IMPLEMENTATION OF RADIOECOLOGICAL EDUCATION IN SECONDARY SCHOOL BY A "RADIATION AND MAN" ELECTIVE COURSE

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Introduction

We are contemporaries of global ecological problems, which are currently gaining more and more importance both in regional and international aspect. One of the widely discussed problems concerns environmental pollution by radioactive substances. This branch of ecology is called radioecology. In particular radioecology studies the migration of nuclides in the environment (*M*), the doses of radionuclides introduced into the human body (*D*), as well as the health effect (B_{eff}) , i.e. $RE = M + D + B_{eff}$ [1].

The growing significance of radioecology is due to three basic reasons: the development of nuclear energetics, the nuclear weapons experiments – one of the main sources of artificial environmental radiation, and the results of accidents at nuclear power plants, which lead to varying degree of contamination depending on the accident magnitude.

A substantial number of studies [2, 3, 5-7] carried out after the Chernobyl Accident shows that the level of radioecological awareness of Bulgaria's population is low. The formation of radioecological culture is a slow and tedious process. Like any other educational activity, it is based on up-to-date, illustrative and convincing information from the civil practice. The studies also show that in our country, despite the efforts of the Nuclear Regulatory Agency (NRA), there is no system that can guarantee synchronized actions of the different institutions specialized in the field.

Moreover, even at secondary school level there is neither enough scientific literature, nor visualization training aids necessary for the implementation of effective education of the students. The modern teaching organizational schemes are still not well accepted.

The paper presents the results of a didactic investigation within the period 1998-2000 carried out at the Chair of Chemistry Didactics at Sofia University "St. Kliment Ohridski" [4]. The results from a questionnaire concerning the implementation of radioecological education and awareness (REEA) distributed among the natural sciences (chemistry, physics, biology and geography) teachers revealed that:

- the natural sciences teachers are very competent, comprehensive and active towards radioecological problems;

However, they report also:

- insufficient radioecological information in the textbooks;
- lack of appropriate literature and didactic materials needed for teaching and topical discussions;
- an elective course was indicated as the suitable educational form.

Understanding the importance of the problem, a team from the Chair of Chemistry Didactics at Sofia University headed by Prof. Dr. Sc. K. Kostadinov and Assoc. Prof. Dr. L. Boyanova and supported by the Committee on the Use of Atomic Energy for Peaceful Purposes, currently called NRA, (acknowledged for their support) developed a project containing the educational requirements for radioecological education and awareness. Based on these requirements, a program of general character for a "Radiation and Man" elective course was proposed [5]. It may be adapted according to the particular conditions at the school, the students' interest and the teachers' qualification. The specificity of the elective training provides an opportunity for application of the "Radiation and Man" program as proposed, i.e. with 36 or 72 hours curriculum, or partially changed with respect to the needs, the motivation and the capacity of students and teachers; separate topics can be included in the students' lessons in physics, chemistry, biology, and geography; the course can be a subject of project-oriented education; seminars on specific topics can be organized, etc.

The proposed system, which includes a program, supplied with appropriate literature, visualization aids and control tools was approbated in three variants, as follows:

- Elective training;
- Presentation of seminars or discussion lessons;
- Inclusion of several topics in the existing physics educational section “From Atoms to Space”, which is enough to provide substantial radioecological information corresponding to the amount planned in the “Radiation and Man” educational program.

The current paper summarizes results from teaching of the elective course to secondary school students (10^{th} grade).

Main stages of the investigation

Planning

This stage included *nomination of schools and teachers* to participate, i.e. to organize and carry out an elective course in radioecology. Time schedule and classes were specified too. The schools were nominated according to the teachers’ qualification and motivation, as well as to their experience in teaching radioecological topics to students. The project was carried out at two secondary schools: “Vassil Levski” in Velingrad and “Yane Sandanski” in Sandanski. These schools were chosen mainly because of their location – outside the city of Sofia and far from the 30 km zone around the “Kozloduy” Nuclear Power Plant (NPP “Kozloduy”). The natural sciences teachers at these schools are acknowledged specialists who are interested in radioecological topics – an important issue in recent years. Some preliminary information indicated that the students had a certain interest in natural sciences. The radioecological lessons were part of an elective course in Chemistry. The project’s implementation started in the middle of the 2001/2002 school year’s second term and ended before the end of the term. The selected period was the best time for investigation, as it did not interrupt the regular educational process and the school year termination. The lessons took place at standard schooling time at the Chemistry laboratories. Thus the students were relieved from the tension of forthcoming lessons or after-school obligations (if the course had taken place after the compulsory lessons). Moreover, the Chemistry laboratory was a natural environment for the

teacher and the students. The place provided the appropriate working atmosphere, which had an additional psychological effect.

The program of the “Radiation and man” elective course consists of nine topics for standard lessons and one topic for a seminar lesson. The material was distributed within a nine weeks’ period, four lessons per week, thirty-six lessons in total.

The experiment was supported by the following specialists: Mrs Nadka Filipova, a Chemistry teacher at “Vassil Levki” secondary school, Velingrad, and Mrs Dineva, a Chemistry teacher at “Yane Sandanski” secondary school, Sandanski. They helped us in choosing the classes. Two graduate students from the Chair of Chemistry Didactics at Sofia University , Vera Dungova and Kalina Nakova, were part of the investigating team too. The teachers took the venture to participate in the project with great enthusiasm and helped us throughout the whole period, for which we are grateful to them.

Setup of the educational process

This stage of the investigation required setting up course contents, the forms of lessons organization and the methods and means of teaching.

- ***Specification of the contents of the “Radiation and man ” elective course***

The “Radiation and man” elective course is based on a program with the same title developed and approved by the Ministry of Education and Science [5]. For this purpose each of the program’s topics was subjected to detailed analysis. Considering the special features related to students’ age, the region they live in, and the teaching goals specified in the educational standards, the program was adapted for a course of 36 lessons at the 10^{th} grade. The planning of the course implementation required determination of students’ weekly workload. The schools governing authorities permitted the lessons to be scheduled as 4 lessons weekly in 9 weeks’ time. The topical sequence of the course and the results expected after each topic were defined too. These are presented in Table 1.

Table 1

№	Topic	Expected results
1.	*Structure of the atom and the atomic nucleus*	• explain atomic structure; describe basic characteristics of electron, proton and neutron; define nuclide, nucleon and isotope
2.	*Nuclear reactions*	• define nuclear reaction and chain nuclear reaction; give examples of different nuclear reactions; compare nuclear and chemical reactions
3.	*Radioactivity*	• define radioactive decay, period of semi-decay; explain basic SI units
4.	*Natural and artificial radioactivity*	• describe natural and artificial radioactivity; characterize ionizing radiation
5.	*Nuclear radiation detectors*	• describe the structure and the mode of operation of some basic types of nuclear detectors
6.	*Application of radionuclides*	• present the application of radionuclides in medicine, industry, power engineering, military science etc.
7.	*Radioactivity and environment*	• describe environmental contamination due to NPP operation and military science; • explain migration and accumulation of natural and artificial radionuclides in the atmosphere, lithosphere and hydrosphere; • introduce the International Nuclear Event Scale (INES) related to NPP safety
8.	Health effects of radiation	• know the basic ways for introduction of radionuclides into the human body; • explain the basic dosimetry terms
9.	Basic ways for radiation protection	• describe the proper actions of public in case of nuclear accidents
10.	Radioactive environmental contamination (discussion)	• express and defend a personal view about the present and future of NPP and the usage of nuclear weapons

Following this sequence, the lessons contents for each topic of the elective program were discussed. The special features related to students' age, the region they live in, and the teaching goals specified in the educational standards were considered, as well as the existing and our newly prepared visualization aids and didactic materials for self-preparatory work. Thus the scheme for educational process management was set up.

- ***Development of didactic approaches for organization of the teaching process***

The solution of this problem was achieved on the basis of investigations focused on the implementation of project-oriented education [6, 7]. They were carried out at the Chair of Chemistry Didactics at Sofia University. Adapted to the elective course education, these approaches have three basic steps: motivation of students, maintenance of their interest and presentation of the results from students' work. The structure of the lessons included application of the project-based method, as well as of standard problem-oriented methods with active participation of the students. Some of the topics were presented as problem-devoted lectures. A detailed discussion of the first lesson will be made, as it played a basic role in the motivation of students. It should be noted that during our first meeting with the students we remained with the impression of keen interest from them. It was evident that this initial interest of the students was provoked by the modern topic.

We used different approaches for motivation of students' cognitive interest at the two schools. The two approaches employed will be described separately.

1. *Secondary school "Vassil Levski", Velingrad*

The first lesson was referred to as introductory. The topic was "Man and ionizing radiation". It was presented as a lecture using a board with the same title – "Man and ionizing radiation" – for visualization. The students received copies of the photos from the board. These provoked certain interest and desire of the students to extend their knowledge on ionizing radiation, as well as on the health effects and the ecological problems originating from such radiation.

2. *Secondary school "Yane Sandanski", Sandanski*

The students were offered to see a film called "The warnings of Chernobyl". They showed even more than the expected interest. During the film projection the students were asking questions: "Why is this reactor buried under concrete?", "Which

apparatus is used for registration of radiation?", "What were the consequences for the people involved in the rescue operations?", etc. We considered this as a sign of marked interest towards the topic. The film touched students' emotions thus playing a major role for their motivation. The initial interest was strengthened further and willingness for participation in the elective course was provoked. The students expected to extend their knowledge about the nature of nuclear interactions, the characteristic features and measures for public protection from nuclear accidents and the questions related to health effects due to ionizing radiation.

Relevant to their interests and abilities, the students chose topics on which to work personally. During the lessons of the elective course, constant interest was kept by encouragement of good personal results, readings of interesting materials, discussions on current problems, etc. The closing stage was planned as a discussion and presentation of results from students' investigations on their topics, as well as of their own projects.

- ***Means of didactic support for the topics***

Appropriate literature sources and web site links were selected for each topic. A collection of overheads, as well as other materials for illustration of different topical questions, was supplied. Some of the visualization materials were prepared especially for this lesson. Students were shown the film "The warnings of Chernobyl".

Selection of tools for data collection from the pedagogical investigation

Questionnaires were made in order to collect data for the expected changes in the quality of radioecological knowledge of the students and of their attitude.

The questionnaire (see Appendix 1) has mixed character. It is basically a test for students' general knowledge about radiation. A single question is aimed at collecting information about the possible change in attitude towards radioecological problems.

- ***Description of the questionnaire contents***

The questionnaire includes twelve questions. The test part consists of "open choice" questions. The pupil's own knowledge and attitude are expressed. Only the last (twelfth) question, i.e. ***Would you take part in a seminar, a workgroup, an elective course or another elective forms of education on radioecological***

problems? Please justify your answer., is different. This question is investigative because it is referred to pupil's opinion about the "Radiation and man" elective course. It helps the assessment of pupil's attitude towards the topics, the provoked interest and the quality of the program.

Below is presented a description of the information contained in every question and the attitude of building a system for radioecological knowledge and attitude.

Question No 1: How would you define radioactivity?

This is the first question in the questionnaire. It is basic. The answers give information for the extent to which students are familiar with the meaning of radioactivity – before and after the elective course.

The question is important from a different aspect too. It is correlated with the other questions in the questionnaire that test students' knowledge about radioecology.

Question No 2: Please write the chemical symbols of at least 5 radioactive elements.
And
Question No 3: List the types of ionizing radiation.

These questions are directly related to the first one, which defines their position in the questionnaire. They are controlling questions, as their function is to check the correctness of the information given in the basic question (No.1). We use them to test whether students' knowledge about radioactivity is complete, and to what extent students are familiar with radioactive elements and ionizing radiation. The questions are directly bound to the material studied in chemistry and physics.

Question No 4: Give examples for application of ionizing radiation.

The question follows the natural logics: a relation of the studied topics with practice. It is in a sense fundamental for comments on hazards connected with the use of ionizing radiation in practice and everyday life, as well as in industry and technology. The students' interest in the topic could be estimated from the answers.

Question No 5: How and where the radioactive waste is disposed according to you?

This question is ecologically oriented and is very important for radioecology. It serves as an indication of the extent of students' familiarity with the ways of radioactive waste disposal and allows drawing conclusions about their personal interest in ecology as a whole and in radioecological problems in particular.

Question No 6: Which means for registration of ionizing radiation do you know?

The answers to this question give information about students' knowledge of radiation "trapping" and about the level of their competence on the apparatus and the methods for registration of ionizing radiation in practice.

Question No 7: Can you specify the ways for introduction of radionuclides into the human body? And

Question no 8: Which are the target organs for radionuclide accumulation?

These questions are directly related to the subject of radioecology. By the answers we can conclude about students' competence on the health effects and the medical aspect of the problem and on radioactivity's hazardous health effects.

Question no 9: Give examples of nuclear accidents, for which you know from history?

The question is of the "open choice" type and is meant for relaxation. It is informative about students' knowledge on the history of nuclear events. The question has a specific radioecological character. The history of nuclear accidents explains the reasons for their occurrence and the radioecological problems they give rise to.

Question No 10: Write down at least five examples of ways for protection from harmful radiation. and

Question No 11: Which sign means "Caution: radiation!"? Please draw it.

By these questions we rank students' knowledge about assessment of a dangerous environment caused by ionizing radiation and about the ways for radiation protection. The questions are related to the behavior of a person in case of a nuclear accident or when located in a radioactive zone. The questions are directed to practice.

Question No 12: Would you take part in a seminar, a workgroup, an elective course or another elective form of education on radioecological problems? Please justify your answer.

This question is the only one focused on the attitude towards the topic. By the answers we can consider the quality of the lessons passed, the interest provoked by the work done during the lessons and the up-to-date nature of the radioecological subject.

Determination of the changes in knowledge and attitude (personal concern) of the students as a result of their participation in the "Radiation and man" elective course

Two investigations, called conditionally "entrance" and "exit", were made for determination of changes in the knowledge and the attitude due to participation in the "Radiation and man" elective course. Identical questionnaires were used, which provided the opportunity for comparative analysis.

The data from the entrance and the exit tests are presented (as percentage) in Table 2.

Analysis of the investigation results

25 students were tested. The data from the investigation are presented in percents.

A comparative data analysis of the results (see Table 2) leads to the following conclusions:

1. The comparison of entrance and exit tests results shows a significant increase in the students' theoretical knowledge about radioactivity, radioactive elements and ionizing radiation (questions №1, №2 and №3).

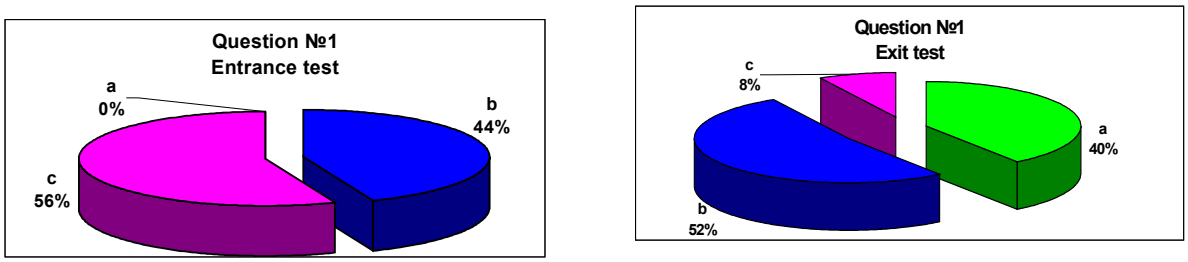
Let us consider the answers to question №1 for example: the preliminary investigation results show that the students cannot define radioactivity absolutely correctly (0%), the partially correct answers being 44% and without an answer - 56%.

Our first conclusion is based on the exit test results: they prove unambiguously that 40% of the students answer absolutely correctly, 52% - partially correctly and only 8% cannot define radioactivity.

Table 2: ***Presentation of the results from entrance and exit tests***

№	Question	Entrance test			Exit test		
		Abs. Correct ans. [%]	Part. Correct ans. [%]	No ans. [%]	Abs. Correct ans. [%]	Part. Correct ans. [%]	No ans. [%]
1	Definition of radioactivity	0	44	56	40	52	8
2	Five radioactive elements.	36	64	0	40	60	0
3	Types of ionizing radiation	4	68	18	96	4	0
4	Applications of radiation	0	100	0	24	76	0
5	How and where radioactive waste is disposed	0	80	20	4	96	0
6	Means for registration of ionizing radiation	0	40	60	36	64	0
7	Ways of introduction of radionuclides into the human body	12	84	4	32	68	0
8	Target organs exposed	0	88	12	44	56	0
9	Important nuclear incidents and accidents	0	92	8	20	80	0
10	Ways for radiation protection	0	60	40	16	84	0
11	Sign for radioactivity	68	-	32	76	-	26
12	Your opinion about the elective course “Radiation and Man”	84	0	16	100	0	0

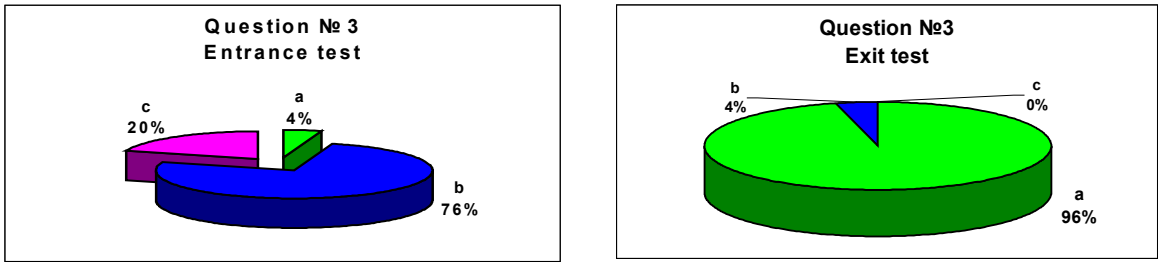
Graphical representation of the data on question 1 from entrance and exit tests



Question 1

Legend: Full answer (a); Partial answer (b); No answer (c)

Similar is the case for question №3. Before the “Radiation and man” elective course only 4% of the students have some knowledge about ionizing radiation and 18% do not know anything about it. But at the end of the course 96% of the students can describe the types of ionizing radiation and only 4% have partial knowledge about the matter.



Graphical representation of the data on question 3 from entrance and exit tests

Question 3

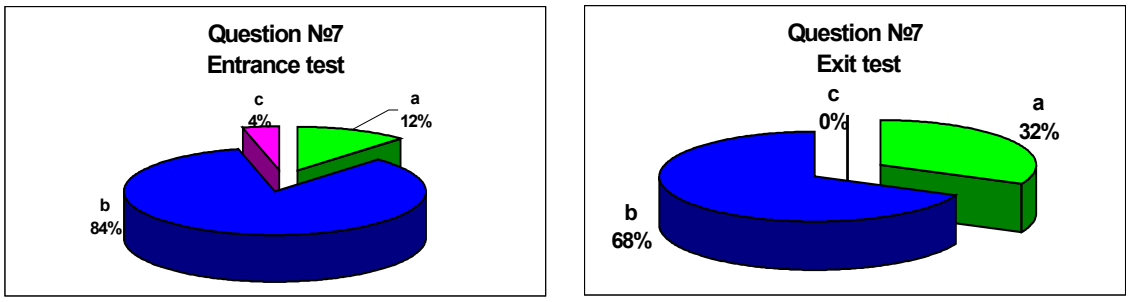
Legend: Full answer (a); Partial answer (b); No answer (c)

2. The “Radiation and man” elective course broadened students’ factological knowledge about the applications of ionizing radiation, the means for its registration, some health effects and a historical review of the nuclear accidents (questions №4, №6, №8 and №9).

The most interesting answers from this group of questions are given to question №4, which treats the applications of ionizing radiation. The entrance results show that all students cannot name five areas of application of ionizing radiation. The exit test results, however, are completely different - 24% of the answers are absolutely correct and 76% are partially correct.

3. The “Radiation and man” elective course formed or extended the ecological and radioecological awareness of the students. This conclusion is confirmed by the comparative analysis of questions №5, №7, №10 and №11.

Graphical representation of the data on question 7 from entrance and exit tests



Question 7

Legend: Full answer (a); Partial answer (b); No answer (c)

4. The results from the last question (№12) undoubtedly confirm the conclusion that the selected system of knowledge, methods and means for teaching lead to a significant increase in the motivation and cognitive interest of the students towards radioecological topics. At the end of the course all students (100%) say YES to the “Radiation and man” elective course.

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Appendix 1

Questionnaire

Name …… School……, class …… №
(Please write your answers in the blank dotted lines)

1. How would you define radioactivity?

. . . . . .
. . . . . .

2. Please write the chemical symbols of at least 5 radioactive elements.

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

3. List the types of ionizing radiation.

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E. I don't know

4. Give examples for application of ionizing radiation.

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

5. How and where the radioactive waste is disposed according to you?

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

6. Which means for registration of ionizing radiation do you know?

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

7. Can you specify the ways for introduction of radionuclides into the human body?

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

8. Which are the target organs for radionuclide .accumulation?

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

9. Give examples of nuclear accidents, for which you know from history?

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

10. Write down at least five examples of ways for protection from harmful radiation.

A. . . . . C.. . . . . .
B. . . . . D.. . . . . E.. . . . . .

11. Which sign means "**Caution: radiation!**"? Please draw it.

12. Would you take part in a seminar, a workgroup, an elective course or another elective form of education on radioecological problems? Please justify your answer.

. . . . . .

Appendix 2

Assessment scale

Question №	**Number of points**	**Max. number of points**
1	per each keyword - 1 point Phenomenon, quality, process – 1p. Spontaneous, no interference – 1p. Unstable – 1p. X-rays, invisible, α-, β-, γ- rays – 1p. Nuclei – 1p. Logical definition – 1p.	**6**
2	Correct answer – 1p. Wrong or no answer – 0p.	**5**
3	Correct answer – 1p. Wrong or no answer – 0p.	**4**
4	Correct answer – 1p. Wrong or no answer – 0p.	**5**
5	Answer “how” – 1p. Answer “where” –1p.	**6**
6	Correct answer. – 1p. Wrong or no answer – 0т.	**5**
7	Correct answer. – 1p. Wrong or no answer – 0p.	**4**
8	Correct answer – 1p. Wrong or no answer – 0p.	**5**
9	Correct answer – 1p. Wrong or no answer – 0p.	**5**
10	Correct answer – 1p. Wrong or no answer – 0p.	**5**
11	Correct sign drawn – 1p. Wrong or no sign drawn – 0p.	**2**
12	Yes, because – 3p. Yes – 2p. No, because – 1p. No or no answer at all – 0p.	**3**
Total number of points	-	**55**