A special method of teaching Physics: Outdoors radioactivity measurements

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Abstract. We recognised that students can be motivated by those issues they are personally affected by. Such topic can be nuclear radiation that we live in. The realization led to the school project of radioactivity measurement. We joined the international Safecast projekt. Safecast is an outdoors radioactivity measurement project that represents a long-term and effective way of informal teaching of Physics outside classroom environment. We noticed a unique contradiction between the demand of developed nuclear technologies and the societal attitude declining these. After the disaster of Fukushima, people’s nuclear sense of security has decreased in a global extent. This model is a successful initiative worldwide for the restoration of trust. Results of the measurement can be viewed by people all around the world on Google Maps and they are incredible impressive. The implemented project is a decent combination of formal and informal learning, based on the model of research-based teaching. After our 1-year observation, we were able to encourage 20% of inactive students to participate in Safecast project – using an informal teaching style. In groups of 20 and 25, the sense of nuclear safety of members increased 18% and 22%.

1. Introduction

Nowadays we all live in the influence of the media (e.g.: TV, Internet, etc.). However this influence is not filtered either by ages or scientific and pseudo-scientific content. This task is entirely left for schools. A traditional school is forced to take a step. The role of informal learning is increasing in the modern societies. A good school should not only teach its students, but also educate its environment and the society. Besides spreading knowledge, schools have to cater for the need of acquiring, systemising and interpreting available information. We need to decrease the distance between formal and informal ways of teaching. This phenomenon is connected to the increasing effect of science and technology experienced in everyday life. Beyond these the problems of physics teaching nowadays in Hungary:

- The students are unmotivated.
- The concepts of the physics are complicated.
- The concepts demand a lot of abstractions.
- The students do not feel the usefulness these concepts in the everyday life.

What is the solution? A traditional school is forced to take a step. Physics teacher need to look for new methods. Let the student’s new cognition be a personal experience. There is a need for subjects’ specific concepts for the right understanding.

2. Concept and implementation in a Hungarian secondary school in Isaszeg

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More than a decade ago, we recognised that students can be motivated by those issues they are personally affected by. Such topic can be nuclear radiation that we live in. This topic has a lot of interdisciplinary connections - just as topics in environmental physics usually. The realization led to the school project of radioactivity measurement. Radioactivity and particle physics are parts of physics that are very abstract for pupils, partly because teachers usually cannot perform any experiment from these fields. Because of this, radioactivity is somewhat covered in a cloak of mystery and fear. There are, of course, successful attempts. [1] [2] The energy of the photons in the electromagnetic spectrum covers a wide scale. The spectrum has two parts: non-ionizing radiation and ionizing radiation. Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become ionized. The amount of energy of any type of ionizing radiation that to absorbed by the human body can cause harm to health. Ionizing radiation damages DNA independently of its source. In the project, the students measure the activity of the ionizing radiations and the dose equivalent inside (in the living) and outdoors. They inform they environment about the measured values and its effect. Cognition of the environmental radiation helps a lot in the creation of the right physical approach. Without accurate measurements we aren’t able to make clear statements. First (connected to other projects) we started the measurement with detectors that we have stationed in houses for 3 months and we measured the radon activity values. Figure 1 shows the solid-state detector used in the project. (Figure 1) It can be seen that the detector is glued to the top of the box and scales are also recognizable. Traces of alpha particles are only visible under the microscope. (Figure 2)

![Figure 1. Solid-state detectors with case](image1)

![Figure 2. The detector under microscope with trail of alpha particles](image2)

We went on with this for multiple years (con these detectors in 300 houses in a small town called Isaszeg. We could prove that the changing of the seasons can cause massive change in the activity values. In houses that are rarely ventilated, the radon concentration increases. Radon is a radioactive, colorless, odorless, tasteless noble gas, occurring naturally as the decay product of radium (of uranium). Radon is responsible for the majority of the mean public exposure to ionizing radiation. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as attics, and basements. Current estimates of the proportion of lung cancers attributable to radon range from 3 to 14%, depending on the average radon concentration in the country concerned and the calculation methods. The analyses indicate that the lung cancer risk increases proportionally with increasing radon exposure. Radon is the second cause of lung cancer after smoking. [3] The value that the EU Joint Research Center shared about the indoor radon activity is 100 Bq/m3. As you can see the value got higher in only a few cases in our town Isaszeg (Figure 3).
Figure 3. Results of 2004-2005 activity measurements

The maximum indoor activity value we measured was 375 Bq/m³. This lifestyle problem was caused by the lack of ventilation. In houses that are rarely ventilated, the radon concentration increases. By the placements of the detectors our students have encountered repulsive attitudes in lot of cases. Most people thought that the detectors are the radiation themselves. Our students couldn’t convince them about the opposite. In a few cases (against the prohibition) in lack of trust they tared the detectors apart. These detectors broke. Based on our experiences born our hypothesis: people are scared from radiation they deny nuclear technology and nuclear energy. We did attitude surveys in 2009 and 2018. In both years, we asked 400 people (between 28 and 54 settlements) about the acceptance of nuclear power and radiation.

We noticed a unique contradiction between the demand of developed nuclear technologies and the societal attitude declining these. (Figure 4, 5, 6 and 7)

Figure 4. Would you agree with the building of nuclear power plant in your region? Year 2018

Figure 5. Would you agree with the building of nuclear power plant in your region? Year 2009
Are you scared or worried about radiation in your environment? Year 2018

Are you scared or worried about radiation in your environment? Year 2009

It’s important, that our research wasn’t asking about the knowledge, it was all about the attitude. We made simple statements. With these statements the experienced attitudes can be explained

- Turning away from “knowledge” and natural sciences.
- The spreading of unoriginal sciences nowadays.
- The denial of nuclear technologies and power plants.
- People are uninformed

The questionnaire

Students’ research project: Monitoring the attitude about radiation and the usage of nuclear energy.

Town: Age:

Please choose the answer that stands closest to you!

1) Would you agree with the building of a power plant in your region? Yes/No
2) Would you agree with the building of a power plant in an African country and receiving electric energy from them? Yes/No
3) Would you agree with the building of a power plant and receiving energy from them? Yes/No
4) Are you scared or worried about radiation in your environment? Yes/No
5) What percentage does the power plant in Paks produces the country’s energy necessity? 10/40%
6) Would you build a house close to a microwave beacon? Yes/No
7) Did you know that you receive the most radiation while sleeping at home? Yes/No
8) Would you be scared from living close to a microwave beacon? Yes/No
9) Did you know that cows give more milk in static magnetic field? Yes/No
10) Are you using a cell phone? Yes/No
11) Should you limit your energy consumption if this way the power plant building could be avoided? Yes/No
12) Did you know that your cell phone is a microwave beacon? Yes/No
13) Did you ever used a magnetic feather-bed? Yes/No
14) Did you know that the sun will consume its resources within 1000 years? Yes/No
15) Would you agree with the decrease of the voltage to 10 V so the accidents could be avoided? Yes/No

Thank you for your cooperation!

Questions can be split in 3 groups:
I. Accepting nuclear energy (1; 2; 3; 5; 11)
II. Worry about radiation (4; 6; 8; 10)
III. Natural scientific culture (7; 9; 12; 13; 14; 15)
Table 1 shows the percentage distribution of ‘yes’ answers.

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|
| 2018 | 15% | 36% | 52% | 60% | 70% | 24% | 25% | 50% | 22% | 92% | 54% | 59% | 10% | 29% | 52% |
| 2009 | 20% | 33% | 40% | 74% | 67% | 20% | 34% | 53% | 29% | 89% | 57% | 63% | 26% | 38% | 45% |

The surveys (see Table 1) proved our hypothesis, most people (80% 2009, and 85% 2018) denies the power plant creation in built up area! A big percentage (40% 2009, and 52% 2018) would agree with the power plant creation in foreign countries and the energy transportation from there. Interesting, that more than the half of the candidates (57% 2009, and 54% 2018) are ready to sacrifice thing to avoid power plant building. 2/3 of the asked people average is worried about radiation. 1/3 of the asked people thinks that our sun will run out of resources within 1000 years. The half of the candidates says that we should lower at home the voltage to 10 V to avoid accidents!

There is abundant research indicating that models of the association between attitudes and behavior provide a framework for understanding. [4] In our everyday thinking process in most cases our emotional motivations are stronger than our knowledge. Attitudes are working in us as a combination of emotions and knowledge. Attitudes take the bearings on our everyday actions. Our surveys proved the hypothesis. It is problem that based on our attitudes people take confident statements in a total lack of knowledge. If people don’t have a positive attitude about something, then they will accept any negative statement without a doubt. These findings are clearly represented by our research. It is other problem that the value pedagogy of the measurements was decreased by the fact that half a year has passed between the settlement of the detectors and the evaluation. We did not have the opportunity of instant reference and feedback.

The solution of problem is outdoor radioactivity measurements in Safecat project. It's a Project Based Learning in Science – Technology – Engineering. The method: do-it-yourself. [5]

Safecast bGeigie Nano is a portable radiation detector equipped with a Geiger-Mueller tube type detector, built-in GPS and logging to microSD card. The bGeigie Nano is a solid-state, fully digital device. Because of its design, its performance is extremely consistent, and unlike devices with analog components that can be affected by temperature and other effects, further calibration is not expected to be necessary. The bGeigie Nano is available as a kit, so the user needs to learn how to solder in order to build it from the supplied parts. (Figure 8 and 9) [6]

It features the LND 7317 pancake Geiger-Mueller tube type detector, a GPS receiver and is expandable with a Bluetooth module. The mode switch offers choice between geotagged radiation logging (data saved to microSD card) and measuring without GPS - showing also Bq/m2 (Cs137) values. Inside the case the unit is calibrated for gamma radiation. The main unit taken out of its case will additionally do α- and β-detection for careful use as a surface contamination spot meter. This device is part of a global

Figure 8. This kit requires soldering.  
Figure 9. Building of bGeigie sensor
environmental sensor network enabling pupils to personally collect radiation and freely use and share the data collected. (Figure 10 and 11) One of the things that differentiate the Safecast bGeigie Nano from other Geiger counters, is that it takes extremely fast alpha readings which allows you to perform spot decontamination.

The main steps of execution of Safecast project in the school:
- Choosing a mentor (physics teacher, science teacher etc.).
- Building the mobile detector, with the soldering technique.
- Registration in the Safecast App. (https://api.safecast.org)
- Start measuring and uploading data them.
- Analysing the environmental radiation measurements.
- Finding of a new plan method, and execution.

The Safecast bGeigie Nano measures every 5 seconds and logs the time and location coordinates. The uploaded data can be viewed on a TileMap, https://safecast.org/tilemap/. (Figure 12 and 13)
The representation of the data is very illustrative on Google Maps. The blue trace indicates the normal radiation values. Red and yellow indicate dangerous values. See Fukushima.

Finally, the result of an interesting excursion in the Mátra Mountains. (Figure 14) It’s a mofette. An opening in the earth from which carbon dioxide and other gases (radon) leak, usually marking the final stage of volcanic activity. This is the result of volcanic aftermath. Depending on the mineral content of the various vapors, the mofette can be used for therapeutic purposes.

Figure 14. Extreme radiation values can be measured in the gas flowing out of the mofette.

The value of 3.377 µSv/h (1128 CPM) is thirty times the average Hungarian dose. The project can be linked to knowledge of other subjects. These can be geology, geography, etc.

Pedagogical advantages of Safecast project in the secondary school:

- In projects out of class even those students can be motivated who are passive in class.
- To discuss radiation we have barely enough time. This project is a good extension.
- Through the measurement experiences ionizing radiation becomes understandable for them. The usage of our own radiation data could be motivating in class. The attitude about radiation and nuclear technology can be led to a positive way.
- In the environment of the students they talk about the project with pleasure.
- The building of the detector is providing early knowledge in the frames of the Safecast Project.
- The students can suggest measurement on their own, they can make their own research plan and could execute them.
- The project can be combined with the students most loved hobby’s like cycling touring etc.

3. Assessment

After the disaster of Fukushima, people’s nuclear sense of security has decreased in a global extent. The model of Safecast is a successful initiative worldwide for the restoration of nuclear trust. Results of the measurement can be viewed by people all around the world on Google Maps and they are incredible impressive. (https://safecast.org/tilemap/) The implemented project is a decent combination of formal and informal learning, based on the model of research-based teaching. The more pupil that collect open and publicly accessible environmental data, the more all of us will be informed about public health risks that impact individuals, families and communities. Pedagogical goal is that environmental data should be open, easily accessible and easy to understand. After our 1-year observation, we were able to encourage 20% of inactive students to participate in Safecast project – using an informal teaching style. In groups of 20 and 25, the sense of nuclear safety of members increased 18% and 22%.

4. References

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