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A Joint Interview with Professor Joonhong Ahn and Professor Cathryn Carson on Nuclear Waste Management: a Technical and Social Problem

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Dr. Joonhong Ahn is a professor in the department of Nuclear Engineering and Dr. Cathryn Carson is an associate professor in the department of History at the University of California, Berkeley.

Professor Carson's interests in nuclear history and the relationship between scientists and non-scientists developed into a collaboration with Professor Ahn that led to the organization of an advanced summer school in social-scientific literacy. They have been working together to bridge the gap between society and engineers, a gap that was evident during the 2011 Fukushima-Daiichi nuclear disaster. In 2015, they published together, along with other experts of nuclear engineering and education, "*Reflections on the Fukushima Daiichi Nuclear Accident: Toward social-scientific literacy and engineering resilience*" depicting various accounts of what transpired in leading up to and in response to the event.

We got the opportunity to talk with both of them in a joint interview discussing topics ranging from technical aspects of nuclear waste and energy to the challenges surrounding the lack of communication between society and engineers.

Berkeley Scientific Journal: How did you involved in your field of research?

Professor Joonhong Ahn: I became interested in the field of radioactive waste management at the beginning of my career. I thought that nuclear power utilization was a crucial issue that needed further research in any country. Just like nuclear fusion, in the 1970s and the 1980s, people said that at the turn of the century we would solve this issue. I started my career around the 1980s, so I thought that would be the best topic for me to tackle because around the middle of my career I expected to see major accomplishments in this field! The issue of nuclear energy is socially very important and technically very challenging, so I thought, "Why not?" The turn of the century actually [happened to be the beginning] of [a lot of advances in the field] which was good for me as well!

Figure 1. Professor Joonhong Ahn teaches courses in radioactive waste management and the nuclear fuel cycle at Berkeley.

BSJ: You mentioned that you were interested in nuclear energy at the beginning of your career. How were you exposed to this field?

JA: I read a book for the general public about nuclear power utilization when I was in high school. I was fascinated by the fact that the nuclear waste issue was not solved or even considered at that time, so I knew that was what I wanted to pursue.

Professor Cathryn Carson: I didn't really get to know Professor Ahn until 2007-08. I was given a year off by the history department to sit in on courses in nuclear engineering as I had a long term history research project on the specialty of nuclear engineering waste management that Professor Ahn was working on. I was in a lot of his classes asking lots of non-technical questions because, for me, nuclear engineering was a perfect example of a problem that was both technical and social at the same time.

CC: I also found it wonderful to have a professor of nuclear engineering who understood where those questions were

coming from and why they mattered. I was supposed to be in there learning the technical stuff, which was useful to me as a historian of nuclear waste. However, it was just a pleasure to get to know Professor Ahn and realize that we could have a conversation across the disciplines on the basis of both a shared interest in his technical specialty and these larger societal questions of how nuclear power fits in in our future.

Figure 2. Professor Carson has been interested in a broad array of topics at the intersection of science, government, philosophy and history.

BSJ: How did you get started on your current collaboration?

CC: As a historian of science, I'm interested in how our thinking of problems can radically change. Back in the 1950s when nuclear waste first became an issue, people were thinking it was a simple problem and by the time I started getting interested, in around 2000, it was a much more complex problem. As a historian, I want to understand how that sense of what makes it complicated changed and getting to know what it looks like now is really important for that.

I can't recall how it was that Professor Ahn drew me into the University of Tokyo and Berkeley collaboration which led over several years to the summer schools he organized. It was just an amazing experience for me to work not just with nuclear engineers around Fukushima but with Professor Ahn, in particular, given the unique position he plays in that debate.

Figure 3. The tsunami from the March 2011 9.0 earthquake led to a nuclear meltdown at the Fukushima Nuclear Power Plant.

BSJ: After an accident like the Fukushima-Daiichi nuclear disaster, what do the societal aspects of recovery entail?

CC: Understanding that there are both technical and societal aspects is key. The effects on people are not just due to exposure from radiation but also from being evacuated from their homes. People died from evacuation, not just from the accident. The uprooting and the emotional upheaval from having their social network destroyed, having their relationships to their homes completely ripped out, being in a state of fear and dislocation for months at a time… All of those societal aspects are so important to understanding the Fukushima-Daiichi accident even though they don't get counted in casualties.

JA: The costs are enormous. Already $100 billion has been spent for the recovery and more money will be put into that region with the hope that the region will recover from the accident. However, before the accident the total GDP of the area was not very large. This has caused the public opinion to be split – "Why are we spending such a large amount of money for just that region? Even if they fully recover, the economic benefits will not be that great. So rather than trying to recover the same lives as before why don't we just relocate those people and let them start a different life?"

BSJ: What exactly was the time period for recovery?

JA: That's a good question, nobody knows yet. I think this is going to be long term damage, so we won't see an endpoint in the near future. For TEPCO (Tokyo Electric Power Company), it is very likely it will take more than half a century, at least, for the decommissioning of the damaged reactors. For people, there isn't enough time for them to fully recover. It depends on how you define recovery and

how you define damage. We'll have a workshop next week and some philosopher participating in that workshop submitted a paper to me where, interestingly, he said there is only damage when someone claims there is damage.

BSJ: From an engineering perspective, how would you counter a delayed response to a nuclear accident?

JA: A hundred thousand people are still evacuated from their homes and would like to go back. So, decisions have to be made as soon as possible. However, because of complex societal discussions compounded by some scientific uncertainties decisions simply couldn't be made in a timely manner.

BSJ: How can we measure the harmfulness of nuclear radiation to humans? How are different types of exposure considered in determining the malignance of nuclear radiation?

JA: If the radiation level is very high we can measure the effects very precisely, and there is very good regulation based on that measurement. If radiation levels are lower, more specifically 100 milli-Sieverts or lower, the effects are not so clear and the uncertainty becomes bigger. The uncertainty is so significant that you cannot draw a decisive relation between the amount of radiation you are exposed to and the negative effects it causes.

Currently there are various hypotheses. Some say that within a range of low radiation levels, there are actually positive effects on the human body. For example, you can invigorate cell activities which make you healthier than without radiation. Others say that the low dose range is the same as higher doses. Under this hypothesis, you can extrapolate the line established for a dose greater than 100 milli-Sieverts into the lower range and to zero. Some say it is more complicated, so it is a mistake to say the relationship is linear. We should also be aware that, in some regions, like India or Iran, the natural radiation levels are very high. Radiation levels in these regions can be 50-100 times higher than in the United States.

BSJ: What contributes to these high natural radiation levels?

JA: Naturally occurring radioactive materials, such as uranium in granite and potassium in salt. In fact, salt is the major contributor of natural radiation. People have been living in high radiation dose areas for many years. Many research organizations have been to those areas and conducted epidemiological studies and have not found any viable differences between populations from those areas and other reference populations. This serves as evidence for the idea that certain levels of radiation have low biological effects. Indeed, some researchers have claimed that this high natural radiation has some positive effects as well. It is an uncertain situation.

I do not think that problem will be solved purely scientifically because the lower the dose the more subtle the effects. In order to have a statistically decisive conclusion regarding the effects of low dose radiation you need a huge sample size; a statistically reliable sample size could be greater than the population of the world! Even though you know how to prove something scientifically, you cannot prove it practically. This is known as a trans-scientific problem. A problem can be defined scientifically but the solution requires more than just scientific knowledge. Maybe in the future molecular biologists will find a more mechanistic way and better modeling systems to approach this problem. Even so, we have many different factors affecting the low dose radiation effects.

BSJ: Back to the idea of responding to a nuclear disaster, the desire is for 'strategic prioritization', the ideal that there should be a threshold which should determine the action that you should take from a waste containment point of view. How exactly do you come up with this model and determine the thresholds?

JA: I think there are two sides. The first is the technological prioritization. Prioritization should be made to decrease the volume of waste to be generated from the decontamination activities. For the reduction of waste generation, technology is certainly very helpful, but it has to be applied in the right place and in the right way. That is what I meant by prioritization. Then, how do we know where is the right place to apply technology? That can be determined with the help of environmental sciences, i.e., how cesium migrates through the environment, and so on. For that, we already have some knowledge but it is not complete [and] we have to improve it.

The second is societal aspect. The social side should be described by Professor Carson! But what I see is that even if you have a technology, you cannot apply that technology if you do not have a public agreement. Often, the question of "right place" or even "right way" is answered societally. Right now it seems to me that the local people have not reached an agreement for whether this decontamination is necessary or which part should be done first.

BSJ: From a quantitative point of view, would you want a fixed definition of this threshold? Is this the right way of convincing other participants in the community?

JA: That is definitely part of the process. Without technology, there is no way of convincing people. But on the other hand, even if you have the technology and perfect

knowledge of cesium behavior, that's not enough.

CC: I want to underline this point so that you don't miss it. It's one of the most powerful things Professor Ahn has said to the nuclear engineering community. Having the engineering solution alone and trying to persuade the public of it is not the way forward. Understanding what the engineering options are is a part of it. But you need societal input, communication from society to engineering, not just from engineering to society. If you don't have listening on the part of engineers your solution is not going to work.

BSJ: In your chapter you define this situation as "socio-technical system"…

CC: A socio-technical system is a technology in its societal setting. You can't imagine a technology, such as radiation technology, without a society around it. That jargon doesn't work with engineers, but the concept is exactly what Professor Ahn is helping to articulate. Yes, you must have the technology, but if you want it to work you can't forget about the society around it.

BSJ: How did an accident like Fukushima Daiichi highlight the importance of work between both engineers and society?

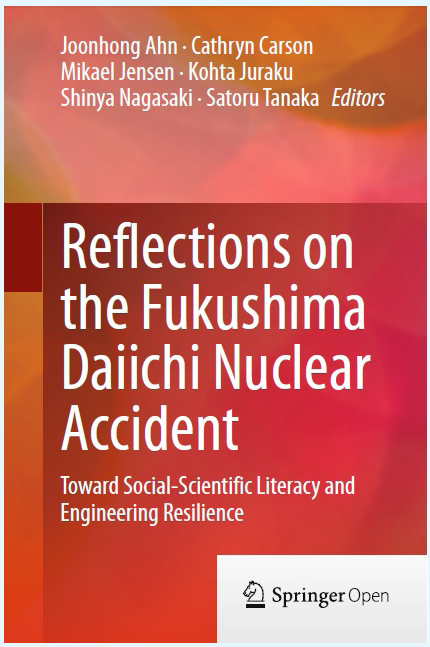

Figure 4. In the book (see introduction) that Professors Ahn and Carson co-edited, the importance of the idea of integrating social-scientific literacy in nuclear engineering education is highlighted in the post-Fukushima era.

JA: Nuclear engineers try to invent something interesting or powerful, and tend to realize it regardless of what society thinks about it. I think that the beginning the Manhattan project was like that. The nuclear bomb was so powerful that nobody would actually object to it, not at the time. So we tend to think that if we invent something we think to be good, it will be good for society and that should be realized.

I think that is applicable for the nuclear reactor. But for waste issues, this is no longer applicable. One technology can satisfy part of society, but not the rest. We need some mechanism to sense what the agreeable solution is. For other industries, I think the market has been the mechanism to know what is best accepted. However, the market doesn't really function like this for nuclear technology. But people are becoming more sensitive about impacts on themselves, and values are more diverse within society and across countries than before. We cannot simply select or impose one technology on the entire society. We need some mechanism to know what is most agreeable, and that is why solving this waste disposal issue has taken so long.

BSJ: You mention in your book that both social scientists and engineers feel powerless. What do you think leads to that sense of powerlessness in both groups?

CC: That's an interesting question. I think it's different for each case. It was amazing to me to realize that engineers felt powerless! I had always imagined that they were powerful, because they could invent and then impose technologies. At least that's how I saw it. It startled me to learn that they felt that there were so many societal obstacles to realizing what they thought was right. So the feeling of powerlessness for engineers is not knowing how to work with a society that doesn't behave like a bunch of engineers.

Society has other criteria, other forms of decision making which are very different from that of the engineering profession. So, in that case, the powerlessness is where society is complex. Engineering teaches you to make problems solvable, and many societal problems are not solvable like they are in engineering. For social scientists, the powerlessness is much more about the challenges for social scientists to offer clear solutions to anything explicitly and exactly because society is complex.

Social scientists often come in and say "This is too complex to solve', which is the exact opposite of what the engineers want to hear. Social scientists are very used to engineers telling them "Go away, you're not helpful." Social scientists and engineers can be like oil and water when you mix them.

BSJ: From what you've said it sounds like the two disciplines can't be reconciled because their mindsets are so fundamentally different. You did, however, attempt to bridge this gap. How did that turn out?

CC: They don't seem to be totally unbridgeable if you look empirically (*looking over to Professor Ahn*)! We don't think alike, but I think we've both moved a bit closer towards the other. It takes acknowledging, either as a social scientist or as an engineer, that your way of tackling a problem is not the only one and you may have to change. That's as hard for me as a social scientist as it is for the engineers that Professor Ahn works among.

I have to find a way to be helpful, because otherwise there is no partnership. If I just say "Oh no, can't do it that way!" that is not respectful of their expertise and it is not helpful in moving things forward. So, in my case, I've found my way to be helpful: not by proposing solutions but by listening, by educating, and by being there for students. I don't know how to solve the problems that Professor Ahn is tackling, but I do know how to help engineers get more clarity for themselves about the character of the problem.

BSJ: And Professor Ahn, how did you get closer to bridging the gaps with social scientists?

JA: : Let me give you two episodes. I had a very interesting discussion with one of the authors here, a Japanese sociologist. After the accident many sociologists wrote books about the accident, criticizing how silly nuclear engineers were. Particularly, some of them pointed out that the way the company managed the regulatory system was bad. In comparison, years ago a seismologist pointed out that there was a big earthquake there about 1000 years ago. The major difference is that the seismologist pointed out the fact before the accident happened, and sociologists pointed out theirs after the accident happened.

So you can criticize us, but why don't you do it before the accident happens so we can change! I could not get any clear answer from sociologists for that part… I'm not criticizing sociologists! I'm just pointing out the difference in how we consider the same things.

The second is related to rationality. We had a long discussion amongst students in the summer school about rationality. Nuclear engineering students have very clear and stiff ideas about what is rational. It is rational to have nuclear power in a country and continue it because it is good for reducing carbon dioxide emission, which is good for energy independence, etc. They have all kinds of reasons for why they think that nuclear power is very rational. They brought their idea of rationality to this discussion with non-nuclear engineering students, and immediately got an objection from other students. So we had a very interesting discussion. I think some nuclear engineering students started to think of rationality in a very different way than they had before the accident. I'm sure that is going to affect their design in the future which makes me optimistic.

BSJ: Outside of nuclear accidents, how do you think engineers get a better understanding of the social aspect of nuclear engineering, and how does that affect how they manage nuclear waste?

JA: I think this accident should affect the way we design everything. The reactor, the fuel, and the waste disposal. The paradigm for safety has been fundamentally questioned by this accident. Nuclear engineers have to consider the social aspects and the safety more fundamentally.

Traditionally, the nuclear safety has been established based on the concept of defense in depth with 5 levels of defense to protect people from negative consequences of accidents. Very simply, levels 1 to 4 are about hardcore nuclear engineering. So, if you do better in design, you can improve the defense at these four levels. But the 5th level is about mitigation, evacuation and recovery from the severe accident. And that is more fundamentally related to societal factors. But because we have a mindset that the nuclear accident would never happen by improving defense between levels 1 and 4, number 5 has been severely overlooked.

But now we have had at least 3 major accidents in the past! And very clearly, we will have accidents in the future. We just don't know the where and when. So, I think that we now have to address this level 5 defense very seriously. That is the integration of engineering and social sciences. While we don't know now what to do and how to do it, that's something we have to develop [very quickly and in the near future].

BSJ: How is waste from nuclear reactors typically created and then dealt with in a safe manner?

JA: Well, the nuclear waste is generated from various stages of nuclear power utilization. But 99% of radioactivity is included in the spent nuclear fuel after irradiation in the reactor. And for that, we have options of either reprocessing or not reprocessing, depending on how we utilize those irradiated fuels. At the end of utilization, we will have to make a final disposal to make sure that the future generations do not get any significant harm. That's the basic objective of having geological disposal. Negative harm includes radiological effects and also economic effects. If you just carry over the treatment and management to future generations, even though the future generations do not get any benefit from this nuclear power, they have to pay some cost to deal with it.

To avoid that situation, the idea of geological disposal was established. With the geological deposal, we think that the negative effects on human beings will be made negligible.

BSJ: What kind of timescales are we talking about in regards to these future generations?

JA: We are talking tens of thousands of years and even millions of years.

BSJ: So, they probably have to be quite deep?

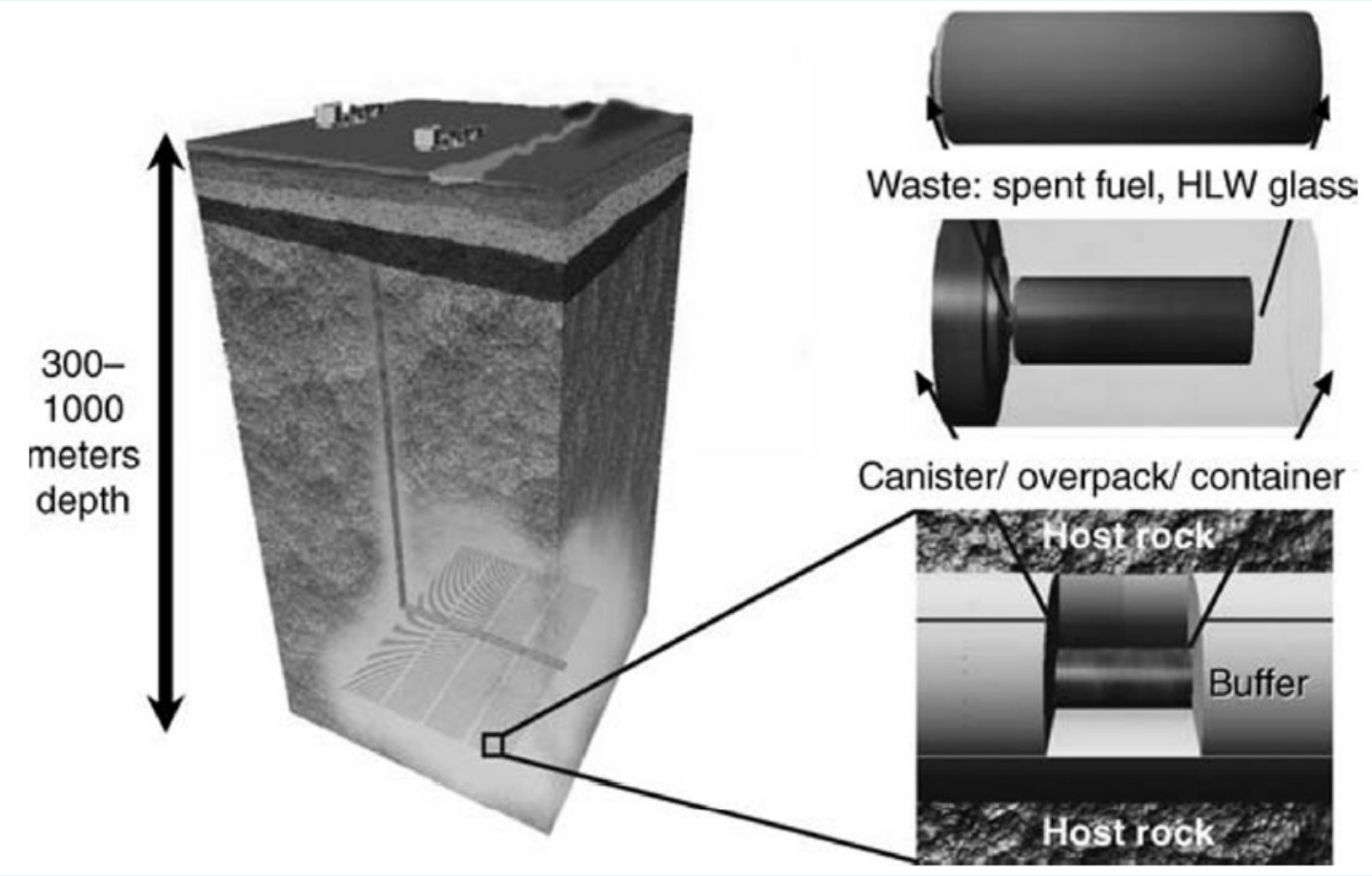

Figure 5. Illustration of a deep geological repository system consisting of various levels of barriers

JA: Yes, very deep! Many repository designs available adopt a depth of a few hundred to thousand meters.

BSJ: We read about the implementation of the Archimedes filter. What is the basic principle behind using this filter in nuclear reactors?

JA: The Archimedes filter was developed for the treatment of harmful wastes generated from the past weapons production activities. I like the idea very much… it is a separation process based on physical process and not chemical process! It's very interesting and probably very effective if it is applied in the right place and in the right application. I understand the DOE (Department of Energy) decided not to use it. The company was resolved some time ago, and the technology was transferred to some other company. So, some day in the future it would be utilized. [But] in principle, it is a very interesting idea!

BSJ: There's the idea that there are issues of establishing trust between nuclear engineers and the general public. What kind of steps have been taken to improve this trust and have they been effective? And what do you think can still be done to improve this situation?

JA: Nuclear engineers took traditionally the so-called 'Decide, Announce and Defend' (DAD) approach and it had been working but not anymore. Particularly, in the back-end fuel cycle issues. Some countries are trying to take into account more participatory processes. But, I've been wondering the following:

The processes taken in this country for the development of the Yucca Mountain Repository followed the due process. In a democratic society, if the President and Congress agree, then that's the reflection of public opinion! But it was turned around by a different President later on. So, democracy and addressing public opinion seems to be different. The decision process isn't just a political process. But more complicated. I don't know how different they are and why they are different.

BSJ: What do you think, then, can be taken towards this?

CC: I think there are two steps that can be worked on. One is, given that societal decision making is more complex that getting a political decision from the President or Congress and given that empirically having a law come out of Congress is not enough, the nuclear engineering profession needs to find ways to work with society that don't simply involve lobbying Congress and lobbying the executive branch. And that involves a different relationship

to the larger public. Whether that's a voting public or an opinion public.

So, that entails a mode of communication that is much less about, "We know the truth and you should accept it," and towards engaging in dialogue with the public. Now, that's very easy to say but hard to do in practice. But I think you have seen some shifts in that. Particularly, in the aftermath of the Fukushima-Daiichi accident. In part, Professor Ahn has done that by modelling a different way of engaging with the public: not just working within the political power structure but being available for public lectures and going to schools. And not simply saying, "I know the truth," but being open to conversation.

So that's one part of it, changing modes of behavior. The other is educating nuclear engineering students to realize that they are going to be working in a world where the problems are as much social as they are technical. It's in the nature of the technology. It is part of being a nuclear engineer post-Fukushima.

BSJ: What would you say is the role of the regulatory agencies for nuclear waste management both from the technical and social standpoint?

JA: I think the Nuclear Regulatory Commission of the United States has been doing a good job. It is not a matter of regulation. I think it is a matter of making decisions beyond regulation. Regulation gives a guarantee that this is a safe action. As far as those facilities are complying with those regulatory guidelines, the facilities are safe, meaning adding negligible impacts on public health. But once you know that it is a safe action, it's not a sufficient condition to start some project. You have to satisfy many other conditions. For example, there must be some clearly understood objective for achieving some project, and it seems to me that, for geological disposal, people don't have a good agreement or understanding about what they want to achieve through it.

BSJ: Education for engineers would helps them factor these social aspects into the implementations that they propose. But do you think that in terms computations like strategic prioritization, these aspects can be directly factored into these models that they have? Or is it more of the broader mindset?

CC: It's more of an attitude. It's less "Here's a piece to stick into your model" and more an attitude of "You want to be thinking about this" and "You will want to learn how to do that kind of thinking and engaging." It will be different in every case, but it has been really inspiring to watch how the graduate students who you have brought through this process have now realized that. Though there is no plug-in to the engineering solution, there is a set of behaviors and mindsets that they take away from it.

It's not disconnected from engineering ethics, it is a substantive form of engineering ethics. Engineering ethics that is not about checking off the requirement but actually about understanding yourself as a human actor with responsibility to the people you're serving. And that really is the educational transformation that can get worked here.

JA: So actually, after the accident, many Japanese universities tried to incorporate such social scientific aspects in their nuclear engineering programs. Several universities in Japan have gotten a lot of grants from the minister of education of the Japanese government to realize this goal. They have started comprehensive education programs for graduate students, including social sciences, multiple foreign languages, humanities, and philosophy, in addition to the core nuclear engineering curriculum. But without the attitude that Professor Carson mentioned, it can easily be very much formal and superficial. They can remain the same old nuclear engineers while coping with this on a superficial level.

BSJ: So, where do you see your individual and your collaborative research going in the future?

JA: That's exactly what we are trying to find in the workshop next week! We are trying to find research questions and a research plan. The ideas have emerged from the observations and discussions made in the book because if you read it, you may notice that all these questions are open-ended. No questions were answered in the book!

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