Prospective Physics Teachers' Awareness of Radiation and Radioactivity

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Abstract
The purpose of this study is to investigate prospective physics teachers' knowledge of and attitude towards radiation and radioactivity. Participants of this study are 56 prospective physics teachers. A questionnaire related with the knowledge about radiation and radiation fear was conducted. The results of this study showed that most of the prospective physics teachers did not have enough knowledge about the ionising radiation and they lacked differentiation between contamination and irradiation. Moreover, majority of them were not aware of the degree of radiation exposure during their daily life experiences. Most of them could not give logical reasoning for their positive or negative attitudes towards radiation. In addition, it was found that the prospective physics teachers who know more about radiation and radioactivity have more positive attitude towards radiation and give more reasonable answers about it.Based on the above facts, the authors recommend that new teaching and information processes are needed to provide more beneficial learning environments about radiation and radioactivity.
Keywords: radiation awareness, radiation fear, attitude towards radiation, prospective physics teacher

Introduction

We experience radiation every day and everywhere in the world we live in (Anjos et al., 2008). Naturally occuring radioactive materials are present in the floors and walls of our homes, schools, and offices and in our foods. Moreover, due to the radioactive gases in the air we breathe, our own bodies (muscles, bones, and tissue etc.) contain naturally occurring radioactive elements. Therefore, people have been exposed to natural radiation arising from the earth as well as from outside the earth (IAEA, 2014).

Radiation is frequently classified into two groups such as ionizing and nonionizing radiation. "Ionizing radiation transfers enough radiation to the body upon absorption to cause chemical changes, or ionization of the atoms and molecules in the tissue or organs"… "Examples of ionizing radiation include X-rays, alpha rays (protons), beta rays (electrons), and gamma rays. Exposures to nonionizing radiation are much more common and usually less hazardous. Forms of nonionizing radiation include all those relatively low energy, electromagnetic radiations such as microwaves, infrared, light (including lasers), and ultraviolet" (Center for Occupational Research and Development,1981: 3).

Apart from its scientific explanation, most people have some specific perceptions about radiation. Though radiation was discovered more than 100 years ago, it is thought that the events followed in the media (Chernobyl disaster, Fukushima nuclear power plant disaster etc.) have a great influence on the perception of many people in terms of radiation and that the word "radiation" is associated with a bad and dangerous situation by them. Therefore, it is started to make researches by the 1990s regarding the knowledge levels of particularly students, their attitude and the effects of the media on this.

Eijkelhof (1996) interviewed with students about radioactivity, ionizing, medical use of radiation, food irradiation etc. Students' ideas within these contexts showed that many of the students' views were dominated by commonsense and information from the media instead of scientific notions.

Furuta, Hayashi, Kakefu and Nishihara (2000) conducted a study investigating Radiation Fair visitors' ideas about radiation and irradiated products. They reported that more than half of the visitors who are 16 years old and upward explained the school lessons and mass media as the sources of their information about radiation. Moreover, school teachers are indicated as an important factor affecting their students' image toward radiation. Similarly, Colclough, Lock and Soares (2011) emphasized that media and formal education play significant role in young people's knowledge about ionising radiation and radioactivity. They indicated the debate about which plays the more significant role in young people getting this knowledge.

Eijkelhof and Millar (1988) reviewed reports on Chernobyl and a lack of differentiation was identified in the terms used, for example: "radiation", "radioactive" and "radioactive material". In addition, the public held a vague concept of radiation being linked to danger, which was confused by the idea that irradiated objects become radioactive. They concluded that this confusion hindered rational risk assessment.

Several studies in different countries have investigated students' perception of radiation and radioactivity and their misconceptions (Alsop, Hanson & Watts, 1998; Alsop, 2001; Colclough et al., 2011; Cooper, Yeo & Zadnik, 2003; Durant, Evans & Thomas, 1989; Eijkelhof & Millar, 1988; Furuta et al., 2000; Henriksen, 1996; Klaassen, 1995; Lijnse, Eijkelhof, Klaassen & Scholte, 1990; Mancl, Heimlich, Fentiman & Christens, 1994; Millar, Klaassen & Eijkelhof, 1990; Prather & Harrington, 2001; Rego & Peralta, 2006). Most science education research related with radioactivity and radiation has shown that students have difficulties in understanding these subjects and so they have lots of misconceptions (Eijkelhof, 1996; Henriksen & Jorde, 2001; Huestis, 2002; Ince, Sesen & Kirbaslar, 2012; Millar, 1994; Millar et al., 1990; Nakiboğlu & Tekin, 2006; Prather, 2005) and continue to have even after instructions (Eijkelhof, 1990, as cited in Henriksen, 1996).

Considering the effects of information followed by the students in the media or acquired outside the school to their thoughts with scientific facts, it is necessary to perform the analysis of the differences between scientific knowledge and common sense information carefully (Lijnse et al., 1990). Therefore, this study was designed to explore prospective physics teachers' knowledge of and attitude towards radiation and radioactivity. Moreover, their knowledge of radiation and radioactivity according to their ideas related with radiation exposure in their daily lives were investigated in this study.

Methodology of Research

Research Design and Participants

This research has a descriptive survey approach. Participants of this study are 20 fourth grade and 36 fifth grade prospective physics teachers enrolled in five years Physics Teacher Education Program of a faculty of education from a state university in one of the cities located on the west of Turkey.

Students attending to this program take some Physics subject matter knowledge courses (mechanics, electromagnetism, optics and waves, nuclear physics etc.), general pedagogical knowledge courses (introduction to teachign profession, methods of physics teaching, classroom management, measurement and evaluation etc.) and general knowledge courses (mathematics, chemistry, biology, foreign language etc.) (Tam, 2006).

Nuclear physics is a four-credit compulsory course for physics education majors at the fourth year of Physics Teaching Departments. This course starts with the fundamental concepts such as radioactivity and its laws, radioactive series, alpha, beta, gamma decay, important nuclear reactions, etc. Lecturing is the main instructional methodology for teaching the concepts. In addition to lecture hours, prospective physics teachers attend the Nuclear Physics Laboratory course at the same semester. During lecture hours, the instructor presents the concepts and solves/explains some examples given in the textbook. In laboratory hours, students perform some experiments such as determining operating voltage of Geiger Muller counter, counting statistics etc. with the guidance of the course assistant(s).

Instrument and Procedures

A questionnaire consists of open-ended attitude and knowledge questions (see Appendix) that are related to the knowledge of radiation (types of radiation, ionizing radiation, radiation sources etc.) and questions related to the attitude towards radiation used in this study. Some of the questions were developed by the researchers and some were adapted from the previous researches. The questions were examined by two physics professors and two physics education instructors both in terms of content and appropriateness. The questionnaire was conducted to all fourth and fifth grade prospective physics teachers at the same time in thirty minutes. The fourth grade students answered the questions at the last week of the semester and the last hour of the nuclear physics course. This means that both of the groups had taken the related course when the questionnaire was conducted.

Data Analysis

The data was analyzed using frequency tables based on some codes generated using the previous studies and the responses of prospective physic teachers to the items in the questionnaire. The researchers analyzed the data separately, and then compared the findings. Moreover, Kruskal-Wallis and Mann Whitney U tests were used to determine if there is a statistically significant difference between their knowledge about radiation and radioactivity and their ideas related with radiation exposure in their daily lives.

Results of Research

Irradiation vs Contamination

The students were asked two questions in order to investigate whether they have difficulty to distinguish irradiation and contamination. The questions were adopted from open-response questions used by Prather and Harrington (2001) who also adopted these questions from multiple-choice questions used by Millar (1994).

In the first question, (see Figure 1) a strawberry is exposed to radiation from a radioactive source. We ask students to explain whether they hesitate to eat this strawberry when removed from the source or not. According to the answers of the students, we can understand to what extend they differentiate the situation in which a matter become radioactive due to the absorption of radioactive material or only irradiated due to the exposion of radiation. Moreover, we may detect whether their answers or reasoning are affected by their attitudes.

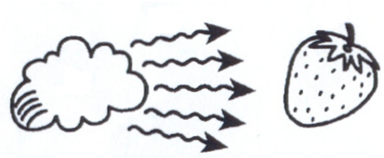

Figure 1. *A strawberry is exposed to radiation from a radioactive source (Prather and Harrington, 2001)*

The correct answer and explanation of the first question would identify that "an object has been irradiated when exposed to ionizing radiation. It neither become radioactive nor emits ionizing radiation. Being irradiated does not mean that it became a radioactive source. Therefore, since the strawberry didn't absorb radioactive material, it would not become radioactive and there is no need to hesitate while eating it". A summary of the responses are given in Table 1.

Table 1. *Do you hesitate to eat the strawberry, which is exposed to radiation from a radioactive source?*

Response Type	**Fourth Grade (n = 20)**	**Fifth Grade (n = 36)**	**Overall (n = 56)**
Incorrect answer *Example of student responses:* *I don't eat since it is harmful.*	65%	72%	70%
Correct answer with incorrect reasoning *Example of student responses:* *Although it harms others, I am not affected and I eat it.*	10%	8%	9%
Other or no response	25%	20%	21%

Majority of the students (70%) gave incorrect answers due to the idea that strawberry become a source of radiation and therefore harmful. Here are some answers given by several students: "I don't eat. Its structure might have degenerated due to radioactive radiation." "I don't eat. Because, if strawberry exposed to radiation is eaten, radiation contaminates us as well and can lead to genetic defects." "I do not eat, because I would let radiation in my body wholly." "I don't eat, once strawberry is eaten, we take radioactive material directly into our body."

In this study, there were some correct answers but the reasonings behind the answers were incorrect. Although some students (9%) stated that they do not hesitate to eat strawberry, they gave incorrect reasoning such as "I eat, because such radiation ingressing in our body will wear off reduced to half after a while. While the rest few students state that they will eat unhesitatingly due to the fact that radiation is everywhere and unavoidable, others either left the question blank or responded as either I eat, do not eat or not sure. In fact, 4th and 5th grade students' responses to this question were quite similar. Owing to the fact that there were no students answering this question accurately, it appeared that students did not learn the difference between the concepts irradiation and contamination well.

In the second question, the students are asked to explain whether they hesitate to approach people, who were injected radioactive material, or not. The correct answer and explanation of this question would identify that “a person has been contaminated when absorbed radioactive material. He/she become radioactive and therefore emits ionizing radiation that is why I may hesitate to approach that person”. A summary of the responses are given in Table 2.

Table 2. *Do you hesitate to approach people, who were injected radioactive material?*

Response Type	**Fourth Grade (n = 20)**	**Fifth Grade (n = 36)**	**Overall (n = 56)**
Incorrect answer *Example of Student Responses:* *I don't hesitate since it is not hazardous.*	75%	30%	46%
Correct answer with correct reasoning *Example of Student Responses:* *I hesitate since they become radioactive.*	10%	50%	36%
Correct answer with incorrect reasoning *Example of Student Responses:* *I hesitate since the person is in treatment process and needs to be alone.*	5%	6%	5%
Other or no response	10%	14%	13%

Although there weren't any students, who answered the first question accurately, 36% of the students made a valid explanation by answering this question correctly. Students gave some explanations like “I hesitate to approach people, who were injected radioactive material, because they become radioactive”. 46% of the students declared that they won't hesitate because it won't be hazardous. Their rationale is that treatment-purposed applications should not be hazardous and etc. 5% of the students said that they will hesitate because it is harmful, but their statements are either inaccurate or irrelevant. The rest of the several students argued that they will not hesitate because radiation is inevitable.

When we compare the responses of the 4th and 5th grade students, we can see a clear distinction in this question. 10% of the fourth class students and half of the fifth class students answered the question accurately. Students mostly think that a person or an object become radioactive when exposed to ionizing radiation and when absorbed radioactive material. Therefore, while there weren't any students accurately answering the first question, there were some that answered the second one correctly.

Fear of Radiation

As to be understood from the answers given by the students to the previous questions, even if the students have a theoretical knowledge on radiation, they are likely to provide emotional or hearsay answers and make wrong or unclear explanations. Therefore, in order to figure out whether students have any fear of radiation or not, a question is asked in order to determine whether the reason for this fear (if applicable) is scientific or not and their justification levels for their thoughts related to this issue. The question "Do you fear to be exposed to radiation in daily life?" was directed to the students which was adopted from the study of Henriksen (1996) as all of the following questions.A summary of the responses are given in Table 3.

Table 3. *Do you fear to be exposed to radiation in your daily life?*

Response Type		**Fourth Grade (n = 20)**	**Fifth Grade (n = 36)**	**Overall (n = 56)**	**Overall (n = 56)**
I'm not afraid of it.	unavoidable	%35	%17	%23	%36
	harmless doses	%5	%11	%9	
	no explanation	-	%6	%4	
I'm afraid of it.	unavoidable	%5	%3	%4	%36
	hazardous	%5	%39	%27	
	no explanation	%5	%6	%5	
It depends upon the dose of radiation.		%45	%14	%25	%25
No response		-	%4	%3	%3

36% of the students stated that they are afraid of being exposed to radiation and 36% stated they are not. Justification of the ones, who responded I am not afraid, is as follows; 23% expressed that they are not afraid because it is unavoidable in their daily lives and 9% stated that they do not fear since it is in harmless doses. But, they haven't stated any extra information about this dose. 4% only wrote down "I am not afraid of" but did not give any justification. Justification of the ones, who answered as "I am afraid of", is as follows: 27% indicated that they fear because it is hazardous and 4% declared that they are afraid of it since it is in everywhere and inevitable. 5% only wrote "I am afraid of it" without giving any explanation.

25% of the students wrote that their fear only depends upon the dose of radiation but did not specify any information related to the dose. Considering on the basis of class, it was revealed that 45% of the fourth class students gave more logical and scientific answers stating that their fear hinges on the dose compared to the 14% of the fifth class students.

Understanding of Radiation and Radioactivity

Since the students might experience difficulties in providing justifications for the answers they gave and this might be related to their lack of knowledge, questions measuring knowledge related to the subject of radioactivity were asked to the students. For example, the question "are there any sources of radiation in indoor spaces you live/do you think there are? (If yes, then what are these?)" was directed to the students. Sources of radiation presented among answers are given on Table 4.

Table 4. *Are there any sources of radiation in indoor spaces you live/ do you think there are? (If yes, then what are these?)*

Sources / Grades	Electronic devices	Air	Soil	Sun	Radioactive Materials	Radon	Water
Fourth Grade (n = 20)	95%	20%	-	35%	5%	-	20%
Fifth Grade (n = 36)	81%	3%	11%	14%	3%	3%	3%
Overall (n = 56)	86%	9%	7%	21%	4%	2%	9%

86% of the students presented electronic devices as an example to sources of radiation in indoor spaces. In addition; sun (21%), air and water (9%), soil (7%), radioactive materials (4%), radon (2%) were given as other examples. It is striking that only one person in the fifth class counted radon as a source of radiation in indoor spaces. Three fifth class students only gave wall as a source without mentioning radon. Except the sources of radiation mentioned in Table 4, one person (in the fourth class) argued that everything we eat is a source of radiation, and one person (in the fifth class) told that human body is a source. Furthermore, incorrect answer was that a fifth class student argued that there is not any source of radiation in indoor spaces and three people said every material is a source.

Another question "What is radioactive and non-radioactive material? Give examples." was asked to the students. According to the results (**Error! Reference source not found.**), most of the students (61%) correctly identified radioactive and non-radioactive material but could not give any example to radioactive material. 30% could define it by giving a satisfactory example. While 7% inaccurately responded, 2% did not answer the question. In this question, the fourth class students were more successful than the fifth class students.

Table 5. *What is radioactive and non-radioactive material? Give examples.*

Response Type	Fourth Grade (n = 20)	Fifth Grade (n = 36)	Overall (n = 56)
Incorrect answer	-	11%	7%
Correct but unsatisfactory answer	65%	58%	61%
Correct answer	35%	28%	30%
No response	-	3%	2%

As an example for the incorrect answer; "radioactive material is a material which is radiating and non-radioactive material is a material which is not radiating" can be given. However, every material is radiating due to its temperature. Whilst more than the half of the students had defined non-radioactive materials correctly, they experienced difficulties in giving samples for these materials, particularly for non-radioactive materials.

The next knowledge question is as follows: "Radioactive materials can radiate in three ways. What are their names? What is the reason of these radiations?" A summary of the responses are given in **Error! Reference source not found.**.

Table 6. *Radioactive materials can radiate in three ways. What are their names? What is the reason of these radiations?*

Response Type	Fourth Grade (n = 20)	Fifth Grade (n = 36)	Overall (n = 56)
Incorrect answer	-	3%	2%
Correct but unsatisfactory answer	30%	44%	39%
Correct answer	70%	42%	52%
No response	-	11%	7%

According to the results, 52% of students correctly replied this question. Evaluating on the basis of class, while 70% of the fourth class students specified that radioactive materials emit alpha, beta and gamma radiation and the reason of this radiation stem from nucleus being unstable, 30% could not mention the reason of radiation. The rate of success in the fifth class students is about 42% that is less. Moreover, 44% could not explain the cause of radiation, only talked about the types of radiation.

As the seventh question, "Are you familiar with radioactive rays? (If yes, what are these rays?)" was asked to students. According to the results (**Error! Reference source not found.**), 75% of the 4th and 36% of the 5th class students correctly answered that radioactive rays are alpha, beta and gamma rays. Should we give example among wrong answers, there were students calling X ray, infrared, ultraviolet and microwave as radioactive ray.

Table 7. *Are you familiar with radioactive rays? (If yes, what are these rays?)*

Response Type	Fourth Grade (n = 20)	Fifth Grade (n = 36)	Overall (n = 56)
Incorrect answer	15%	28%	23%
Correct and unsatisfactory answer	10%	17%	14%
Correct answer	75%	36%	50%
No response	-	19%	13%

The definition of ionizing and nonionizing radiation was asked as the last knowledge question. According to the results given in **Error! Reference source not found.**, while very few students (12%) correctly explained ionizing and nonionizing radiation, 55% did not answer the question.

Table 8. *What is definition of ionizing radiation and nonionizing radiation?*

Response Type	Fourth Grade (n = 20)	Fifth Grade (n = 36)	Overall (n = 56)
Incorrect answer	15%	11%	13%
Correct but unsatisfactory answer	40%	8%	20%
Correct answer	10%	14%	12%
No response	35%	67%	55%

The answers provided by the students are in common like; “Ionizing radiation causes the ionizing of the atoms in the environment it spreads and thus the permanent change of their structure. But non-ionizing radiation will not ionize the atoms in the environment it spreads and thus not cause a permanent change of the structure of the material it affects.” But there are students, who gave such correct answers but gave the gamma rays as sample for non-ionizing radiation, too. This is the question, which is passed over particularly by students of the fifth grade. This situation indicates that knowledge is not persistent.

Knowledge Level According to Attitude

Kruskal-Wallis H test results of prospective physics teachers’ knowledge about radiation and radioactivity according to their ideas related with radiation exposure in their daily lives are given in Table 9.

Table 9. *Kruskal-Wallis H-test results of knowledge scores according to attitude*

Attitude	N	Mean Rank	df	χ^2	p	Difference
I am afraid of... (1)	23	18.96	2	14.58	0.002	1-2 1-3
I am not afraid of …(2)	21	33.19				
it depends on its dose	10	38.35				
no commend (4)	2	39.75				

Table 9 shows that there is a significant difference between prospective physics teachers’ total scores of knowledge questions and their ideas related with radiation exposure in their daily lives [$\chi^2(2)= 14.58$, $p< .05$].

Mann Whitney U test was used in order to determine that the statistically significant difference observed was based on which groups. As a result of the research, it was determined that significant differences occur between the prospective physics teachers who answer as “I am afraid of radiation exposure in my daily life” and those answer as “I am not afraid of radiation exposure in my daily life” and those answer as “it depends on its dose".

Discussion

When the two questions (“Do you hesitate to eat the strawberry, which is exposed to radiation from a radioactive source? and “Do you hesitate to approach people, who were injected radioactive material?”) about irradiation and contamination were analyzed, answers given to these two questions indicated that students do not know the difference between irradiation and contamination well. It was observed that they gave answers in view of superficial knowledge and display their attitudes such as “hazardous, not hazardous, it is inevitable because it is everywhere, if it was harmful it wouldn’t have been injected” rather than conceptual and meaningful explanations (such as “it will become radioactive or not”).

Similarly, in Prather and Harrington’s study (2001) many students had the idea that “strawberry became both a source of radiation and radioactive after being exposed to radiation”. In another study, Millar et al. (1990) investigated children’s ideas about radiation and radioactivity. They found similar ideas regarding irradiation of food. According to them, many children think that "radiation is absorbed" which is different from the scientific one. Many believe that sterilised objects using radiation such as syringes and dressings become radioactive and they subsequently emit radiation. In addition, it is remarkable that Sesen and Ince (2010) scanned 200 websites to check whether information obtained from the internet was a source of misconception about radiation and radioactivity, and found that 24,3% of the sites included the misconception "if an object is exposed to ionizing radiation, it becomes radioactive."

Colclough et al. (2011) conducted interviews about scenarios and asked multiple choice questions to assess 73 pre-service physics, chemistry, and biology teachers' subject knowledge and their misconceptions about radioactivity and ionising radiation. According to the results of the study, although the pre-service physics teachers had the higher levels of knowledge, they held misconceptions such as confusion between irradiation and contamination.

Different from this study, Prather and Harrington (2001) described two more cases to the students. In the first case, it is stated that a strong beam of radiation is directed to a cancer patient's tumor and in the second case a small amount of radioactive material is injected into a patient. The students were asked in which case or cases the patient would become radioactive. The results have shown that approximately 18% of the college students from physics courses and nonscience majors differentiated the two cases and explained that only in the second case contamination causes patient to become radioactive.

Prospective physics teachers' answers about the sources of radiation in indoor spaces show that electronic devices, air, soil, sun, radioactive materials, radon and water are the most known radiation sources in indoor spaces. Only one of the prospective physics teachers identified radon as the source of radiation and three of them explained that wall as a radiation source without mentioning radon.

According to Rego and Peralta (2006), although a majority of the students have heard about radiation, a significant percentage does not know about natural radioactivity. They emphasize that "the difference between ionizing and non-ionizing radiation is mostly unknown. Many students are able to identify x-rays, but not visible radiation. Radon is practically unknown, since sources of radiation and even the radiation content of food and soil are barely known".

Henriksen (1996) investigated the understanding of non-expert university students' conceptions of radiation phenomena. When asked radiation sources the author reported the confusion between sources of radiation and other environmental accidents since the respondents gave nuclear power plants, nuclear submarines, radon, smoke detectors etc. that is why he emphasized the effect of media and school knowledge on students' answers.

According to the answers of the question of "What is radioactive and non-radioactive material? Give examples", most of the students correctly identified radioactive and non-radioactive material. However, when the answers of the questions ("Radioactive materials can radiate in three ways. What are their names? What is the reason of these radiations?") were investigated, 52% of the students specified that radioactive materials emit alpha, beta and gamma radiation and the reason of this radiation stem from nucleus being unstable. In the study of Henriksen (1996), 34% of the university students correctly stated what the radiation consisted of in alpha, beta and gamma radiation although 89% of them knew these three radiation types.

Prospective physics teachers' answers about their familiarity with the radioactive rays show that 75% of the 4th class students and 36% of the 5th class students answered it correctly. This situation demonstrates that knowledge is not lasting. It is beneficial to determine the method to be used well owing to the fact that methods of instruction used in course have a huge effect on making knowledge permanent.

Another striking outcome was obtained from analysis results; although some students left the question “what are radioactive rays?” empty or answered incorrectly, it was seen that they answered types of radiation emitted by radioactive materials accurately. Likewise, it was observed that students, who replied the question “what are radioactive rays” inaccurately, answered “what is radioactive material?” correctly. This outcome exhibits that the terms radioactive ray and radioactive material have not yet fully grasped by students. Similarly, Tsaparlis, Hartzavalos and Nakiboğlu (2013) reported in their study that Turkish students confused radioactive radiation with other types of radiation.

According to the results of the question of “What is definition of ionizing radiation and nonionizing radiation?” while very few (12%) students correctly explained ionizing and nonionizing radiation, 55% did not answer the question.

Students’ and laypeople’s conceptions of ionizing radiation have previously been described (Eijkelhof & Millar, 1988; Henriksen, 1996; Henriksen & Jorde, 2001; Klaassen, 1995; Lijnse et al. 1990). The results from our study are largely in accordance with previous findings concerning the conceptions of ionizing and nonionizing radiation in various groups of learners.

Moreover, significant differences were observed between the prospective physics teachers who answer as “I am afraid of radiation exposure in my daily life” and those answer as “I am not afraid of radiation exposure in my daily life” and those answer as “it depends on its dose". This shows that the prospective physics teachers who know more about radiation and radioactivity have more positive attitude towards radiation and give more reasonable answers about it.

Conclusions

In this study, 56 prospective physics teachers were asked eight open-ended attitude and knowledge questions about radiation. It is inferred at the end of this study that responses given by the students are not at an expected level. Because, the main concepts present in the questions we have asked were both described in the course of nuclear physics and most of them is mentioned in our daily life (in media) that is why, the fourth grade students, who learned these concepts recently, were more successful than the fifth grade students in most of the questions. However, this situation also displays that learned knowledge was not long lasting due to the fifth grade students’ performance. After graduation, these students will be physics teachers at high schools and will probably have some difficulties about these concepts. Anjos (2006) states that high school teachers rarely manage to discuss the effects of ionizing radiation exposures with their students due to the fact that most teachers themselves have not learnt these subjects during their university training. Therefore, since the method of instruction used in related university courses has a considerable impact on this subject, it may need to be reviewed.

Henriksen (1996) states that although the students have a basic understanding of radioactive processes, they have difficulty to manage to use this knowledge while answering the questions and reasoning correctly. Apart from the method of instruction and the teacher effect related with the formal education, the researchers emphasize the effect of the media on students’ knowledge of and attitude toward radiation. Therefore, people should also be informed by the help of media. There might be more detailed and informative programs targeting especially the young people and the gap between the public and scientific understanding of radiation phenomena should be eliminated.

Considering the information obtained by the students at early ages through their formal education or the affect of the media on knowledge they will obtain during their high-school and university life, it is very important that they obtain the appropriate knowledge at primary education levels. Since the teachers, providing education at primary education level are science teachers, it is necessary that not only the physics teacher candidates but also the science teacher candidates should be informed at sufficient level on this issue.

Based on the above facts, the authors recommend that new teaching and information processes are needed to provide more beneficial learning environments about radiation and radioactivity. Moreover, prospective teachers' preconceptions about radioactivity should be taken into account and their conceptions about radiation belonging to their daily life experiences should be integrated with the university knowledge that is obtained from the related courses. Students' misconceptions, fears, attitudes and the effect of the media should be taken into account while designing the courses. By improving new teaching and information processes, students' awareness toward radiation should be improved and information about radiation should be transferred at the right stage of education accurately. Prather and Harrington (2001) states that students show progress in their conceptual understanding about ionizing radiation and radioactivity after using some instructional strategies such as hands-on laboratory-based activities, interactive lectures, and worksheets prepared with directed-inquiry approach.

Finally, since the radiation subject might be handled in other lessons and students might be requested to discuss on this issue, it is necessary that not only physics and science teachers, but also non-science specialists cooperate with the specialists of the subject.

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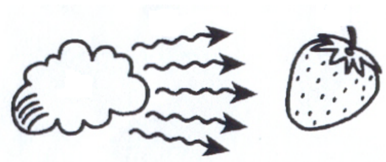
Appendix

Questionnaire

1) Do you hesitate to eat the strawberry, which is exposed to radiation from a radioactive source?



2) Do you hesitate to approach people, who were injected radioactive material?
3) Do you fear to be exposed to radiation in daily life?
4) Are there any sources of radiation in indoor spaces you live/ do you think there are? (If yes, then what are these?)
5) What is radioactive and non-radioactive material? Give examples.
6) Radioactive materials can radiate in three ways. What are their names? What is the reason of these radiations?
7) Are you familiar with radioactive rays? (If yes, what are these rays?)
8) What is definition of ionizing radiation and nonionizing radiation?