Conversations with Nanotechnology Researchers

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What do individual researcher scientists and engineers believe about nanotechnology, their own research, and their role in the future which nanotechnology may bring? How might those beliefs and understandings, their unique perspectives and perceptions be embedded inside of the research itself? What types of beliefs are at work in their perceptions? In my research, these types of questions are considered, in the hopes of bringing into the public domain, the personal commitments and beliefs held by some of the very people on whom the nanotechnology initiative depends[1] . The intention has been to elicit their ideas and concerns, beliefs, fears and motivations, as those pertain to their work as researchers in nanoscale science and technology. The aim here is to help "disparately interested parties overcome their language differences in order to join in a common cause."[a]

My studies follow these scientists over a period of five years, as they move deeper into their own abilities and understandings, and as they make more discoveries, broaden their collaborations and facilitate the development of new technologies. The participants are principal investigators who are conducting nanoscaled research in their own laboratories, at universities across the United States. They and their institutions' names are held in anonymity.

Originally, 50 individual researchers were asked to participate. Thirty five said, 'yes,' and met with me once. Twenty three have met with me twice, and I anticipate that by the time of this writing, eighteen of those will have completed or were scheduled for a third conversation, and one will have had a fourth. It could be argued that the group of twenty three continuing participants is a self-select group. It is likely that those who continue to make themselves available for these discussions probably have a genuine interest in reflecting on the meaning and ethics of their work in nanotechnology. They may have been predisposed to participate.

I began meeting with researchers for this study in the summer of 2002. The interviews last an average of 1 to 1.5 hours. On occasion, the researcher is happy to continue, but most have very demanding schedules and are pressed to give even one hour of their time. On large part, this work is intuitive, on my part. My hope has been to evolve a theory of how particular values and themes comprise the structural framework for meaning-making and beliefs about nanotechnology. My intuitive approach to the conversations, and my interpretations of them, closely resemble the evolving Grounded Theory approaches of Glaser and Strauss. Using the methodology of Grounded Theory, (which refers to theory that is developed inductively from a corpus of data; in this case, the conversations themselves) I can take a discourse oriented perspective which assumes that variables interact in complex ways. Grounded theorists are concerned with or largely influenced by emic understandings of the world, using categories drawn from respondents themselves, toward making implicit belief systems explicit.[b]

From my perspective, the relationships have become more trusting and open with each subsequent interview, which means that the researchers and I are likely adapting to one another in ways which may be altering the types of questions asked, and the types of answers given. Nevertheless, there is valuable data in the interviews, in that the language used and stories told belong uniquely to the researchers. Although there may be some self-conscious maneuvering on both my part and that of the individual scientist or engineer to provide what we believe is expected of one another, there is ample evidence to suggest that honesty pervades these discussions. There is another feature worth noting. That is, changes seem to be taking place. I have been changing as a researcher who was initially somewhat skeptical about the research scientist or engineer's commitment to consider ethics as it pertains to their work. (I now perceive a consistent and genuine concern on the part of most of those I have spoken with.) Some of the researchers I am working with seem to be changing as well. In the beginning they were participating out of politeness, and answering my questions guardedly. Now, most are coming across as personally engaged and interested in these discussions. Perhaps in the end, personal growth for all of us will be an unanticipated consequence of this basic research project.

As an example of what kinds of ideas emerge, here is an excerpt from one conversation:

Russell

ROSALYN: Alright, assuming a divine order or intelligence in the universe, is there a connection between that intelligence, and our increasing capacity to manipulate and control the material world, and where we seem to be going with it? If there is one, that's what I want to talk about today.
RUSSELL: OK.
ROSALYN: I am searching for a reason for this madness, whether it has to do with the convergence of these technologies that are emerging and what that might mean in terms of a radical reconstruction of humanity. That gives me pause to ask, OK is there something cosmologically connected to what we're doing?
RUSSELL: That's a very large question. I told you I read Prey this summer.
ROSALYN: Yes, you did.
RUSSELL: And I guess for the first time I would say I understood why it is that some thoughtful people might look at the possibilities of nanoscience and say 'thanks but no thanks' and it has to do with this convergence of bio and nano and info in the creation of self-adapting mechanisms.
ROSALYN: Right.
RUSSELL: But also with the possibility of self-adapting mechanisms that are freed from one of the very important constraints of evolution in the historic past as in the long past. That is, as you discover in reading the book, the problem is there are no natural enemies to this system that has been created and therefore there is no check or balance on what evolves from this and if the creators of the system do not have, or by some means lose their sense of direction about what it is they want to have happen, then you have this situation that… I think in my very first conversation with you I mentioned this sentence from Hannah Arendt's, On Human Condition that has stuck

with me. "Then we become thoughtless creatures at the mercy of every gadget that is technologically possible no matter how murderous it is." In that sense, nanoscience is no different from atomic weapons technology, for example, but it is more dangerous. I think it's potentially more dangerous. I worry about it in the sense that I happen myself to believe that there is an order in the universe and that there are certain things that are natural and appropriate and so on and there are other things that are not. I worry about the fact that the scientific community and especially in the live sciences part (and this is true at the intersection of nano and bio as well) is also inhabited by some people who may be among the most thorough going materialists and reductionists in the entire scientific community, and that's a worrisome prospect.

ROSALYN: I think that's in part where my question is coming from. OK, are you suggesting that there may be limits other than material limits to what we do with nanotechnology?

RUSSELL: There are two kinds of answers to that question I can think of. One is the question of whether or not the technologies themselves have the potential to do harm.

ROSALYN: Sure, sure.

RUSSELL: OK, and that clearly is wrong. But then there's also the question that Freeman Dyson has raised very articulately in recent years and that is, in the face of enormous needs that are far more basic than the issue of whether we can compress a computer to the size of a pinhead, are we justified in pushing ahead and spending lots and lots of money to do this in the hopes of creating economic benefits, perhaps technological benefits, when in fact, some of us who are working on this ought instead to be building houses in Paraguay, or . . .

ROSALYN: If we would we just get potable water to everyone on the planet.

RUSSELL: For example.

ROSALYN: Yes we could, so why don't we?

RUSSELL: We probably could. And, in fact, it is possible that nanoscience might well contribute to that. As you probably know, environmental issues like that are a major part of the Rice initiative in nanoscience.

ROSALYN: That's what I understand. .

RUSSELL: Perhaps if our focus is on things like that, then ultimately people will say yes, there is something more than just curiosity value or gadget value in what comes out of nanoscience.

ROSALYN: What I'm hearing is that fundamentally this is about curiosity and that there is great satisfaction in the hope that it could actually improve the quality of life.

RUSSELL: Yes.

ROSALYN: OK.

RUSSELL: That's fair.

ROSALYN: When I ask what are we really up to, and I would love to know, the answers are more varied than that. Do you think about this? In the larger scheme of things, what is it we're up to? Are scientists and engineers doing something for the whole of humanity? You serve a very specific role in terms of the human community. For those of you who are pursuing scientific knowledge and particularly the application of it to nanotechnology, what is that all about? Particularly in terms of that divine order that we have agreed exists?

RUSSELL: OK, I think if you ask that question in a university, you're likely to get a different answer than if you ask it in the Naval Research Laboratory or at a pharmaceutical research facility such as Merck, Sharpe, and Dohme.

ROSALYN: Sure.

RUSSELL: All those places have nanoscience efforts going on.

ROSALYN: Merck is a for-profit pharmaceutical, we know what they're doing. They are doing basic research to bring new drugs onto the market which will increase shareholder value.

RUSSELL: The executive from Merck next to whom I rode on an airplane recently said that they weren't always attentive to increasing shareholder value in the long run. He felt that in some

cases they had neglected basic research over the last four or five years, increasing shareholder value in the short run but leaving the company in a weaker situation in the long term.
ROSALYN: Hum.
RUSSELL: Be that as it may, in a university I think the situation is a little different in the following sense. At least in the physics department we are relatively remote from interest in applications, the focus is on trying. In nanoscience I see as one very interesting aspect of the whole question of can we learn to understand very complicated material systems better than we presently do and nanoscale objects, especially as we learn how to fabricate them, give us an opportunity to ask those questions in a way that we never could before and to isolate features of complex behavior that we could not understand before. The long-term view of that and my belief as a researcher, whether with undergraduate or graduate students, is that my contribution to the world revolves less around whatever specific things I am doing at any given time and much more around my capacity, my opportunity to interact with very bright young people and train them in the art of solving complicated problems while learning a certain set of skills, which they apply. That capacity in some sense adds to the store of human potential that is available for solving problems. Some of my students are in the academic world, some of them are in the industrial world, some of them are at national laboratories, so my hope is that they are carrying with them that sense of how to responsibly, creatively, effectively go about applying those skills that you learn in universities to the solution of other classes of problems. But there is nothing in that activity as I see it that relates explicitly to the ethical or moral dimensions of the question that you ask. I mean, the only way those things get developed in our group is through the informal interactions that we have with one another as individuals and not particularly as scientists.
ROSALYN: That's understandable. As I have remarked to others, we bring ourselves with us to work. In one conversation I asked, 'Was it necessary to check your belief system at the door?' And the response was in effect 'yes,' because there is not room for those questions in science. They just don't have any relevancy in science, which is about discovery, and learning, so.
RUSSELL: Yes, but if you, if you water at a public trough as we do, in terms of where our funding comes from.
ROSALYN: Yes?
RUSSELL: Then it seems to me that implicitly if not explicitly you cannot check your belief system at the door because you must have some sense of the value of what you are doing to the people who pay for it.
ROSALYN: If you take your water from the trough of the public, but inside you have a belief system where you take your water from the trough of God, then how does this work with nanoscience research?
RUSSELL: Well, in our faith tradition, there is a very strong concept of stewardship, of individual stewardship, not only over material sources, but over time, energy, and the sense that all of these things are, well in fact, this idea; this notion is generally referred to in our Church as the law of consecration and stewardship. The idea is that fundamentally everything that we have and are or can be is a gift from God and that we as stewards are obliged to both husband it carefully but also to recognize that life itself and all that we do in it, whether it is my work here or time spent with our children or whatever, is in some sense to be lived as a consecration and -- the way I put it is that my own personal view of myself is that there is no part of my life, at least to the extent that in my life's activities I am doing things that I know I should rather than things I know I shouldn't-- that all of that is part of this idea of a consecrated stewardship; whether it is involved with doing physics or listening to music or being with my wife or whatever. So for me, I don't feel the necessity for checking anything anywhere, it's all kind of a package.
ROSALYN: Now whether or not other scientists, nanoscientists, have that belief, would you say nanoscience is a gift from God?
RUSSELL: Yes, especially to the extent that it has the potential to relieve suffering, to make the world environmentally or ecologically a better place than what it has been or is now. If

nanoscience could, for example, rescue us from some of the pollution created by an industrial revolution which was too little animated by use of stewardship, for example, long-term responsibility, sure, and I think also pure curiosity has a place in that world. I don't think that the idea of stewardship is necessarily bound up entirely with utilitarianism.
ROSALYN: *Yes.*
RUSSELL: *You know, if Johannes Kepler could look at his planetary ellipses and believe that through this new geometry that he developed that he was getting a glimpse into the mind of God, then why not through nanoscience?*

Loosely following the approach of grounded theory, I have begun to identify some of the emergent categories inside of these interviews, and their properties. Although they are subject to change, currently there are 17 such categories.

<u>Emergent Categories and Properties of Analysis [c]</u>

I. Categories

1. Matters relating to reporting of research results
2. Matters relating to grant writing and other elements of gaining support
3. Personal responsibility
4. Political perspectives
5. Personal aspirations
6. Beliefs about science
7. Perceptions about nanotechnology generally
8. Conceptual blocks to ethics considerations
9. Ethics in nanotechnology generally
10. Personal values pertaining to nanotechnology research
11. Collaboration issues
12. Problems, concerns, and fears
13. Notions of failure and success
14. Issues pertaining to financial profit and personal fame in the profession
15. Pure science versus engineering or application
16. Future directions and applications of nanoscale science and research
17. The role of the government

II. Properties identified.

A few preliminary properties have been identified in most of the 17 categories. Those are as follows:

1. <u>Matters relating to reporting of results</u>

   All of the researchers I have formally interviewed are principal investigators. Some have spoken of there being a great deal of time pressure on them to report findings. They seem to feel that the time is too short to do so adequately, that too many interim reports are required, and that there are pressures to get results out prematurely. A few have found this process to be compromising to their work, but acknowledge its critical role in assuring their continued financial support. Other reporting pressure comes from the competition to get journal articles out quickly, and before others do. While laboratory work can take a great deal of time, and be difficult to control, they commonly feel that there are external, professional pressures to gain and hold high status. The way to do this, primarily, is to get results into the top journals first. High status, they say, brings the rewards of more grant money, which means larger labs with better and more equipment and more graduate students to do the work, which in turn means more work can be done to produce faster results. Unfortunately, this is a real challenge for the junior professors, except for the "hot shots" and to women, most of whom are junior professors.

2. Matters relating to grant writing and other elements of gaining support

A few have spoken cynically of nanotechnology as a way to get more money for what they were already doing before nanotechnology became "hot", but which was not recognized before the initiative came along. They feel that there is a language game that must be played to assure fundability of their projects, and they find themselves adapting their primary research questions to fit the goals of the nanotechnology initiative. Some, especially those who are senior level scholars at the top of their fields, and internationally recognized, express no such criticism. They speak optimistically and with enthusiasm about their prospects for new findings and particularly, for the creation of new processes, devices, and applications. The smaller group PI's have on occasion referred to the "big guys" with established nano centers as being the ones who "always" get the federal grants, as opposed to themselves, who they perceive are out of the "in" group of highly recognized and therefore politically attractive for funding.

3. Personal responsibility

Ever since a scientist got caught and widely popularized last year with falsified, published data, the subject of reporting integrity has come up regularly. Most expressed some empathy, and were anxious and nervous about what happened. They seemed to see themselves as vulnerable to the same mistake, given the enormity of the pressures they feel to compete for the place of "first" in reporting new findings in the literature. The issue of far reaching effects of what a scientist may learn from his or her work and its possible unintended consequences has also been a theme in these discussions. Almost without exception, the researcher says that they cannot be held responsible for what someone else does with the new knowledge they themselves gain and report. For example, I was asked, "Just because Einstein discovered $E=mc^2$, was he responsible for its application in the atom bomb?" Whenever we talk about what happens to the new knowledge they acquire, or the new devices and applications they contribute to, the researchers say that their only responsibility really is in accurate reporting. Otherwise, most feel, they would be immobilized. Another concern regularly expressed is over responsibility for graduate students. Nearly every researcher spoke of his or her graduate students as their primary focus. The sense they gave is that there is a family structure where the principal investigator functions in the parental role; teaching, guiding and caring for their student, while the students, much like children in a family become a source of personal pride, and carry the investigator's "name" out into the world. There is also some deep commitment to responsibility to the profession, or to science generally, in terms of the quality of research and adherence to the principles of the scientific method. Finally, because most of these researchers are receiving public money, the theme of responsibility to the public emerges periodically as well.

4. Political perspectives

A few senior researchers have talked about nanotechnology as a politically driven initiative. In those discussions, there have been concerns raised about the use of nanotechnology to increase power and wealth in the developed west, and particularly for a few already wealthy people. Health care issues are given as examples of politically motivated funding for nanotechnology; whereas one of the biggest sources of human suffering in the world is still malaria, cancer research gets priority because this hits most closely to home for the politicians who are making the funding decision. For those researchers who have concerns about this, there seems to be some frustration about putting their efforts and resources forward in these areas, as opposed to the areas they believe warrant greater social effort. They hope that there will be some trickle down effect from their work to the developing world, but they do not see the mechanisms for making it truly effective. International graduate students in the labs of PI's have also raised this issue. They feel badly that at home, people have no access to potable water, yet they are doing research here on technical questions pertaining to increased wealth for the developed world, such as how to beat Moore's law. Otherwise, most don't discuss politics at all.

5. Personal aspirations

When speaking about their personal aspirations, most of the researchers seek to make a change in our world, to have an impact on the people. Most of these changes deal with new ways of manipulating matter, which would provide us with new vaccines, new scientific tools, new consumer products, or new ways of living. One of the scientists quotes his friend, the inventor of the supermarket bar code reader, saying: "Every time I go to the grocery store, I feel like I did something important". This type of feeling and personal recognition appears to be what the researchers are truly aspiring toward. Peer recognition also seems to be of great importance. Most scientists and engineers in my group talk about the importance of being a leader in the field, of making a breakthrough, and of being recognized for their discoveries. A lot of the researchers project these goals onto their graduate students. In fact, while a considerable part of the researchers direct their team, some of them admits that their students do the core of the work, and that those are the ones who will make the breakthroughs. In the interviews, the researcher-student relationship is often portrayed as a parent–child relationship, in which the parent lives his dreams and aspirations through the success of his or her children.

6. Beliefs about science

My entire group agrees that science is a social good and that scientific research is a morally neutral enterprise. Most believe that the material world is out there, waiting to be discovered. In this context, science takes the form of a search-tool, devoid of human values, used to dig a way into the mysteries of the objective world. As a consequence, researchers believe that their discoveries are in themselves neutral, but they agree that the applications of these discoveries carry moral values. A lot of science and engineering examples are usually discussed, going from the invention of a hammer or a knife, to the invention of the atomic bomb. The consensus seems to be that you can use a hammer to hit a nail on the head, or you can use it to hit a person on the head. Hence, science is neutral, but its applications are double sided. In our conversations, the notions of progress, scientific advancement, and human progress, are often spoken of as synonymous. Indeed, most scientists will use these notions interchangeably. Science, being progress, is thus portrayed as an entity with its own specific direction and momentum, whose course we cannot and should not stop.

7. Perceptions about nanotechnology generally

There seem to be very distinct visions of nanoscale science and engineering research within the group I interviewed. First, a few researchers disagree with the fact that it is a field of its own. They argue that "it's just chemistry", or that all they do is material science, physics, or biology. Hence, there seems to be a belief that there is nothing truly different about nanotechnology, because nano is just the continuation and evolution of already existing fields. Who actually does nano and who doesn't is also a source of debate. While some scientists adhere to and enjoy the multidisciplinary aspect of nanotechnology research, others tend to separate their work from that of physicists, or material scientists, or biologists, or computer scientists. Eric Drexler, among others, is often placed into a completely different field of knowledge[3] . When referring to a particular aspect of the field, some researchers would reply "that's Drexler", or "that's physics", reflecting their belief that this isn't truly nanoscience. Hence, there are different degrees of belief in the existence of the nano field itself, and in the multidisciplinary aspect of this field also. On the other hand, when the researchers are asked to talk about their work, what they do, and what they invent, there is a unique element that comes up. Indeed, the discourse suggests another revolution in terms of economics, social implications, laws of physics and chemistry, and devices soon to be created. There are those researchers who do claim that the field instills never-before-seen collaboration between disciplines. Some researchers do claim, or at least do not deny, that there is something new about nanoscience. This leads to the conclusion that nanoscale science and technology is not really different in terms of the disciplines themselves, or the knowledge associated with it. Rather, nanoscience appears to be a revolution in terms of the collaborative research structure built around it, its incredible potential to alter our material experience, and the degree of control over natural elements (including ourselves) that it provides us with.

8. Conceptual blocks to ethics considerations

Almost all of the researchers are highly concerned with issues of ethics. This concern however, is accompanied by a feeling of powerlessness. As previously said, they see the danger of nanoscale science and technology in its applications, not in its discovery or in the conception of nano devices. Therefore, a few of them reject any obligation to make ethical decisions, often placing this responsibility on the shoulders of policy-makers. This separation between nanoscience and ethics becomes apparent in the interviews. For instance, when I ask a question about the technical side of the researcher's work, followed by a question regarding concerns about his or her work, a few researchers pause for an instant, and ask me "have you asked a philosophical question?" or "are we talking about ethics?" This clearly defines a line between the scientific nature of some of the researcher's work, and matters of ethics. Hence, the beliefs that their work is neutral, that they have no power over its applications, and that their work and ethics are two distinct fields, are the primary roadblocks to a careful consideration of ethics.

9. Ethics in nanotechnology generally

It is interesting to note that researchers do view nanoscale areas other than their own bearing a big ethical weight. For instance, when I ask biologists, chemical engineers, or material scientists what they think about the social and ethical implications of nanoscale computer engineers or physicists, they usually see a load of moral dilemmas that should be addressed. When asked about their work however, the computer engineer or the physicist would reply that, for instance, they are only working on the theoretical level, and that the real concerns are found in biochemical engineering. From this example, it seems clear that although they do spend a significant amount of time thinking about ethics and morality, the researchers have a really hard time viewing their own work as a source of ethical concern. Nevertheless, a very few researchers demark themselves from the rest in that they are deeply concerned about their personal work and its consequences. One of the researchers expressed how deeply affected she feels when hearing scientists publicly claim that they use stem cells for their research solely for the sake of science and personal curiosity. She acknowledges her responsibility to the public and affirms that she makes every effort to pursue worthy goals while employing ethical research methods.

10. Personal values pertaining to nanoscale research

A number of the researchers have spoken about their childhood-born interest in science and engineering. Most talk in terms of wanting to make a difference in the world, toward improving the quality of living, alleviating suffering, curing diseases, and the like. Others are frank about simply being curious. Every one means to be conscientious and to do what's right, but the most consistently expressed and deepest values pertain to the acquisition of new knowledge; the contributions each might be able to make to "the literature." This, beyond all else, seems to be the most significant value for the researchers. In a few cases, personal experience with tragedy, such as losing a loved one to cancer or suffering from it oneself, point to the value of human life. It is also expressed as a source of motivation, one that has largely determined the direction and purpose of the research.

11. Collaboration issues

Most are excited about the new opportunities offered through collaborations. No one has expressed any hesitation to collaborate. In fact, they often say that their work at the nanoscale could not be done without the help of people from other fields of expertise. Overall, they are both stimulated and challenged by having to learn and understand the technical language of fields of expertise outside of their own. While there is a real sense that collaborations are expected by such agencies as the NSF and DARPA, they are motivated by the apparent financial opportunities that collaborative efforts represent, and by the fact that their research is more likely to be successful when collaborated.

12. Problems, concerns, and fears

Most problems raised stem from the financial costs of running a laboratory, and the exceptionally high prices for equipment and supplies needed to do research at the nanoscale. Keeping graduate students funded is a related and very serious concern for those who are running relatively small labs on short term, soft money. Problems related to international graduate student visas are mounting. No one answered my question about what fears they might have. In fact, it was generally seen to be a strange question.

13. Failure, success, and the competitive race

In our conversations, scientists and engineers clearly express what it means for them to succeed or fail in their research efforts. For most of the researchers, success is associated with a breakthrough. One of the scientist mentions that just one true breakthrough in a lifetime would be enough to meet his notion of success. Recognition in the field is also an indication of achievement. This notion of success primarily based on making an impact in the world and obtaining recognition in the field parallels the researchers' aspirations mentioned previously. At the same time, scientists acknowledge that not everyone can be successful. One of the scientists believes that there are only about 3% of leaders in the field. The rest of the scientific and engineering community belongs in the remaining 97%. For that particular scientist, the notion of success means to be in this leading 3%. This idea is paraphrased in other interviews. Numerous researchers speak of nanotechnology research as being a race, in which one has to make a finding first. It is a very difficult race, in that the person who gets second place obtains very little credit. As a matter of fact, for some researchers, making it to the "finish line" late, or not making it to the finish line at all is what constitutes failure. Through these interviews, one can sense a strong, perhaps tacit, desire to compete against the rest of the research community, and to come out first. While most research teams are openly cooperative and multitalented, from a global perspective, these teams are competing in an arena with teams from all over the world. In other words, this pressure to "be the first to" suggests a mind war involving teams from all over the globe. While failure in the athletic world is represented by giving up, being weak, or arriving last, failure in the nano research world is to give up a research project, not come up with significant results, or being outdone by another research group. At least one of the researchers does believe however, that this competitive structure is beneficial. He, in fact, claims that this pressure to succeed brings more results in the scientific community. Moreover, he believes competition/imitation to be the finest form of admiration, and suggests that having several teams work on a specific research topic will help investigate all aspects ("holes") of the subject, and in doing so, will build a stronger foundation for science to move on.

14. Issues pertaining to financial profit and personal fame in the profession

Nearly everyone of the participating researchers has expressed a longing for professional recognition for their work. Most seem hopeful that their research will culminate in some product that will be taken up by a business venture of some sort. A few have started their own small development companies, or joined efforts with existing for-profit companies.

15. Pure science versus engineering or applied science

There is a distinctive difference between scientists who are working at the nanoscale, and the engineers, in the way they speak about the nature of their own research. At the same time, the theoretical, philosophical and practical divisions of science and engineering are blurred at the nanoscale of inquiry. While the scientists (physicists, chemists, bio-chemists, etc.) tend to speak about basic research and answering questions simply for reason of their own curiosity and contributing to the body of existing knowledge, the engineers (bio-medical, mechanical etc.) are very clear about wanting to get something to work in order to solve a specified problem. With an increasing focus on collaborations between formerly distinctive disciplines, and with the focus of nanoscience research on very specific nationally stated goals and objectives, the notion of pure science for science sake is somewhat obscured. With only a few exceptions, nearly all of them speak more in terms of tasks and problems than in terms of knowledge.

16. The Direction of Nanoscale Science and Technology

There is great hesitation on the part of most to answer the question of where nanotechnology is leading. Some feel that this cannot be known. Others feel ill equipped to think in those terms. A few, who are key public proponents of nanotechnology, are very clear about the possible applications of their own work and of nanoscience generally. All have been willing to project ten years out about their own research developments, but with caveats about the unpredictability of science research. Interestingly, when the subject of science fiction comes up, and the respondents are given the freedom to think fantastically and creatively without their ideas being judged, then they offer many possibilities about the futures of nanotechnology. But always, they qualify their statements.

17. The Role of the Government

There exists a conceptual and perceptual tension over whether the scientists serve the interest of the government, and private business, or some otherwise neutral, universal quest for knowledge. While there are those who adamantly defend their role as independent, others acknowledge the source of their financial support as inextricably linked to the determination of their academic freedoms.

The voices of researchers provide a critical vantage point from which to engage the conscientious process of setting nanotechnology development on an ethical course. If left to the random influences of corporate market incentives, institutional ingenuity, personal curiosity and national struggles for global dominance and economic power, the nanotechnology quest is likely to be indeterminate (vulnerable to an uncontrollable, boundless course of evolution). If public policy makers, industry leaders, politicians, venture capitalists, the lay public and laboratory based researchers will engage in an open, honest dialogue toward the negotiation and determination of nanotechnology's course of direction, then there is hope for humanitarian ends. This kind of dialectic has the powerful capacity to 'focus an otherwise indeterminate reality.' It can offer a critical means through which the social/cultural process of meaning–making about nanotechnology's influence on the future of our civilization might occur.

What is it that we, in various societies around the globe, might rightfully ask and expect of our researcher scientists and engineers regarding nanotechnology? To avoid any harm, which may come to humanity as a result of the knowledge we gain and the nanotechnology technologies we develop, while bringing forward envisioned improvements in our material existence? To take heed of the values that are implicitly a part of their technological designs, and to be more aware of the moral responsibility that comes with them? To avert any unintended consequences of nanotechnology which may adversely affect the public? Some research scientists and engineers respond to those expectations by placing moral responsibility for the outcomes of technological development squarely back on the public, and on its policy makers. It may be that because of the unknowable elements of nanotechnology development, the researcher has very particular obligations with regard to precautions and safety. Yet for the purposes of the ethical development of nanotechnology, where else might members of society look for leadership and responsibility? Who is in the position to provide ethical direction for its outcomes, to establish its directions, to articulate its purposes?

As experts, and by virtue of their training and capacity to reshape our world, research scientists and engineers do have a particularly high level of moral responsibility for the development of nanoscale science. But what power do they really have as individuals, what responsibility can they be assigned for the use, application and direction of nanoscale technology development? Perhaps they hold some, but none alone. Those responsibilities have to be shared widely, not just placed primarily in the laps of those who by training and cultural induction are in a position to foster and pursue the new discovery and understanding, which makes possible our continued evolution as an increasingly technological species. Nor should responsibility be given over to policy makers who may or may not be scientifically or technically trained, but who nevertheless write the laws which may or may not avoid or ameliorate the harmful consequences of nanotechnology development. And despite what some of the researchers themselves are saying there is no such willful entity or force as a "society" in which to place responsibility for the ethical and societal implications of nanotechnology. Technological society is a collection of individuals, not an entity unto itself. Science, which leads to technology, is a reflection of who we as individuals perceive and wish ourselves to be. The two are linked to our identity as individuals, families and communities, and intrinsic to our politics, beliefs and values formed through and in response to the narratives we weave.

My conversations have instilled in me an appreciation for the beauty of basic research toward the unknowns of discovery, and the intrigue of unanticipated application. They have also confirmed what I suspected; that while the unknowns of application are valued, the basic nanoscience researchers are pressured to focus on their applications, largely as a matter of practicality. Like the engineers who are by nature interested in solving practical problems, the scientists are caught in the emerging culture of nanotechnology which says, *make your work do something useful, soon, and more money will come to support your continued research.* Nanoscience and engineering present a number of nodes of ethical concern. Among them is the external pressure on research scientists and engineers to move as quickly as possible through basic research to marketable application. More highly valued by sponsors and investors than discovery for learning sake is the promise of potentially high returns on financial investments. The system of rewards makes that obvious. It seems to be especially true that in nanotechnology, "the pure scientists have become more detached from the mundane needs of humanity, and the applied scientists have become more attached to immediate profitability."[d] It would appear that under current conditions of the nanotechnology initiative, basic research for its own sake gets devalued, and applied science is artificially accelerated. This condition alone could stymie the critical reflection and deliberation over ethics, meanings and beliefs about nanotechnology, which is essential to its humanitarian development. Other than the scholars of such things, who has the time, really?

It would be especially wonderful if this project might lend some moral support to those research scientists and engineers, whose intent it is to contribute conscientiously to the ethical development of our nanotechnology future.

Works Cited

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3. Drexler, K.E., C. Peterson, and G. Pergamit, *Unbounding the Future : The Nanotechnology Revolution*. 1st Quill ed. 1991, New York: Quill. 304 p.
4. Dyson, F.J., , and *Imagined Worlds*. 1997, Cambridge, Mass.: Harvard University Press. 216 p.

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notes

[a] See 2. Fuller, S., *Philosophy, Rhetoric and the End of Knowledge*. 1993, Madison: The University of Wisconsin Press., for discussion on the role of rhetoric in Fuller's approach to the social epistemology of science.

[b] For further, detailed explanation see,*Introduction to Grounded Theory* by Steve Borgatti, available at http://www.analytictech.com/mb870/introtoGT.htm

[c] This section is taken verbatim from Appendix B, Nanotalk.

[d] 4. Dyson, F.J., , and *Imagined Worlds*. 1997, Cambridge, Mass.: Harvard University Press. 216 p., pg. 199

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