effects are being discussed and focus on regulating nanotechnology and the steps taken by EU law in this field. Singh et al. [3] deals with the social implications which arise out of the increase in the number of discoveries at nanoscale. The properties of the materials at micro are different and establishes than at nanoscale where it can be manipulated and yet not fully studied. Innovations and the diffusion of this till the last strand of society. There are unintended consequences where the producers are unaware about the consequences later in the stage of the product. Public involvement in debates and decision making and educating students, scientist of multidiscipline and public about nanotechnology ,its research and consequences. Mnyusiwalla et al. [4] mention about the gap between the paces at which science is moving forward and the research in ethical, social and legal issues are lagging behind. The author mention about *NE²LS* i.e. nanotechnologies ethical, environmental, economic, legal and social implications and elaborates the effects of ethical study which help to reduce the publicity of potential benefits, preventing the misuse of technology, environmental misuse and global wealth distribution. Also, science with advancement has come at a borderline between quantum and classical physics, impacting society for good, investment by industries and applications into commercialization. Purohit et al. [5] writes about the social consequences, environmental effects, health effect, ethical issues and its impact on society and the surroundings. How nanotechnology can help us to reach the goal of a better society that it will have confronting certain psychological questions such as what kind of society we want for ourselves. The author puts lights on effects of nanotechnology on society explaining about the toxicity and its implications on human health, on environment where its size leads to water pollution, on health where inhaling of nanoparticles may show different reactions in the body after entering it. Sweeney et al.[6] talks about the human ability to manipulate matter at the molecular and atomic level has made us bring about a discussion regarding the social and ethical issues of nanotechnology and to understand it better it is necessary to understand the perspectives of current and future and how they conceptualize this in their work. The research experiences for undergraduate (REU) program conducted to understand the ethical issues is being discussed where the students are involved and they themselves practically experience and discusses various issues related to the technology. Markova et al. [7] highlight about the ethical issues at every stage of the progression

of nanotechnology which should be solved by means of applied ethics. The framework of Ethical, legal and social implications program (ELSI) is discussed which is a draft of the ethical issues in nanotechnology. The ethical issues which may emerge in the future are discussed where the future of nanotechnology is taken as the self-replicating robots. The solution to these future risks is defining the subject and purpose of nanoethics as nanotechnology goes interdisciplinary. Change in the properties at the atomic level need to be researched fully, detection of toxicity and its study. The testing with earlier concepts may not be capable to test nanotechnology, utopism and distributive justice issues needs to be addressed. Gebeshuber et al. [8] mention that Nanotechnology has applications in many field because of which it will amplify the social effects of those other fields. The term nanoscale unites the three major fields of biotechnology, information technology and cognitive science also called as NBIC. Risk assessment and competent research is the need of hour. Social implications can be studied by involving social scientist in the study along with nanotechnologist, analyzing the contribution, its effects and promotion of nanotechnology. Ethical issues where military applications of nanotechnology must be limited to defense, equity, research should be accurate, industries to be self-regulating, debates and discussion and economical distribution across the globe. Lewenstein et al.[10] discusses about the term of social and ethical implications being used in varied research texts and changes it to 'social and ethical issues' as it may include both benefits and risks rather than only been associated with risk. Author argues that the concepts of ethics such as equity, justice, fairness, and especially power, unite 'social and ethical issues' in nanotechnology such as environmental health and safety, privacy, media usage. As the applications of nanotechnology are ever-expanding, the ethical issues related to it are unclear. Rules of patents vary across the globe and patents are important to secure intellectual properties. Wolfson et al. [11] takes into consideration the effects from biotechnology and the convergence of biotechnology and nanotechnology. Also, mentioning of five important issues related to ethical and societal concepts related to nanotechnology where 1) about inequity creating have and have not's of technology, 2) about the weaponization and misuse, 3) to prevent the inadvertent spread of nanotechnology, 4) need of regulations for nanotechnology and 5) the nanotechnology shield which can defeat any miscreant nanomachine.

3 Ethical Implications

When nanotechnology is used to create a commercialized product then a systematic approach must follow, where the ethical aspect is taken into account from very first stage till the end i.e. while development, production, sales, application and then to disabling. Nanotechnology has benefits and risks both. A uniform definition and understanding of nanotechnology all over the world will help to regulate the technology in a better way. The ethical issues related to the advancement of nanotechnology are as follows:

1. No methods are there to assess **the risks associate with nanotechnology** [2]. Since in material science up till now, the materials were used in actual size but with emergence of nanotechnology the size has reduced. The material properties changes when the material is reduced to nanoscale where its surface area increases, size

decreases, toxicity increases etc.

2. Issues are raised about equality in distribution [7] of the technology and nanotechnology as privilege for the rich. Equality comes when there is no difference between developed and developing nations, rural and urban societies, rich and poor. For instance poverty is an issue in developing countries even if they want to eradicate poverty with the help of nanotechnology they might not be able to afford it as nanotechnology might depend upon country's wealth.
3. Unintended consequences [8] are those which are not intended by the researcher or producer while creating it. These consequences arise out of the physical or actual working of the technology in the market. A good example is been illustrated in the research work is the use of nanotechnology in medicine where the nanotechnology has helped improve the life span of elder people which reduces the mortality rate and enhances the health of the elder people but the unintended consequences will be population rise, second career taken up by the elder people, an extended retirement, more government spending on pensions.
4. Security issues arises related to the advancement of nanotechnology which can store a large amount of personal data and could potentially be used to provide data to the insurance companies, consumer manufacturing companies and health sector which will then mend their policies accordingly with targeted advertisement which is a failure of security.
5. Issues of freedom of choice [10] where the consumer of the technology decides about what products consumer wants to use irrespective of what effect it will have on environment and health. So sometimes it becomes difficult to bring strict limits without harming the freedom of choice of the consumers. Consumer's rights to decide and research scientist's moral obligation to guard against misuse must go together.
6. Animal testing during the time of clinical trials is being sometimes called unethical because of the animal life at stake but scientists give it a very justifiable answer that to test the new vaccine which will be further be used to cure humans, can only be done on animals for knowing exactly how it will react after entering into human body.
7. Toxicity of nanomaterials due to its nanosize, the accumulation of Nanoparticles is observed at this size. It leads to contamination of the process in which it is used such as environment or if enters into the human body that indirectly affect health or can be disastrous. More detailed research is needed in understanding the properties of nanomaterials and its detection of toxicity.
8. Patenting problems are faced by the scientific community in the field of nanotechnology where the rules are different for different countries and not well defined for nanoscience. It is easy to patent new products and production methods, but scientific discoveries cannot be patented. Issues related to the patent laws where debate is about the unknown future risk about nanotechnology which can be a reason to exclude it from patenting like biotechnology.
9. The false news about nanotechnology which creates doubts in the mind of people which indirectly discourages the research in the emerging field and also makes big loss for the patent holders to bring it into commercialization. Reports must bring transparency in the actual benefits and risks of nanotechnology and constrain themselves from false reports.

When we talk about the ethical issues of privacy, safety etc. they must be related and

read along the concepts of ethics such as fairness, justice, power and equity. Researches ethics are to be followed in order to bring out a detailed and transparent research in front of the scientific community, industries and people.

4 Societal Implications

Due to the progress in medical field using nanotechnology, improvement in physical strength, memory and removal of disability such as Parkinson's disease has been possible. With the design of new systems at atomic scale we are developing the capabilities to redesign the structure of all the materials present in surroundings [9].

1. **Conflict of interest** [10] between various stakeholders can be detrimental for the growth of the technology. It may be researched with a different intention but if is needed to produce for a different applications will make the decision making difficult because of conflicting interests.
2. The issues of replacement of older to newer technology have surfaced a lot and same is the case with nanotechnology where the benefits may cost older technologies. This issue is also taken along with the issue of workforce. There are two issues related to workforce i.e. the skills that needs to be changed and the safety of workforce while working with newer technology. Replacing older technologies takes time and in the case with nanotechnology which will coexist for a longer time.
3. The developments of new technology once these are technically and commercially feasible are much convenient to users and innovators similar to the field of economics where the demand and supply connotes the similar meaning.
4. The issue of environment pollution where the size and properties of nanoparticles effect the environment for example the use of electric vehicle may reduce the pollutants coming out of the gasoline vehicle but we cannot estimate the pollution done by the release of lead into environment while manufacturing and disposal of an electric vehicle battery. Discarding the byproducts and used products is also an issue.
5. The penetration of nanotechnology is taken to be going along a chain which starts with wealthy nations, wealthy societies, urban class rich, rural class and then to poor nations. **A good example of this is the penetration of computers and internet in the world and societies** [11].
6. Accidental spread of nanotechnology is an issue as in case of biotechnology where genetically modified plant seeds were thought to be not entering in the human food chain but the technology penetrated and showed adverse health effects on the human health. Experiences from these can come handy to nanotechnologists, researchers and society about how to handle, deal and enhance the engagement with nanotechnology.
7. Nanotechnology brings the matter to the smallest level possible while enhancing its properties. This small size can bring compactness which aids easy dispersal. This property can be misused as a terrorist weapon and transferring it will be more easy and undetectable. A possible solution to this is while creating technologies, the solutions must also be researched and worked along and a parallel work must be encouraged.
8. University and industry relationships must not only be of feeder as well as producer

of technology but also bring in synergy amongst them about the moral aspect. These two players must advance their knowledge to students and educational institutes.

A superior technology brings leadership which in turn increases the force in global politics. Similarly when the government has substantial force in national politics it aids a balanced growth of the country where it fulfills its responsibilities towards the citizens.

5 Way Forward

Nanotechnology is in congruence with biotechnology, information technology and cognitive science. The study of societal and ethical issues with the subject will bring out a broader picture of nanotechnology which will help policymakers and public to have an understanding of its positivity and implications.

The way forward will be to look upon the ethical and societal issues raised.

1. Change in the way to educate students about nanotechnology by maintaining a balance between specialization and interdisciplinary training over the four or two years of course integrated with industrial exposure. Web and internet provides a lot of opportunities for virtual learning and understanding. Students would find the economic, intellectual and social opportunities of nanotechnology to bring forward the scope all over the world for careers in science and technology.
2. Social scientist needs to be encouraged by the social science, professional societies, universities and government agencies to gain scientific literacy and rope in new talents having technical background and research orientation that would allow them to conduct a competent research about the ethical and societal implications of nanotechnology which will build confidence amongst users.
3. High priority must be given to equal distribution of products and services meant out of nanotechnology. The concept of corporate social responsibility can be roped into this field for betterment of the society and an equal distribution. This responsibility on nanotechnologists and nanotechnology can be named as “nanotech social responsibility”. Nanotechnology bridges the societal disparities within people giving those rights to survive with dignity, respect and provide the basic satisfaction to human being. A very good example is of people with disability reaping the benefits of nanotechnology.
4. Use of nanotechnology in military must be limited to defense and security and not for selfish motives of politics or military propaganda. Military use nowadays is about deterrence and surveillance for which nanotechnologies are being used to improve and enhance their arsenal. Nanotechnology in defense can be included under rules and regulations of the international organizations dealing with the usage, storage and transfer of nuclear, chemical, ICT, biological technology. Punishment for unethical use of nanotechnology must be followed.
5. When technology comes in environment takes a back seat, limited pollution is always tolerable if the technology is for the betterment of the unprivileged. So, there should be a continuous process of debate and discussions involving multidisciplinary experts about the effects of nanotechnology on environment.
6. For improving the scope, spreading the subject and to bring in legitimization of the subject three main players are students [12], society and industries. Students are the

future of any technological advancement. Society helps it to grow with their acceptance which comes from transparency, knowledge and needs. Industries help in research and patents commercialization which is dependent upon the need or demand of the technology in the market.

7. For more research in the field of ethical and societal issues of nanotechnology government must give a push with allowing funding for research. The need of interdisciplinary experts is necessary as nanotechnology in itself is not limited to one field but it is multidisciplinary. Various initiatives by various governments across the world are taken to aware people about nanotechnology and keep them away from any false information. To name a few united kingdom project DEEPEN (Deepening Ethical Engagement and Participation with Emerging Nanotechnologies), Netherlands project Nanopodium, Belgium's project Nanosoc, Germany's project Nanologue, US's NNI [13], EU's Code of Conduct, Malaysia National Nanotechnology Initiatives (MNNI) [14] etc.
8. As nanomaterials are used in various industries and are entering into many home products so it should be the responsibility of the manufacturers to mention about the use of nanomaterials in the product on the packaging itself to inform consumers.
9. Regulations of newer technologies are a complex process, the first question about regulations is whether the technology needs to be regulated, if regulated should it be comprehensive or not. Unregulated activities such as software and internet are faring well and are benefiting from no regulations similarly nanotechnology may yield a rapid growth and bring innovation with the help of market. Regulations are needed at all stages i.e. application, production and marketing [15].

Every technology has emerged and enhanced in its own way with the motive to take the country forward in each front. The most important fronts are economy and defense. This brings up a question about whether the advancement of new technology is for power and superiority or for equity and humanity.

Conclusion

Nanotechnology as a area has gone a long way and with the emergence of new applications, lesser knowledge about its properties and behaviour as they are ever evolving, scientists found the need to research and discuss more about the ethical and societal parameters of nanotechnology. Experiences from implementation of biotechnology come handy to build confidence in nanotechnology. Social issues involve a nanodivide, unethical or illegal use, workforce safety, conflict of interest, research ethics, university-industry relationships, intellectual property and patent, equity, public participation, transparency, health and environment. Ethical issues involve clinical trials, unintended consequence, genetic changes, toxicity of nanoparticles, privacy issues, human health and freedom of choice. A multidisciplinary approach to rope in social scientist which will fill the gap between scientists, students, industries, government and common man. Stakeholders such as researchers, industries and people while working must keep the moral issues at fore. Educating scientists from different discipline and students can build a better future for nanotechnology. Government funding for research and discussions to support the discoveries will help to overcome the societal needs and commercialization to gain

benefits of the technology. Nanotechnology will help society which is at the centre of the creation provided the fact that the ethical and societal implications are well researched before implementation.

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