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Perceptions of Nano Ethics among Practitioners in a Developing Country: A Case of India

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Abstract Many developing countries have allocated significant amounts of funding for nanoscience and nanotechnology research, yet compared to developed countries, there has been little study, discussion, or debate over social and ethical issues. Using in-depth interviews, this study focuses on the perceptions of practitioners, that is, scientists and engineers, in one developing country: India. The disciplinary background, departmental affiliation, types of institutions, age, and sex of the practitioners varied but did not appear to affect their responses. The results show that 95% of the Indian practitioners working in the area of nanoscience and nanotechnology research recognized ethical issues in this research area, and 60% of them could offer specific examples, which included possible ill effects on environment and human, use as a weapon, hype, professional ethics, laboratory testing on animals, cyborgs, widening the gap between rich and poor, self-replication, and longevity of human life. The results may offer opportunities for future cross-cultural research, as well as offer examples that can be used to raise the awareness of other practitioners in India and elsewhere regarding the importance of ethical issues.

Keywords Cyborg · Ethical issues · India · Nanotechnoscience · Perception · Practitioners

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Introduction

Nanoscience and nanotechnology, which we refer to as *nanotechnoscience* [18], is an evolving scientific research area. Most of the current debates surrounding ethical issues in nanotechnoscience are derived from the examples of past technologies like biotechnology and information technology [21]. Debates also exist over whether nanotechnoscience has any unique ethical issues or whether the ethical issues of past technologies apply to nanotechnoscience too [6, 17]. Scholars have extensively written about possible ethical scenarios that might coincide with the evolution of nanotechnoscience [8, 12, 13, 22, 25, 26]. Other studies conducted in the area of nanotoxicology have suggested risks [10], including ill effects of nanoparticles on humans [1, 3, 4, 15], fish [19], and the environment [16].

Although the last decade has witnessed a number of scholarly articles and a specific journal devoted to

ethical issues related to nanotechnoscience [9], to date there are few empirical studies conducted among the practitioners, with some notable exceptions [11]. Further, to date, empirical studies have focused on views of practitioners in western or developed countries. One question is the extent to which practitioners in developing countries are also considering ethical issues in nanotechnoscience.

The present paper offers the perspectives of practitioners in India about ethical issues related to nanotechnoscience. Many developing countries have allocated significant amounts of funding for nanotechnoscience research [23]. Although considered a developing country, the Indian government has allocated major funding (approximately 200 million USD for five years starting from 2007) to nanotechnoscience research. In comparison, other research areas such as agriculture, which some would argue is imperative for the Indian economy, have seen less financial support. Therefore, one could argue that the ethical issues extend beyond concerns about nanotechnoscience to the question of the costs versus benefits of financing this expensive research in India [20]. Until now, however, there has been little formal study, discussion, or thinking concerning the social and ethical issues related to nanotechnoscience in India.

Methodology

To identify practitioners we downloaded papers, from the *Sci-Finder*[1] database, published in peer-reviewed journals in the area of nanotechnoscience from India between 1990 and 2006. We did not identify any publications in this area prior to 1990. This database is used most often by Indian practitioners for their research. The word 'nano' was given for the initial search and that brought in words such as 'nanoseconds', 'NaNO2', 'nanogram', etc., which were excluded from the list. We considered papers in which 'nano' appeared either in the title or abstract. The final list consisted of about 3,000 papers. Using the name of the author(s) and the affiliation of the author(s) in the list of publications, we identified the practitioners working in this area along with their institutional and disciplinary affiliation. Graduate students, postdoctoral researchers and laboratory technicians were excluded from the list although informal interactions occurred with them. The final list consisted of about 120 practitioners. Further, we employed multiple stratified random sampling to select nearly 50% of these practitioners as our respondents. The departmental affiliation, types of institutions, disciplinary background, age, and sex of the practitioners varied. Our sample was drawn from universities (state, central, deemed), Council for Scientific and Industrial Research (CSIR) laboratories, independent Research and Development (R&D) institutions, and Indian Institute of Technologies (IITs).

We then visited 21 laboratories located in several places in India between December 2006 and November 2007 and conducted in-depth face-to-face interviews with 58 practitioners. We had practitioners from departments such as physics, chemistry, materials science, polymer science, biochemistry, metallurgy and materials engineering, environmental engineering, chemical engineering, and mechanical engineering. Thirty practitioners (52%) were in the age group above 50, and 28 practitioners (48%) were in the age group below 50. There were seven female and 51 male practitioners, suggesting that there were few female practitioners working in this area in India. There was only one practitioner from industry, which reflected the fact that during the study, there were few industries working in this area and, further, that most of the industries in India did not have their own R&D.

In our study, we have used a grounded theory approach. Grounded theory is a systematic qualitative research methodology in the social sciences emphasizing the generation of theory from data in the process of conducting research [24]. This approach provides a researcher tools with certain flexibility to conduct empirical research and develop concepts and categories to formulate theory. Moreover, given the fast emerging research area such as nanotechnoscience, it is difficult to decide if the existing theories are flexible enough to accommodate such cases or we need to reconsider some modifications in the existing theories. Hence, a grounded theory approach seemed appropriate.

The following questions stimulated initial discussion with the practitioners: Q (1) "What is your opinion regarding ethical issues related to nanotechnoscience?" Q (2) "Are you aware of any ethical issues related to

[1] https://scifinder.cas.org

nanotechnoscience?" However, in some cases, we did not ask the second question because some practitioners elaborated on specific ethical issues in response to the first question. In such cases we considered that those practitioners were aware of ethical issues. Since it was a qualitative study, the questions were open-ended in nature and the practitioners were encouraged to reflect upon as much as they could without any interruption. In this unique situation we also had time and opportunity to further probe and effectively interact with the practitioners during the interviews asking them to elaborate more on different ethical issues. This further provided us more clarity for analyses of our data. The interviews were tape recorded and later transcribed. After carefully going through the transcribed interviews, we inferred on a case-by-case basis if a practitioner was aware or was not aware of ethical issues related to nanotechnoscience. We used the following criteria in our analyses. When practitioners were ignorant about ethical issues we considered them as 'not aware'. We considered them as aware, when practitioners (i) mentioned some discussion over possible ill-effects of nanoparticles or cited literature on nanotoxicology, (ii) discussed about ethical issues in other science and technology and believed that those would translate over to nanotechnoscience, (iii) discussed about possibilities of ill-effects of nanoparticles at a later stage, (iv) believed that ethical issues arise when one deals with toxic nanoparticles, and (v) provided examples to demonstrate several types of ethical issues such as possible ill effects on environment and human, use as a weapon, hype, professional ethics, laboratory testing on animals, cyborgs, widening the gap between rich and poor, self-replication, and longevity of human life. In the following section we elaborate on these criteria. To protect the practitioners' confidentiality, we have not used names or other identifying factors with quotes throughout this paper.

Perceptions Among the Indian Practitioners

We inferred that 5% of the practitioners were not aware whereas 95% of the practitioners were aware of ethical issues related to nanotechnoscience (see Fig. 1).

Twenty percent of the practitioners were aware of the concerns regarding possible ill-effects of nanoparticles, and thus associated ethical issues, still they contended that there was nothing unethical in pursuing nanotechnoscience (which we call "aware but unconvinced"). This category is qualitatively different from the "not aware" category because in "not aware" category practitioners had no knowledge about ethical issues whereas practitioners in "aware but unconvinced" category were aware of references citing possible ill-effects of nanoparticles. When probed further, the practitioners in "aware but unconvinced" category dismissed the validity of discussion or literature on possible ill-effects of nanoparticles. Therefore, we considered them under "aware but unconvinced" category. A further 9% said that ethical issues in nanotechnoscience were like that of any other technology ("aware but nothing new"). In this category, the practitioners were aware of several ethical issues that could exist in any science and technology, and believed that those ethical issues would translate over to nanotechnoscience too. However, they did not identify any unique ethical issues existing in the area of nanotechnoscience. Therefore, we considered practitioners in this category as aware yet they were not assigning unique ethical issues to nanotechnoscience. Six percent of the practitioners said ethical issues were thus far unknown ("aware but unknown") and thought that some ethical issues might appear later as the research area was still evolving. We considered practitioners in this category as aware of ethical issues since they were discussing about these and were predicting the possible emergence of ethical issues in the near future. Further, 5% of the practitioners said ethical issues could be handled ("aware but under control"). Practitioners in this category mostly talked about the ill-effects of nanoparticles and thought that handling those nanoparticles would be unethical, but thought those could be taken care of. Finally, 60% of the practitioners identified several types of ethical issues exclusively related to nanotechnoscience ("aware and knowledgeable"). Practitioners in this category provided several examples of what they considered as unique ethical issues associated with nanotechnoscience. Therefore, we considered them as aware and knowledgeable about ethical issues.

Below we elaborate on these categorizations, offering quotes to illustrate the perceptions of the practitioners representing each group. We did not encounter any case in our study where there were overlaps between categories.

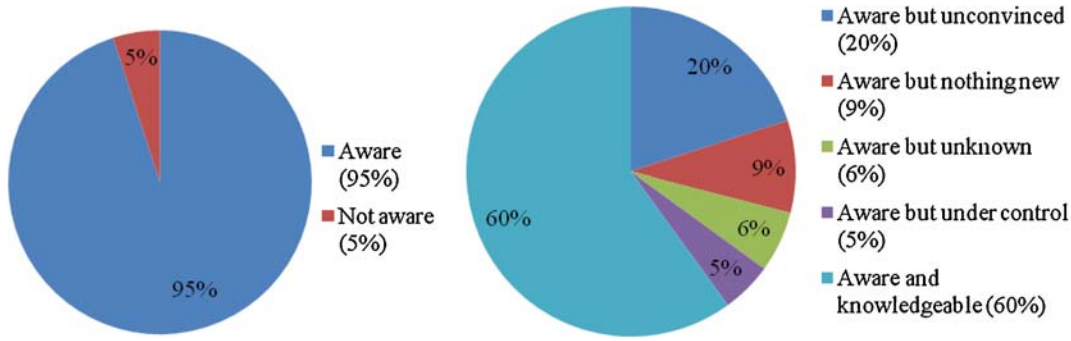

Fig. 1 Percentage of practitioners aware and not aware of ethical issues related to nanotechnoscience. To the right, the figure shows the expanded version of the 95% who were aware

Not Aware (5%)

Practitioners in this category were not aware of any ethical issues related to nanotechnoscience and could not reflect further on it. According to a practitioner, ".....I do not know about any ethical issues in nano [nanotechnoscience]." This quote further explains the ignorance of the practitioner about ethical issues in nanotechnoscience. Practitioners in this category, in response to Q (2), said that they were not aware of any ethical issues and when probed further, they could not reflect much on these issues. In some instances the practitioners even asked us to explain them about possible ethical issues. Therefore, we inferred that practitioners in this category were not aware of ethical issues associated with nanotechnoscience.

Aware but Unconvinced (20%)

Practitioners in this category were aware that there were several discussion about ethical issues arising out of ill-effects of nanoparticles but did not believe that there were any ethical issues. In the words of a practitioner:

> .....Unethical, nothing is there. Have you seen anytime any technology unethical? New concept, new idea, new science, nothing is unethical. These ill-effects of nanoparticles are a western propaganda to discourage our research. When American scientists and funding agencies are pouring money like water then make sure it has a very big promise.....

The above statement indicates that the practitioner was aware of the discussion over possible ill-effects of nanoparticles but believed that it was untrue and resulting from competing interests. The practitioner also thought that ill-effects of nanoparticles were largely discussed by western countries to discourage 'their' research. "Aware but unconvinced" category represents practitioners who, although being aware of the discussion about ill effects of nanoparticles, did not accept it. In response to Q (1), the practitioners started defending by citing several examples of articles published in the area of nanotoxicology. These responses suggested that the practitioners were aware of resources yet at the same time, dismissed these findings as not credible and as propaganda. They were aware of discussion over ethical issues arising out of possible ill-effects of nanoparticles but thought that there was no ethical issue in the area of nanotechnoscience. The practitioners in this category were unconvinced that anybody working in the area of nanotechnoscience should be, at least, concerned about the possible ill effects of nanoparticles.

Aware but Nothing New (9%)

Practitioners in this category thought that ethical issues involved with nanotechnoscience were like that of any other technology. In the words of one practitioner:

> As such, I don't think there are any specific ethical issues which are there only in nanotechnology. The[se] issues that are there in all aspects of science and technology are there in nanotechnology also. The kind of ethical issues that arise, for example, in biotechnology may translate over to nanotechnology.....

Practitioners in this category discussed about ethical issues in any science and technology and thought that it would apply to nanotechnoscience too. They did not, however, identify any unique ethical issues in nanotechnoscience.

Aware but Unknown (6%)

Practitioners in this category predicted that although, currently, there may not be any ethical issues arising out of ill-effects, the possibility of ill effects of nanoparticles at a later stage cannot be underappreciated. In the words of one practitioner, ".....So far, there are not many ill effects of nanoparticles. They are all decent materials. But this is an open-ended thing and you never know what will happen tomorrow....." In this category the practitioners thought that ethical issues arise when one has to deal with ill-effects of nanoparticles and possible ill-effects of nanoparticles may not be impossible in the near future.

Aware but Under Control (5%)

In this category, practitioners mostly considered the toxicity of nanoparticles as unethical to work with given the laboratory conditions in India; however, they believed that the ethical issues associated with toxic nanoparticles could be handled. As one practitioner stated, "One can handle the toxic effects of nanoparticles. Other than that I do not see any other ethical issues....."

Aware and Knowledgeable (60%)

By far, the largest category included practitioners who were aware and able to identify several types of ethical issues. In response to Q (1), practitioners in this category discussed about specific ethical issues, which they thought were unique to nanotechnoscience. These issues can broadly be arranged into 9 types. We recognize that these ethical issues could be rearranged into different types depending upon the structure of the study and the interpretation of the researcher associated with it. We reasonably think that in our study these ethical issues fall into 9 types, listed below.

1. *Possible ill effects on environment and human.* Practitioners in this category talked about possible ill-effects of nanoparticles on environment, and on human health both within and outside of the laboratory. Below we discuss the opinions of the practitioners providing quotes to illustrate their viewpoints.

   a. Possible ill effects on environment. Here, practitioners alluded to the potential environmental hazards of nanoparticles. According to a practitioner:

   > .....If we have nanoparticles, be as a drug or some industrial use, what is the impact? Suppose you are producing nanoparticles in a factory and there is a leak and the nanoparticles are released to the atmosphere. So, nobody knows how it will react.....

   Although the Bhopal gas tragedy occurred 25 years ago, Indians have not forgotten the massive havoc it created; the second half of the above quote reflects concerns of a similar tragedy.

   Other practitioners also mentioned concerns about nanomaterials having toxic effects. According to one practitioner, ".....Those who are working on semiconductor nanoselenium, they are [working on] toxic [materials]. That is why people are going for biopolymers. Synthetic polymers have environmental toxic effect....."

   b. Possible ill effects on human health and safety. Some of the practitioners mentioned the possibility of nanoparticles crossing the blood-brain barrier and affecting human health. According to one practitioner:

   > .....If you make use of nanotitania for cosmetics it gives your face some coloration and will stick and remain for a long time. But the danger is that nanoparticles through pores of skin can get inside the body and then you do not know how it will react to the body. Nanoparticles can cross blood-brain barrier and get into the brain. Similarly, since you have learnt from other [past] technologies, you should be more careful.....

   Others mentioned about research in nanomedicine exploring the possibilities of targeted drug delivery, as well as parallel studies examining the behavior of nanoparticles inside the human body. As one practitioner said:

   > .....The question is what happens to the nanoparticles inside the body after the drug has been

> delivered? The question is where would the particles go? Will they accumulate in the liver or kidney? Would they create cancer after accumulation? Many issues like this are still not known.....

Still other practitioners drew parallels between cement/asbestos particles and nanoparticles and thought that nanoparticles could be harmful. In words of one practitioner:

> .....Any nanomaterial, which is a particle, is a dust. For example, extremely small particle of cement is very harmful for human so also these particles [nanoparticles]. It has to be carefully handled, particularly toxic nanomaterials. Tellurium, selenium, arsenic and such nanomaterials can't be handled so easily.

In the past asbestos particles contributed towards the lung cancer known as mesothelioma [14]. The length of asbestos/cement particles fall in the range of nanoparticles and the quote mentioned above reflects similar concerns of possibility of nanoparticles being carcinogenic.

c. Unsafe laboratory conditions. Practitioners in this category were concerned about the laboratory safety measures where research on nanoparticles was carried out. According to one practitioner:

> .....One has to be very careful about nanoparticles in the laboratory. They are very small and very light too. You won't be able to see it, smell it and still they will enter into our systems. If you work with pure nanosize chromium oxide particles, you can have these particles floating around the environment and the experimentalist might inhale this in the laboratory and without knowledge it might go into his/her system.....

Another practitioner recounted a personal anecdote that underscores the previous combination of ethical and safety issues:

> .....I remember when I started working in this area many years back. I took some iron oxide nanocrystalline powder in my hand and I was rubbing it and I saw that it disappeared. So, my PhD supervisor said, "you know what you have done? It has gone inside your skin because the particle size is smaller than the pores of your skin".....

This particular case raises several ethical questions about the laboratory conditions in India. The practitioner, above, was not even wearing a pair of gloves while conducting experiments and, that is how, the nanoparticles entered into his body through the skin. One question is the extent to which this is an isolated case of poor safety measures in one laboratory or illustrative of a larger issue related to a lack of awareness of or attention to safety in the laboratory.

2. *Use as a weapon.* Practitioners in this category referred to the use of nanotechnoscience for destructive purposes as unethical. According to one practitioner:

> .....One thing which has bothered me sometimes is one can make use of this nano research for destructive purposes. I am thinking of it as a weapon system such that I develop a formulation of a nanomaterial and make sure that it is highly toxic which will bring out annihilation of a large body of people whether civilians or military personnel. All you have to do is go in an aircraft, put it in an enclosure and drop it, and this will be spread in the enemy territory without anybody realizing what is happening.....

The above statement alludes toward the growing use of nanotechnoscience in military research areas such as armor, biosensors, Hi-MEMS[2], surveillance, etc.

3. *Hype.* Several practitioners thought that there was too much exaggeration or hype about nanotechnoscience. They also thought that the hype was generating false hope of future employment. In the words of a practitioner:

[2] In the USA, the Defense Advanced Research Projects Agency (DARPA) has a 'Hybrid Insect- Micro- Electro- Mechanical Systems' (HI-MEMS) program, which aims to implant and place MEMS inside insects such as moths and beetles during the early stages of metamorphosis. That way, as the bugs mature, tissues grow around and fuse together with the nano machines. This is popularly known as 'cyborg insects'. The program is aimed to develop technology that provides more control over insect locomotion, just as saddles and horseshoes are needed for horse locomotion control. Due to the small size of anything related to nano, the issue of surveillance becomes imperative. This kind of project already exists and there bound to be ethical concerns if this technology falls in wrong hands. For further information on the project please visit http://www.darpa.mil/mto/programs/himems, accessed on August 10, 2009.

.....The problem is when there is too much of hype about a given area then many can take advantage of that. Sometimes people misguide, like starting nanotechnology B. Tech. [Bachelors in Technology degree] program and telling that you can get a job. Sometimes even peer groups in enthusiasm to propagate nanoscience and nanotechnology support [this idea].The fact is that, it is premature to have B. Tech. program in this area.....

4. *Professional ethics*. Ethical issues were also raised in regard to the professional research by practitioners inside the laboratory. According to one practitioner:

.....When one analyzes electron microscopy results, one can easily manipulate the results. The images that you get can be manipulated easily by changing the color or by highlighting the portion you want to emphasize. You can, at the same time, deliberately hide the portion of the results which you do not want to show. The reproducibility and repeatability are given short cuts.....

Plagiarism has been an age-old ethical issue that is present in every science and technology [5]. Even so, the practitioner, quoted above, reflected on how these issues were pertinent to nanotechnoscience since electron microscopes play an important role in this research.

5. *Laboratory testing on animals*. Laboratory testing on animals was perceived to be unethical by some practitioners. One may think that this type of ethical issue is not only unique to nanotechnoscience but is also present in other branches of science and technology that require laboratory testing on animals. However, practitioners in this category mentioned about laboratory testing on animals to be unethical in the context of nanotechnoscience research. According to a practitioner, "Clinical trials on animals are unethical....."

6. *Cyborgs*. Some practitioners drew our attention to an ethical question which is related to incorporating gadgets to human body and enhancing the capacity of human beings. In one of the practitioner's words:

.....There are certain ethical issues in nanotechnology when you talk about inanimate applications. For example, you talk about nano iPod. It is a manifestation of nanotechnology. But at the same time, it does not actively interfere with humans. But when it comes to the question of incorporating these gadgets to the human system, then I think the question of ethics takes a major role.....

Cyborgs (cybernetic organisms) are constitutive of partly human and partly machine. By combining living human and machine components there is a possibility of enhancing the capacity of 'normal' human beings. Enhancing the humanly capacity in this manner questions the definition of humanity itself [7]. Some ethical considerations in this case would be: How many body parts of a human being can be replaced by machines and still maintain the essence of human entity? When does something stop being treatment and starts being enhancement, and when does enhancement become unacceptable? Some practitioners claim that advances in nanotechnoscience are going to enhance the capacity of the 'normal' human being. Therefore, people who will have access to this technology will be able to enhance their capacity. A related ethical concern would be whether access to a particular technology will further create a gulf between people who have access to the technology and who do not have access to the technology. A similar ethical issue is discussed below.

7. *Widening the gap between rich and poor*. In this category practitioners thought this area is widening the gap between the rich and the poor. In a practitioner's words:

.....Anything to do with nanotechnology is very expensive. For that, you need high investments, which can only be done by multinational companies. In that sense, exploitation of nanotechnology for industrial gain will completely be dominated by big multinational companies. From that point of view, nanotechnology can be exploitative. Nanotechnology brings asymmetry in your economic structure.....

Another practitioner in this category said:

.....What is projected is that nanoscience and nanotechnology developments may increase the longevity of people, contribute to targeted drug delivery, etc. Those countries, which are rich,

are much ahead in this race of projections. Those who don't have resources will lag behind. There might be gap again.....

One of the questions concerning ethical issues related to nanotechnoscience is, will all sections in a society have equitable access to this technology? Some see the technology as a means of leveling the playing field to make all people equal. However, the history of technology shows that some technologies, instead of bridging the gap, widen the gap between the haves and have-nots within and across cultures. Even though advocates of nanotechnoscience claim that this will bring sweeping changes in the lives of human beings for the betterment of the society, still some of the practitioners perceived this as contributing towards creating asymmetry in one's country's economic structure.

8. *Self-replication.* Some practitioners mentioned the book *Prey* [2], which describes self-replicating nanoparticles gone wild. Although one practitioner recognized the possibility of self replication, he still considered *Prey* to be an extreme example. In a practitioner's words:

.....Can we use toxic nanoparticles and spray in the atmosphere? I think one should be concerned. The book *Prey* is an extreme example. Self-replicating comes, yes, this is evolution of a machine. We make machines; someday machines will self replicate.....

9. *Longevity of human life.* Practitioners in this category mentioned the longevity of human beings as an ethical issue. According to one practitioner:

.....Ethical questions come when some scientists speculate that this [nano] can make life eternal. But life will be very boring. In principle, it is possible. All cells in a human body must be cured as soon as any cell gets diseased. This is possible because you have the targeted drug delivery system, each and every cell which is diseased can be hit or removed.....

To summarize, we identified 9 types of ethical issues perceived by the Indian practitioners such as possible ill effects on environment and human; use as a weapon; hype; professional ethics; laboratory testing on animals; cyborgs; widening the gap between rich and poor; self-replication, and longevity of human life.

Conclusions

Nanotechnoscience, like any other knowledge and associated practices that were developed in the past, is getting shaped by scientific, technological, social, and economic forces. Although in India, research in the area of nanotechnoscience started about 20 years ago, there has been no significant study conducted in the area of social and ethical issues related to nanotechnoscience. With regard to the generalizability of our findings, it was beyond the scope of our study to determine whether these ethical issues apply to any technoscience in general or are unique to nanotechnoscience. Future research could examine this issue based on our study findings, where we identified 9 types of ethical issues. While presenting the results, we tried to draw comparisons to other fields when available. A connected question is whether these ethical issues are unique to India or present in other developing or developed countries. Issues like widening the gap between rich and poor, and unsafe laboratory conditions could be unique to a developing country like India, although similar concerns could arguably be raised in developed countries as well. That 95% of the practitioners in our sample were aware of the ethical issues related to nanotechnoscience suggests that the Indian practitioners in our study were very aware of the ethical issues. To our knowledge, there is a lack of any other qualitative study to directly compare our findings. Our study findings may offer opportunities for future cross-cultural research to know the cultural specificities contributing towards the high level of awareness among the Indian practitioners. Also more research in other technoscientific areas in both developed and developing countries could address some of these questions raised here.

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