ROUNDTABLE DISCUSSION ABOUT SOCIALLY SENSITIVE ISSUES IN PHYSICS EDUCATION

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László Egyed: Some twenty or fifteen years ago, researchers at CERN looked around and said: "We have excellent instruments, but who will operate them, work on them in twenty years? Children are turning away from science, all around Europe, and without researchers, scientists, these instruments by themselves are useless!" So, they organized the first big conference called "Physics on Stage". I was so fortunate to participate in this event. They collected physics teachers from Europe to discuss and show each other, how they can teach physics in a more interesting way. This movement has expanded since, and became Science on Stage, an international science communication landmark, and David Featonby is one of the leaders of this movement. A conference is organized in this spirit every second year: teachers show each other, how science can be taught in a more exciting manner, how they can raise interest in science among their pupils. How can they make their talented students interested in a science career? And I think this is the most important socially sensitive issue nowadays: how to raise interest in science. How successful is this movement? Professor Featonby, have you experienced the increase of students in science?

David Featonby: I think this philosophy about enthusing teachers to enthuse the children, is very important. To comment on the beginning of your talk, to raise interest in students: we live in an interesting society. Society doesn't understand numbers. And that is a big problem. My wife is mathematician. We go to a party and people there are saying: I don't understand maths, I could never do maths. This is what I call *innumeracy,,* which can be experienced in lots of ways. For example, the ways in which people don't understand statistics, probability and so on.

On the other side of things, is that we don't balance views. If a hundred people think one thing and one person thinks another, we look at the television and that one person gets two minutes and the hundred people get two minutes. And so people don't understand the balance, don't understand the essence of things very much. They may think something is a problem when it isn't And therefore we get all this misunderstanding around us. For instance, when I am going home later this week, what is the most dangerous thing I will do? People probably think: getting on the airplane. That is probably the safest thing that I will do. The most dangerous thing will be crossing the road outside. This *innumeracy*, or lack of number sense comes back again and again. And we have to get over with the „I don't like, I can't do math" stand, before people get engaged with the real issues.

Now, coming back to your question: Science on Stage, is all about enthusing teachers to enthuse the children. That is one step towards making that difference. We particularly believe that encouraging giving enthusiastic teachers the opportunity to share with each other can

have a very significant impact. It's a massive issue right across Europe, where children are dropping out of the sciences. We do think that we have made some inroads in England and it seems that we could turn around the numbers taking science, not massively but I think the downward tendency has turned. This comes back to how society looks at things. When I was first married, every weekend I was fiddling with my car, and, if I wasn't mending the car, I was inside the washing machine, repairing it. Nowadays we have a black box society, very few people understand how anything works. If it doesn't work, throw it away and get a new one. This all links to this lack of real scientific understanding. And yet, when you can engage the children, when you can strike that light, when you can make them interested, you have hit the jackpot.! What a joy for us as teachers when a child's eyes, (or adult's eyes) light up the the glow of understanding. "Well, is that all it is! I can understand it.!" And people are genuinely surprised by the joy of learning. And that's the road we are trying to travel.

László Egyed: I must add that it is the goal of the manufacturers to turn things into black boxes – if anything goes wrong, you buy a new one.

Hannu, science centres are very important places to teach science to children and also to adults. You worked for Heureka, the Finnish Science Centre for decades.

Hannu Salmi: First of all, they are important, but are not the centre of the Earth or the centre of the Universe, or the centre of the society, so there are many inputs around them. But for sure, science centres have been developing into some kind of key players in public understanding of science and became forums of science. I think that maybe the most important thing is that they have been diminishing the false kind of negative emotional attitude towards science. But I think science centres are not so important for those already eager for science and want to engage in it, they come there, they enjoy it, they bring their own input, but an even more important role of science centres is to diminish this negative emotional attitude towards science, technology, research etc. In my opinion, it is false trying to direct young people to science, – young people choose their own directions. And the biggest mistake is if you give false promises to young people. You have to show reality.

Contrary to the UK, in Finland and in some other countries, the lack of people being interested in science and technology is not the main dilemma. Some people in technology should look into the mirror, I suppose. It was so easy to choose a career in science and technology, when I went to university in the seventies. The big thing is that still half, no, fifty one percent of the population is really a big resource for science. Ad now, to refer to this eternal gender issue, that there certainly is a lot to do in this field. And the point is how you make it somehow meaningful to work for something.

And there is this constantly growing impact of informal learning. Not as a drive to obtain more knowledge, but as an emotional quest. For example. when we made a survey with the participation of one thousand and one hundred students in all the faculties of the University of Helsinki, and we put a question: „How did you choose your career?" we received different answers. One reason they mentioned was social pressure: you do what your mother tells you, or your uncle is your role model, etc. Or you follow the course of your friends. Other people want to choose a profession for money. Then there are people who say: "I want to follow my interest and my spirit, I want to learn aesthetics and I don't go for a good job or a good salary. Though sometimes they go to work in a museum or become an art director and actually get a good salary in the end. These are the four alternatives in career choices, but the fifth one is an option that has becomes more and more important: informal learning. Not as a source of knowledge, but as some sort of a hobby, for entertainment. You can't find a veterinarian doctor who did not have a rabbit, or a pony, as a young girl or boy.

László Egyed: Well, let's speak about a really socially sensitive issue, nuclear power. Once I listened to a discussion about nuclear power with Nobel laureates, and at this session, Carlo Rubbia summarized the three points nuclear power plants should fulfil. First, there must be no connection between power generation and the manufacturing of nuclear weapons. Second, the laws of nature must exclude the probability of accidents, and third, the amount and the lifetime of nuclear waste must be reduced drastically.

Attila Aszódi: I think, Professor Rubbia is right, and these are key elements in the acceptance of nuclear energy. Let's start with the waste. The nuclear industry is a very special case. This is in fact the only industry which is collecting its waste, collecting, handling and treating and finally disposing of it. In nuclear industry the waste is in a much higher concentration, this is well understood but therefore we really need the facilities, and we have appropriate facilities. The issue is how the public, how members of society accept that we really do that. Finally we need some facilities for the final disposal. The amount of this waste is not that high, but because we do not distribute this waste into the environment, we need something for the final storage. I think Germany is a very… – I try to say it is a good example, but in fact it's a bad example of how the society could be turned against the final solution, and through that route make nuclear energy unacceptable for society. But there are lots of misunderstandings. Professor Featonby mentioned what a big issue it is for a lot of people to understand math, and I say, that understanding of probability is even more complicated. And nowadays this knowledge of probabilities would be extremely important because without them, the risk, the evaluation of the risk and the evaluation of probability the real decisions can't be made. I can't say how we can resolve this issue, because probability is one of the most complicated parts of math. But the lawmakers and the decision makers and maybe the wider public should understand much more about risks and probability.

David Featonby: Can I add something? One of my old pupils worked in the nuclear industry and his task would be an inquiry on a nuclear power station in England. And of course you are not allowed any lee way in the nuclear industry - you simply can't afford to have any accident. None at all. And then this former pupil got a job in the gas industry. "It's really great, David, he said, we are allowed nine deaths a year" The reason is that in the gas industry that (i.e 9 deaths) is acceptable for society. For nine deaths in the nuclear industry, there would be a shutting down of power stations. If coal was discovered tomorrow, that would be banned before the end of the week, because of the number of accidents occurring in the coal mining industry, not only in the mines but also the transport of it, etc. It comes back to this probability thing as well, and the sort of social understanding and misunderstanding. Nuclear industry is one of the safest industries in the world, the public perception of nuclear industry is that it is the most dangerous industry in the world. So that's why we got to inform people.

Attila Aszódi: But you know, the reason for this has been very well described by social scientists. As I mentioned at the end of my presentation, it is hard to love nuclear energy because it is complicated, and its risk perception is totally different.

László Egyed: Similarly as in the case of an airplane crash and a road crash.

Attila Aszódi: Exactly. It is very subjective, so if something happens in a nuclear power plant, it draws a lot of attention. The other factor is the way future generation will be influenced by this kind of difference. If you just look at the news of the last days, there was a terrible industrial accident in China, maybe more than one hundred death cases, but nobody is speaking about that any more. On the other hand, if you remember, the Fukushima accident, had been covered by the whole press for one and a half years, although it only caused two deaths, not more.

But please remember that it is described by social science why the perception is so different for different risks. Let me just shortly answer your other two questions. So I think especially for Hungary, but for other countries as well, nuclear weapons and nuclear power plants are well separated, I think for the developed world, nuclear bomb production, and nuclear industry are totally separated, so I do not see it as a big problem. And the third point that you mentioned is safety, and I think this is a field where nuclear industry has developed a lot. The nineties and the last decade have been used to develop the so-called generation 3+ and 3 reactors, which really have the safety features, applying passive safety solutions, so the robustness of the plants, the redundancy of the safety systems is much more developed than in the past. In the new constructions, safety level is at least two or three order of magnitude higher as compared to generation 2 reactors which are well accepted worldwide.

Hannu Salmi: Just a short comment. It is interesting that in Finland many people have been great supporters of nuclear energy for decades. They changed their minds during the last five years, for two reasons, which have nothing to do with the safety issue. First, one is that this Areva reactor that should have started yesterday is now seven years late … no ... they are not disclosing anything about a timetable anymore, so that other people can't say that you are late. It's the same thing why there are timetables of trains in Congo, not that you know when the train comes, but to know how late it is. So that is one issue: the new reactor is late. Seven years and four billion euros late. Even the biggest nuclear energy supporters can't say: well, I like this. I want to have more of this. And the second issue is that nuclear energy politics are increasingly out of the control of democratic decision making, and that has turned many people.

Attila Aszódi: I totally disagree. It's nice to have this comment on democracy but could you explain how democratic are the Kirchoff' laws? They are laws of physics. And the physics laws are not democratic because they are regulated by nature. I think you are right saying that politics is highly involved in the whole picture but it is not only a nuclear issue. It is a very big contradiction that the security of supply is the responsibility of the government, and you or others could think that the electricity system can be developed in a democratic way. Electricity supply security cannot be ensured if everybody does what he or she wants. The electricity system is much more complicated, and, as I explained in my presentation, there are different means needed in the system, to make it stable, and this a really big challenge. How politics can make it understandable for the public is another issue. But really hard decisions are needed not only today but also in the future. Related to your Finnish problem, I have to tell you that the delay of Areva in Olkiluoto 3, is a very good example of how Europe can lose a competence which has been a major competence in the past. Because of the low interest in physics, because of low interest of public in science, and because of the low development in the industry. So, if Areva and other European nuclear companies would have been able to construct nuclear power plants in the last 20 or 30 years, there would be no problem at all in Finland with Olkiluoto 3. This is fact.

László Egyed: In the ATOMKI, the Nuclear Research Institute in Debrecen, you are trying to bring nuclear physics closer to people, to make it "user-friendly".

Zsolt Fülöp: Well, we are acting even broader. If you go to a hospital, for a kind of health checkup, and you don't have your x-ray, you don't have your CT, you don't have your ultrasound, you don't have your NMR, and then you are complaining that you are not treated well. This is the basis when you enter the hospital, that you have this and this and this medical stuff. So I think, if we can just make people understand that physics and nuclear physics are present everywhere, and the one I mentioned is a real-life example, then you can change the world. You see, because for them, even for the kids, it is evident, that it is there. Mobile

phone, GPS, I don't want to list everything, but somehow you can always make the connection between physics, physics research, or high level research and those new things or, I wouldn't mention any new, absolutely useful and necessary things, which you would miss, if those weren't available. I think this is very important. Moreover, I think we should really emphasize this list.

And there is again, I would say, another big problem, that if you compare, let's say modern physics research, and let's say, mathematics research, and you go to a high school kid, if there is a smart kid, who actually learned some mathematics, for example number theory, you can quite easily explain what kind of big problems you can solve in number theory. Maybe he can't solve it, but he can understand it, and say, "Yes, this is a very interesting problem". But with the present high school physics curriculum, of course, you have to teach those knowledge elements that have been taught before, because if you taught them, you wouldn't have time to teach new things. And then I see a gap actually between the classic and modern curriculum content. If you want to explain modern physics to students, it's very difficult, because there is this gap. I suspect that in mathematics, this knowledge gap is not so huge, because you can teach the basics much more easily.

László Egyed: There is a lack of time at school.

Zsolt Fülöp: There is a lack of time. So what I do and say, probably nobody agrees and that's why when I am offered to go to a high school, to give a special class, for example, for students, I have two requests. Prerequisites, so to say. One: the teacher can't be there. If they ask me to give a talk to the kids, I don't want to have the teacher there, I want to talk to the class. As a teacher. And I don't want the teacher sitting next to me analysing what the kids are asking. Because the kids are afraid that they ask something stupid. And everything is frozen. And the second thing is, if I am invited, then I should have the right to two or three good marks for the kids if I think that they were so good. No wonder, I am not invited. But you understand that there is a big difference between a scientist – and this is the bottom line –, who does physics day by day and follows his science, and let's say the layman, even an interested layman, who can read many things, but because there is this information overload, it's very difficult to distinguish what is, how to say, "clear information", and what is "not so clear information". And I think this is the responsibility of the society to make this difference. But it is very very difficult, and I am not so sure if we can solve this problem

David Featonby: I always say to children that a hospital is just a physics lab with a few bodies. You look at the physics in a hospital and that's true. Unfortunately the doctors often do not understand physics. That's a different story, but when you ask how is this working, when they poke in something in you, they say: "oh, I don't know, it is just a black box". I recently had an operation under general anaesthetic, the operating theatre was full of interesting measuring devices, I was just beginning to find out what they all were when I fell asleep! But even the bed I was on when I came round was a masterful example of technology. But basically a hospital is a physics lab with bodies. I ask the students "Do you want to work in a physics lab with bodies, or in a physics lab without bodies?"

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László Egyed: The problem is, and this is true in the case of socially sensitive issues too, that science sometimes needs complicated explanations, which people do not understand, they

understand simple explanations of an antagonist of nuclear power better. For example, if I explain nuclear power, it is complicated, but if the opponents say: it is radiating – people understand it at once. How can you resolve this problem?

David Featonby: Can I just say that for us as science teachers, our teaching should be like peeling an onion for our students. And our skill is to know how far into the onion to go. One of my favourite topics is spinning tops. I can explain the behaviour of a spinning top by saying: this top has a pointed end, and that top has a round bottom. Ninety percent of the population is happy with this explanation as to why one top folds over and this one regains an upright position. But then for the remaining five percent I include an explanation about the centre of mass and centres of curvature,. And so on and so forth. To another few I will give a description using a right hand rule, you can explain with that, taking friction and couples into consideration. If we go too deep, we lose people. And that is the danger – my son has a PhD, the first chapter of his thesis was great, but after that I really didn't understand a great deal. So our skill as teachers is to get the right level that gives enough explanation to make informed decisions. We have to do that for politicians as well, if we talk science with politicians, we begin to peel the onion. (Maybe we don't have to peel too deeply!) We have to gently peel the onion for the general public too, so that we don't appear to be talking a foreign language whenever a scientific topic comes up. The skill is to get to the level that people are at, and go a little deeper. That's our skill as teachers, get to a student's level and then stretch just enough, but not to breaking point. And it's a challenge, but it applies to all sort of things. That's our business.

László Egyed: Professor Fülöp, what is you experience with explanations?

Zsolt Fülöp: A year ago I had a one hour radio program in the Catholic Radio, where there were three persons invited. I was there as a physicist, there was a priest, and there was the leader of the show, and we were discussing the Big Bang. And I survived. So I think you – whatever the circumstances are, you have to accommodate yourself, and always understand a bit of your audience. And if you do this, then I think you are on the right track. So you shouldn't hold a lecture, and go along with this regardless your audience, and that's why, for example, Attila Aszódi asked some questions from the audience. I also like this approach. Here, at least you know if there is a reflection and not just sleeping people there. I think it is very-very important.

Hannu Salmi: One of the biggest truths in pedagogy and education is that you can teach something to someone else only if you know it yourself. And you know something probably only if you can teach it to someone else. You experience it very often nowadays: for example, I have a problem with a computer, then I'm asking the helpdesk and he comes there and solves the problem: look, now. But if I ask: let me know how I should do it, then even this most skilful ICT expert realizes: he can't do it, he is just trying several things and now it was there. And this is I think also one of the dilemmas of public understanding of science, that there are so many examples of people doing something in a mystical and arrogant way and saying that this is so difficult to understand. And then there are the best examples like Carlo Rubbia or Hannu Miettinen, his right hand, or many other scientists who can really make complicated things understandable without making the mistake of making it too trivial, but showing it. Recently I have made this related to your topic the Boltzmann constant. How the molecular movement is related to the energy. So that warmth is not Celsius or Kelvin but it is energy. Here is this nitrogen molecule which moved there with a given speed, but here it moves faster, because here there is so much energy coming from all of us and warmed it. So one thing is that you must have the message and the other, equally important thing is that you should be able to tell it clearly.