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2.2 NUCLEAR PHYSICS TEACHING FOR JAPANESE TEACHERS FROM A HUNGARIAN PHYSICS TEACHER

with Love and Respect

Tóth Eszter

Lauder School and RAD Lauder Laboratory,
Budakeszi 48, Budapest, Hungary H-1121

ABSTRACT

I intend to give belief to science teachers living in an efficient society where entrance examinations and evening schools, making money and art of advertisement seems to be the emperor of the children's mind. If a nation does not want to import creative people from abroad, it will change the education any way. The changes should come from genuine teachers who work on the field, who meet the young people day by day. Nuclear literacy is only an example to show how we can catch the attention of the open minded young people. The teachers who love their students will find further possibilities.

1. LECTURES AND READING

At about 1980 the Hungarian physics teachers noticed that their students are not so interested in physics lessons as before. If the students were in a good term with their physics teachers they questioned them about semi-conductors or super-conductors, about molecular biology or nuclear power in break-time. And their questions were on *how these work, how they can be used* and not about the names of old and wise physicists having lived at the beginning of this century. That time the Hungarian Academy of Sciences initiated a movement to create a new science curriculum for schools. Then new school books were born. And new teaching methods begun to form.

One of the new chapters is nuclear physics. (The Japanese version of the Nuclear Physics text book was published by the Maruzen Co., Ltd., Tokyo in 1998 December in the excellent translation of Jumpei Ryu and Tae Ryu.) In this book nuclear physics is based on the binding energy of nuclei, or better: *on the changes of energy of nuclei*. In this structure nuclear physics consists of three main parts in the text book:

1. Experimental discovery of nuclei and neutron (Rutherford's, Chadwick's and other experiments, shown by computer simulation)
2. Droplet model for heavy nuclei (mapping the energy valley in the plot of energy per nucleon versus the number of neutrons and the number of protons)
3. Applications of the droplet model (radioactivity as "cooling" of nuclei, fusion, fission; natural and artificial radiation, health effects, reactors, power plants, bombs)

In Hungary this book is used in the last year of the high school which means about the 25% of the whole population. According to the last national curriculum (1996) a very simple version of nuclear physics and radiation protection have to be introduced to the whole population in the middle school before the age 16.

Problems (*in italics*, a possible solution in roman characters):

A good percentage of the older high school teachers, and all the middle school teachers missed the nuclear chapter of physics in their education. In the last 10-15 years many of the physics teachers went to voluntary postgraduate teacher training in nuclear physics courses because of the pressure of their students.

At the entrance examinations there are no questions about nuclear physics. In Hungary there are a few physics competitions where the first 10 students are accepted in universities without entrance exams. In the last year the Leo Szilard Competition on radiology was accepted also as one of these competitions.

Nuclear physics in the last year of the high school was too late, the students arrive with many ugly misconcepts about radioactivity learnt from newspapers and television. This is why the newest national curriculum brings nuclear physics earlier: to the age less than 16 years old and for the whole population.

2. SIMULATION AND EXPERIMENT

Nuclei don't age: their decay occurs as randomly as traffic accidents. Let ask the students of the whole class to stand up, then to throw a 10 Y coin every time when you clap! Those whose coin fall with the value facing upwards have to sit down. Let count the students standing after each clap! With this simple game you simulate the randomness of radioactive decays, in order to introduce the idea of half life time.

The computer offers many other possibilities for simulations, and not only for half life time but for the Rutherford's and the Chadwick's experiment, for the nuclear chain reactions, reactor or power plant simulations as computer games. These simulations can help to understand the non-visible phenomena, the experiments with expensive equipment.

But to understand something in a deep way means not only to be able to follow the logical steps of a proof leading to a conclusion. If you introduce everything via computers then your students will forget about the real world, nuclear physics may become a "virtual reality" (where everybody has at least three lives). In science one can understand something if one has one's own experiences. The teacher needs to offer experiments (not only computer simulation or video) for their students in the classroom. Here there are a few of the classroom experiments what is used in Hungary:

^{137}Cs is an artificial element on Earth, born in nuclear fission. It has a half life of 30 years, and by β decay it becomes ^{137}Ba. The ^{137}Ba is born usually in excited state, so it has to make a γ decay, with a half life time of 2.5 minutes. The Cs and

Ba can be separated by chemical solution. Many years ago East Germany produced a so called "school isotope generator": a porous ceramic pill absorbed ^{137}Cs on its inner surface was taken into a syringe. Thus the chemical solvent was able to wash out the Ba from the pill easily. The radioactivity of the solution containing ^{137}Ba can be measured by the simplest Geiger counter. Because of the short half life time, this experiment fits to lesson time.

From educational point of view it is important to show the students that radioactivity is a natural phenomenon. Putting six layers of ordinary medical gauze at the end of the tube of a vacuum cleaner one can collect the very small dust particles and small water droplets from the air in about 30 minutes. If there are any radioactive ions in the air they will stick to the dust. In this way, again with the simplest type of a Geiger counter, one can show the radioactivity of air in the school..

Even more simpler way to collect the radioactive ions from the air is by using a balloon. Blow a big balloon, rub it with hair to make it negatively charged, and hang the balloon not too far from the floor. (For better result use the ground level of the house.) Measure the clicks per minute by a Geiger counter before you blow up the balloon, this will be the background radiation. About a half an hour is enough to wait for the collection of radioactive ions from the air. Then let the air out of the balloon, and measure the clicks per minute again on the original sized surface of the balloon. (The surface was large when it collected the ions. Now, on the smaller surface there is higher density of radioactive material.)

In the last two cases one can also make a *measurement* and not only an observation of the presence of natural radioactivity. The radioactive ions in the air are coming from the decay of radon, the radioactive inert gas. Radon is everywhere on the Earth. After the decay of radon (^{222}Rn) radioactive polonium (^{218}Po), then radioactive lead (^{214}Pb), then radioactive bismuth (^{214}Bi), etc. are coming. The lead and the bismuth makes β and γ decays. This is why the simplest Geiger counter is able to detect them. The half life of the radioactivity of the dusty medical gauze or that of the balloon is about 40 minutes. (This comes from the 20 minutes half life of the ^{214}Pb and the 27 minutes half life of the ^{214}Bi.)

Problems:

Some teachers who were amazed by the computer possibilities tried to introduce "everything" by computer codes. - The only solution is to WAIT! Wait till the teacher realizes again that science is interesting because it can not leave away the real world. Most Hungarian teachers have already been cured from the disease of virtual reality.

*East Germany does not exist any more to create such an inexpensive school isotope generator (*60 *US Dollar that time). Thus only those schools are happy to use it which bought this* ^{137}Cs *source before* 1985 (*the half life of* ^{137}Cs *is* 30 years). B*ut other schools are poor to buy the expensive American or Japanese version of the same isotope generator.* - The radon is present everywhere, collecting the daughter elements by vacuum cleaner or charged balloon can solve this problem.

In the early 80-ies the Soviet Army was still present in Hungary. It was easy to buy from the soldiers (on the very black market) military Geiger tubes Bright young boys built up the electronics for these tubes creating very good Geiger counters. But the Soviet troops went out from Hungary ... These days some Ukrainian people bring relatively cheap Geiger counters from the Chernobyl region, selling them on the (not so) black market. In Japan the Geiger counter is not a problem, you can lend it from the State, each student could use them in the school or even at home.

3. EXPERIENCE AS EARLY AS POSSIBLE

When you teach your son to count, you use his fingers: "one, two, three, ..." You use his fingers although you do not explain at first to him that fingers are consisted of living cells, in those cells there are water molecules and DNA, and proteins... You use these fingers because they are at hand. When you teach your son to count, you do not stop at 2 and 3 and 5 explaining that they are primary numbers, even the concept of odd and even number is coming later when he is able to count routinely. The students know a lot of things about numbers before they learn number theory. We should not forget this practice when we want to make our pupils and students to be familiar with radioactivity.

With the help of a Geiger counter every pupil at the ages 10 to 14 can map the radioactivity in his or her environment. Where the Geiger counter is clicking faster, there is more radioactivity. They can observe the radiation of furniture, the swimming pool, the wall of the school, the soil in the garden, flowers, mushrooms or even their own body. If they find a granite wall they become excited and happy. (See also the experiments in the Fourth Elementary School in Nerima-ku, Tokyo).

In Hungary all the researchers thought there was no radon in homes at an unhealthy high level due to the geology of Hungary. Then in 1992 it turned out surprisingly that there was a small village in North Hungary where because of special geological reasons the indoor radon levels were high. The Hungarian School Network of Radon Survey started in that year. In that nice village, Mátraderecske, people did not understand why the white collar researchers were entering their homes and murmured not understandable words; the local people questioned them whether they were in danger or not, but it was in vain: there was no answer. Newspapers cried about the hell of radioactive homes in their village, about catastrophic situation but at the same time people did not sense anything special in their homes. Then I arrived to the village together with my students.

We went to the village school and we played together with the local students to make them experienced with Geiger counters. We talked about radioactivity, and about its health effect. The elementary school pupils became literate in radiation protection. They went home and they explained their parents what happened in the school. They asked their parents, grandparents, and other relatives, whether they could bring home small detectors (CR39) to know how high was the radon level in their bed rooms. In this way we were able to measure the radon in all the homes of the village. When the results came, together again with the local pupils we gave the results to the house owners. The pupils had to explain what was the meaning of 500 Bq/m^3, they had to speak about the meaning of yearly average, about the possible health effects. In the homes where the radon level was higher then 800 Bq/m^3, with the students we found out very cheap and effective mitigation methods after having consulted with the house owners.

In Mátraderecske our school laboratory (named RAD Lauder Lab) had learnt:

1. To make measurement at home (not only in physics lab) is a huge attraction for pupils.
2. It has became natural for pupils: radioactivity is everywhere, even in their bed rooms.
3. It is very important to let the house owners know the results in their home, with explanation at a mental level what they can follow.
4. The students were excited to learn as much as possible about the topics because they wanted to be well informed in front of their parents and relatives.
5. The pupils had to learn also how to communicate with people at different literacy levels and different attitudes towards the radioactivity.
6. We also learnt in Mátraderecske how to reduce the radon level where it is too high.

After the first two years of these lessons in Mátraderecske we have invited any other villages to take part in the radon survey. Up to now the RAD Lauder Lab - in co-operation with the local physics teachers and pupils - measured the radon level in more than 15 000 homes in Hungarian villages. This means also that about 15 000 Hungarian pupils learnt about natural radioactivity in the above mentioned direct way together with their parents. (Hungary is a small country, 10 million inhabitants, so 15 000 pupils are many.)

Problems:

Money for the detectors. If you want to make similar radon measurement in Japan one (only one!) detector costs (together with the evaluation done in USA) 60 US $. In Hungary it is much cheaper. I buy the CR39 track detectors from United Kingdom for 0.5 US$ each. We use a very simple box (0.07 US$) for container. We have learnt how to etch the detectors. My old students built up a tracks counter machine. They also wrote an excellent image analyzing program for IBM PC. One result costs less than 1 US$, including mailing, but not including the work made by the teachers and many pupils of the RAD Lauder Lab without any extra payment. To take part in the survey would costs about 2-300 US$ for each school, but up to now I were able to create money by finding sponsors, so to take part in the survey is free for any Hungarian school.

One could think that this is *only childish work*, but in each year we take part at the International Intercomparision of Radon Measurement organized by the National Radiation Protection Board, England, and our data turn out to be good. The students and pupils are generally much much reliable than the adults ...

4. RESEARCH

"One can not make fire if one does not bear the temperature of fire." If a teacher has never felt the smell of scientific research at least on a small scale, he/she would not be able to educate for scientific thinking.

When a village school gets the results of the radon levels of homes, the teacher and the pupils try to explain themselves the differences. Why there is higher radon level in one room than in the neighboring room? Why was the result larger in Autumn than in Spring? Last year Winter the radon level was lower than this year, WHY? And so on, there are many more questions for discovery because the indoor radon level depends on many parameters: geology, house structure, meteorology, the way of living, etc. Discussing these questions - even only in the short breaks - a good teacher can teach deeper scientific thinking than during the official lessons by slopes and pulleys, AC and DC. For pupils and students the unknown is the real challenge. Taking part in the radon survey they feel that there are no written answers to choose one of them, but *they are* themselves who have to make hypothesis what should be checked by their own experiments.

In the last seven years the RAD Lauder Lab measured the radon level in many homes, enough to ask the question whether there is any health effect of high radon level. We collected the cancer cases with the help of the local doctors, and identified the bed rooms of the patients 15-20 years before the cancer turned up. In the case of women (younger than 60 years, no smokers) we can state with a probability not less than 98% that between 100 Bq/m^3 and 170 Bq/m^3 the cancer incidence is less than at lower or at higher radon activity concentrations. (For your orientation: the Japanese radon average in homes is only 39 Bq/m^3!) It means that a few times higher radioactivity from indoor radon than the average would result lower cancer risk! This was published in the medical journal Pathology Oncology Research, London (the editors did not say it would be a childish work).

From time to time in human history teachers should think it over whether what they teach is important for the next generation or it is not. One thing is sure: if the students hate to take part in physics lessons then those lessons are not worth at all. As teachers we have to *respect* the way of thinking of our students, because they will create the *future*. When the students refuse our pedagogical tricks which we wish them to lead the conclusions what was discovered many years ago by scientists, and when the students say that the evening schools are better than our morning schools because those tell them The Good Answer for the entrance examinations, I am afraid, they are right. They want to survive the entrance exams! If you are not able to fight against those creativity killer exams, you should find something else which is more interesting for your students. As a physics teacher I think the reality is the most interesting for my students. The Hungarian experience in the School Network of Radon Survey shows us a way how to activate again the curiosity and the responsibility in our students.

Problems:

There are many problems left! But these are interesting challenges. And **the love for your students may help you every time to solve these problems.**