

# Attitudes and Behaviors of University Students Towards Electromagnetic Radiation of Cell Phones and Wireless Networks

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## ABSTRACT

The research into the electromagnetic radiation of mobile phones and wireless networks is relatively small, although they are some of the devices that people use daily. The study aimed to investigate the attitudes and behaviors of college students about electromagnetic radiation from mobile phones and wireless networks, as well as to examine the impact of the curricula of the university departments in which they study. The study involved 619 students from six different university departments. Data collection was performed using a closed-ended questionnaire. The general conclusion of the research was that students have incomplete knowledge about the electromagnetic radiation emitted by mobile phones and wireless networks, while at the same time they have a negative attitude and consider it dangerous to the health of living organisms. However, their behaviors regarding the protection of their health do not match with the attitudes they have formed, while in the majority they are significantly related to the university department in which they study.

**Keywords:** attitudes, behaviors, electromagnetic radiation, smartphones, students, wireless networks

## INTRODUCTION

### Smartphones and Wireless Networks in Contemporary Life

The smartphone is one of the most important developments in information and communication technologies (ICT) while at the same time there has been a significant increase in the use of wireless communication and especially wireless networks (Dixit et al., 2010). Smartphone technology and continuous internet connection throughout the day have led to a huge increase in the number of users (Kumar et al., 2011; Nasser et al., 2018; Piper et al., 2019; Salehan & Negahban, 2013; Zickuhrs, 2011). The use of these technologies is so widespread by people of all ages and also replaces other devices such as cameras and corded telephones (Walsh et al., 2008).

Young adults use smartphones for communication, entertainment, and browsing. Young children use them in education and games, while older adults use them in e-government and e-commerce (Dresselhaus & Shrode, 2012; Kang & Jung, 2014; Krithika & Vasantha, 2013; Muhanna & Abu AlShar, 2009). The huge popularity of smartphones in all age groups affects the attitude and patterns of use people (Kumar & Sriram, 2018; van Deursen et al., 2015).

People are becoming more and more interested in issues related to electromagnetic radiation, because devices that are part of their daily lives, such as mobile phones, laptops, tablets, modern game consoles and wireless networks, emit electromagnetic waves in the radio frequency range (Subha, 2017). Human exposure to artificial sources of electromagnetic radiation has increased rapidly in recent years. The reasons are the development and use of wireless technology and the change in human social behavior (Bernroider et al., 2014; Han & Yi, 2018; Kuss et al., 2018; Omar et al., 2018; World Energy Council, 2016). The information that users search on the Internet about radiation is related to whether a mobile phone can cause cancer in humans and what are the consequences of nuclear accidents (Neumann, 2014; Neumann & Hopf, 2012).

### Effects of Electromagnetic Radiation on Human Health

Public health organizations and the scientific community, due to the rapid growth of young users of mobile phones and wireless networks, are showing increasing interest in the relationship between the health of children and adolescents and their exposure to electromagnetic radiation in the radio frequency range (Shinde & Patel, 2014). Because it can take more than twenty years for a cancer to form and grow, the current negative research findings do not indicate the absence of risk. That's why the International Agency for Research on Cancer (IARC) has classified electromagnetic radiation as carcinogens in group 2B, i.e., possibly carcinogenic to humans.

Children and adolescents start using mobile phones at a much younger age than adults, at a time when the child's body is still growing (Al Khelaiwi & Meo, 2004; Fowler & Noyes, 2017; IARC, 2011; Pendse & Zagade, 2014).

The absorption of energy from RF radio frequency fields can cause molecules to vibrate, which leads to heating of body tissues. This absorption is determined by a physical quantity known as the specific absorption rate (SAR). It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg) (ICNIRP, 2009). The exposure rate to these radiations varies from handset to handset.

The United States and the European Union has set safety limits for the energy absorbed by the body from exposure to a mobile phone. In Europe, Council Recommendation 1999/519/EC sets a safety limit for a localized SAR of 2 W/kg, averaged over any 10 g of body tissue in a person's head and trunk, and of 4 W/kg in a person's limbs. In United States the Federal Communications Commission (FCC, 2009) requires that phones sold have a SAR level at or below 1.6 watts per kilogram (W/kg) taken over the volume containing a mass of 1 gram of tissue that is absorbing the most signal (Varshney et al., 2018).

Human body, when exposed to electromagnetic radiation emitted by mobile phones and cell towers, absorbs it, and this can be associated with various health hazards (Levitt & Lai, 2010; Nasser et al., 2018). Specifically on the issue of electromagnetic radiation, there are many researchers who express strong concerns about the effects of long-term exposure to electromagnetic radiation sources can have on living organisms (Al Khelaiwi & Meo, 2004; Baste et al., 2008; Carlberg & Hardell, 2012; Hepworth et al., 2006; Klæboe et al., 2007; Lonn et al., 2005; Yan et al., 2009).

In addition, research has shown that electromagnetic radiation in the radio frequency range used by mobile phones and wireless networks can even affect human cognitive functions. The results of psychometric tests on mobile phone users aged 11-14 years, showed reduced cognitive function (Abramson et al., 2009; Fowler & Noyes, 2017), while the addictive use of the Internet is harmful to the mental health of people (Shinde & Patel, 2014). In other words, they found that the widespread use of mobile phones and wireless networks can have an impact on a person's physical health, cognitive health, and social health.

At this point we should clarify that the electromagnetic radiation from mobile phones and wireless networks is not responsible for all the problems that have been recorded during their use. For example, the musculoskeletal effects that have been identified in users who adopt abnormal postures and involve problems in the upper back and neck are due to the way the device is used (Fowler & Noyes, 2017; Gustaffson et al., 2011). In addition, another study investigating the effect of drivers' use of mobile phones on road safety, found an increased risk, which again is not due to radiation but the way the device is used (McEvoy et al., 2005).

Despite warnings of health risks, mobile phone has been described that has the ability to permanently changing the way we work, live and love (Fowler & Noyes, 2017; Kasesniemi & Rautiainen, 2002).

## Education in Developing Critical Thinking for Health Decisions

With the ability to access the Internet through cell phones and the communication it offers, teens enter a very extroverted period of their lives prioritizing these communication opportunities over their own health (Hassoyet al., 2013). Adolescents' risky behaviors have been shown to be associated with their perceptions of risk and may remain in the form of habits throughout their lives (Gullone & Moore, 2000; Martha & Griffet, 2007). Studies on adolescents' risk perceptions for cell phones are very rare. However, some studies have shown that there are significant differences in the perception of risk in relation to age, gender, education, and culture background of the individual (Hassoy et al., 2013; Kang & Jung, 2014; Siegrist et al., 2005; van Deursen et al., 2015; WHO, 1998).

In addition to acquiring knowledge, the development of critical thinking is one of the main goals of education (Abrami, 2008; Marin & Halpern, 2011) that contributes to the creation of active citizens (Behar-Horenstein & Niu, 2011). Students should be able to think critically and use their knowledge to make the most appropriate decisions to solve life problems, but also for their personal safety and health, avoiding risks. In order to design more effective didactic approaches, which will aim at developing knowledge and critical thinking towards the electromagnetic radiation coming from devices that people use every day, it is necessary to further investigate the perceptions, attitudes, and behaviors of users, because as mentioned earlier the number of relevant studies are limited.

## Research Questions

The research questions (sub-objectives) of this study can be summarized, as follows:

1. What is the attitude of university students towards the electromagnetic radiation in the spectrum of radio frequencies emitted from mobile phones and wireless networks in terms of risk?
2. What are the behaviors and practices of the students regarding the protection from the emitted electromagnetic radiation of these devices?
3. Is there a correlation between attitudes and behaviors of students, with the knowledge they acquire in the university departments they study?
4. Is there a correlation between attitudes of students towards electromagnetic radiation emitted by mobile phones and wireless networks, with their protective behaviors towards it?

## METHODOLOGY

### Participants

A total of 619 university students (n=619) participated in the present survey, of which 116 respondents attended the Pedagogical Department of Primary Education, 105 attended the Pedagogical Department of Preschool Education, 71 students attended the Department of Philosophy, Pedagogy and Psychology, 107 students attended the Department of

**Table 4.** Participants of the study

University department	Frequency	Percent	Cumulative percent
Pedagogical Department of Primary Education	116	18.7	18.7
Pedagogical Department of Preschool Education	105	17.0	35.7
Valid Department of Philosophy	71	11.5	47.2
Department of Computer Science	107	17.3	64.5
Department of Physics	111	17.9	82.4
Department of Medicine	109	17.6	100.0
Total	619	100.0	

Computer Science, 111 respondents studied in the Department of Physics, and the 109 respondents studied in the Department of Medicine (Table 1).

### Study Participant Selection

These university departments were selected in order to determine as accurately as possible the properties of the population, by studying the census data of this sample. Specifically, the Science departments' curricula negotiate issues related to electromagnetic radiation and prepare future secondary school teachers. Education departments negotiate issues of natural sciences and prepare future primary education teachers. Department of Philosophy is the one whose curriculum does not include courses related to natural sciences and finally Medical School includes courses related to physics and in particular to the applications of radiation for medical purposes.

### Survey Instrument

The collection of quantitative data was carried out using a closed questionnaire. The research tool was created, after first understanding the characteristics of the respondents, because the formation of attitudes and behaviors is influenced by the experiences and knowledge they acquire during life and education, inside and outside the school environment (Richardson, 1996). The questionnaire and the data of the present research study are part of Gavrilas (2017) postgraduate thesis. The questionnaire was intended to investigate four thematic sections, which included knowledge, attitudes, behaviors, and symptom statements. Due to the size of the questionnaire, the limited time to complete it, and the special characteristics of the sample, after the advice of the experts, no Likert-type questions were chosen, but questions with binary answers.

Although Likert-type questionnaires are mainly used in research when attitudes are examined, for the purposes of the specific research and the limitations mentioned, binary questions would lead to clearer results. The validation and feasibility of the questionnaire was carried out in the pilot study, through distribution to 30 randomly selected respondents (six respondents from each university department). To confirm the face validity and the content validity of the research tool, three experts related to the research topic participated (Trochim, 2005). After first making all the required corrections it was distributed for the final collection of all survey data.

Considering the fact that our results are mostly binary variables (i.e., answers yes or no) for this tool, a derivative of Cronbach's alpha was used to determine the internal consistency of the tool. Kuder-Richardson formula 20 (KR-20)

coefficient is a reliability that refers how consistent the results from the test are, or how well the test is actually measuring what you want it to measure (Capik & Gozum, 2015; Quagrain & Arhin, 2017). The scores for KR-20 range from 0 to 1, where 0 is no reliability and 1 is perfect reliability (Dodge, 2008; Klein & Dabney, 2013). The value in the present research was .722. In general, a score of above .5 is usually considered reasonable (Glen, 2016). We should mention that only the results of the questions that are related to the research questions of this study are presented.

### Data Collection

The questionnaires were distributed during the teaching of courses at the university after consultation with the responsible professor of each course in order to provide the required time before the start of his teaching. After an introduction about the purpose of the research was first made and after the required instructions were given for completing the questionnaires, they were distributed to the respondents for their completion. The time allocated to the student respondents was fifteen minutes. After the end of the time, the questionnaires were collected again so that they could be registered, and the further analysis of their data could be done.

### Data Analysis

The statistical processing and analysis of the data was based on the statistical program SPSS (statistical package for social sciences) version 21. Descriptive statistics were used, and the appropriate tables and diagrams were created for the visual representation of the results with Microsoft Excel 2007. To inquiry the correlation of the answers with the variable "university department" of the respondents, the statistical criterion  $\chi^2$  test (Pearson Chi-square) was used with a significance level  $\alpha=.05$ , while the Cochran Mantel Haenszel test (CMHT) was used to inquiry correlations between the questions with a significance level  $\alpha=.05$ . In the statistical program SPSS, the CMHT is known as linear-by-linear association (Agresti, 2002; Mantel, 1963).

## RESULTS AND ANALYSIS

### Questions for Radioactivity

According to students' responses to 1<sup>st</sup> question: "Do you think cell phones/ smart phones emit radioactivity?", it was found that 74.2% mistakenly believe that they emit radioactivity. The highest percentage of correct answers were given by medical students while the lowest given by the students of Philosophy Department (Figure 1).

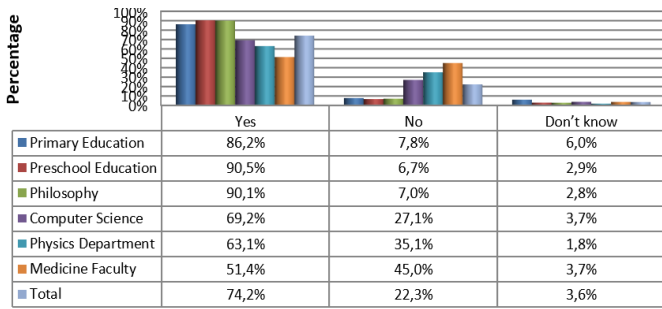


Figure 1. Distribution of students' answers to the 1<sup>st</sup> question: "Do you think cell phones/smartphones emit radioactivity?"

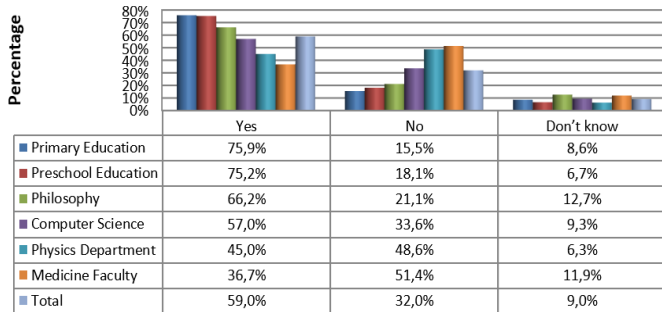


Figure 2. Distribution of students' answers to the 2<sup>nd</sup> question: "Do you think wireless networks emit radioactivity?"

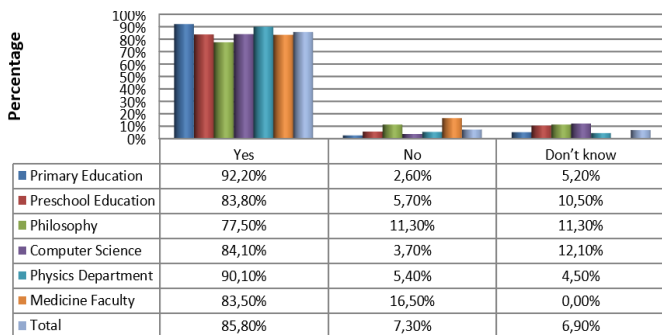


Figure 3. Distribution of students' answers to the 3<sup>rd</sup> question: "Do you think that the use of cell phones / smartphones causes biological effects on humans?"

A Chi-square test of Independence was performed to assess the relationship between the answers to the 1<sup>st</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(10, n=619)=85,882, p=.000<.05$ .

In the 2<sup>nd</sup> question: "Do you think wireless networks emit radioactivity?", only 32% of respondents gave the correct answer. The highest percentages of correct answers were recorded by medical students (51.4%) (Figure 2). A Chi-square test of independence was performed to assess the relationship between the answers to the 2<sup>nd</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(10, n=619)=68,816, p=.000<.05$ .

In the 3<sup>rd</sup> question: "Do you think that the use of cell phones/smartphones causes biological effects in humans?", 85.8% of respondents believe that there are biological effects. The highest percentage of students who consider that there are no biological effects is from the Medical School with 16.5%

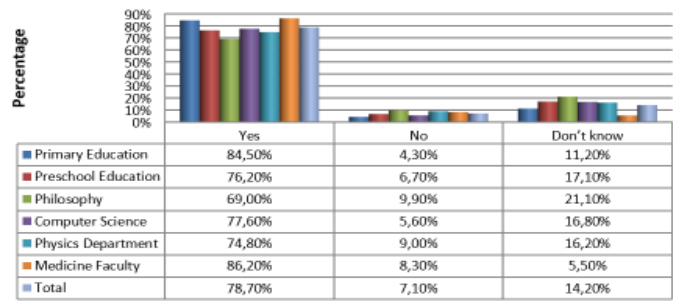


Figure 4. Distribution of students' answers to the 4<sup>th</sup> question: "Do you think cell phone towers have biological effect on animals?"

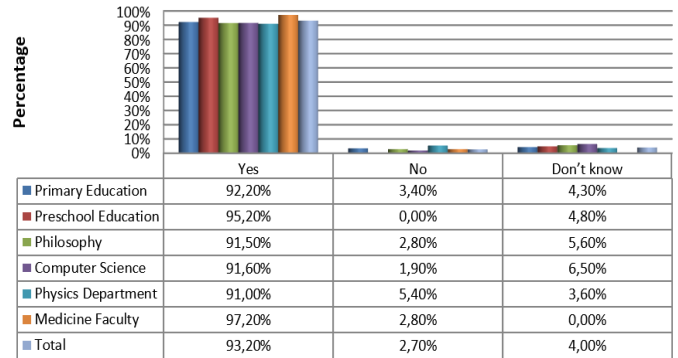


Figure 5. Distribution of students' answers to the 5<sup>th</sup> question: "Do you think that electromagnetic radiation can cause health problems in humans?"

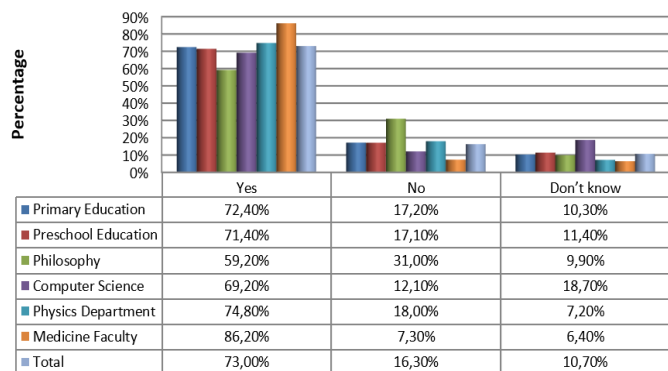
(Figure 3). A Chi-square test of independence was performed to assess the relationship between the answers to the 3<sup>rd</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(10, n=619)=39,127, p=.000<.05$ .

In the 4<sup>th</sup> question: "Do you think cell phone towers have biological effect on animals?", 78.7% of respondents believe that there are biological effects. The highest percentage of students who consider that there are no biological effects was from Philosophy Department (Figure 4). A Chi-square test of independence was performed to assess the relationship between the answers to the 4<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(10, n=619)=16,012, p=.099>.05$ .

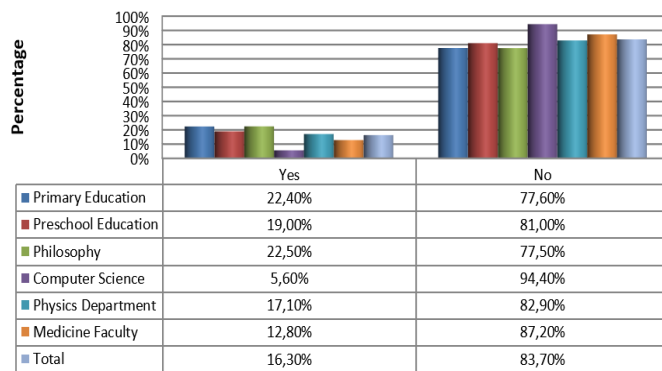
In the 5<sup>th</sup> question: "Do you think that electromagnetic radiation can cause health problems in humans?", 93.2% of respondents answered yes (Figure 5). A Chi-square test of independence was performed to assess the relationship between the answers to the 5<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(10, n=619)=13,328, p=.206>.05$ .

In the 6<sup>th</sup> question: "Do you think that electromagnetic radiation is more dangerous for young children than adults?", 73% of respondents answered yes. The highest percentage of students who answered negatively to the above question is from Philosophy Department with 31% (Figure 6). A Chi-square test of independence was performed to assess the relationship between the answers to the 6<sup>th</sup> question and the department of the participants. There was a significant

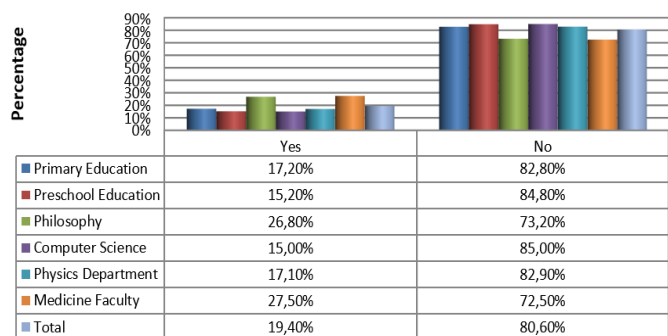




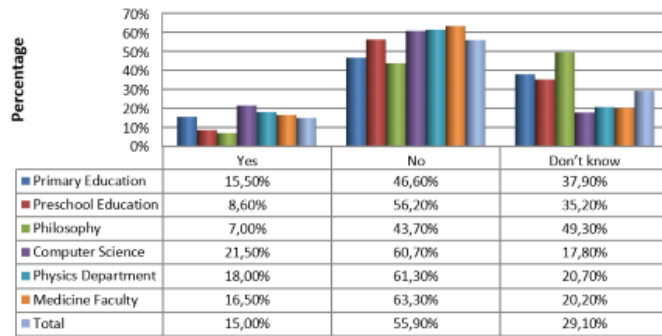
**Figure 6.** Distribution of students' answers to the 6<sup>th</sup> question: "Do you think electromagnetic radiation is more dangerous for young children than adults?"



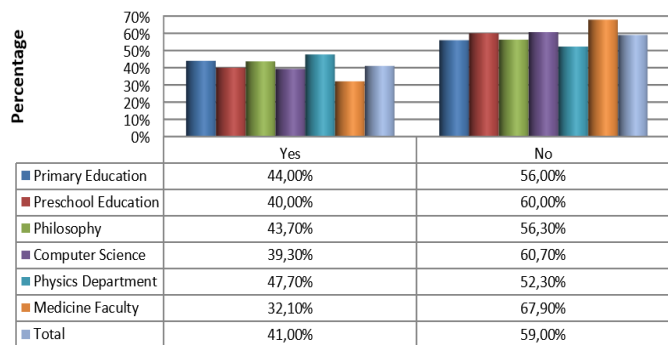
**Figure 9.** Distribution of students' answers to the 9<sup>th</sup> question: "Would you rather not have wireless networks within the university (classrooms, laboratories)?"



**Figure 7.** Distribution of students' answers to the 7<sup>th</sup> question: "Would you install a cell phone antenna on the roof of your home?"



**Figure 10.** Distribution of students' answers to the 10<sup>th</sup> question: "Is the rate of SAR of a cell phone the main criterion for you when buying it?"



**Figure 8.** Distribution of students' answers to the 8<sup>th</sup> question: "Would you prefer, within the boundaries of your municipality or area, to not have cell phone towers?"

relationship between the two variables,  $\chi^2(10, n=619)=30,635$ ,  $p=.001<.05$ .

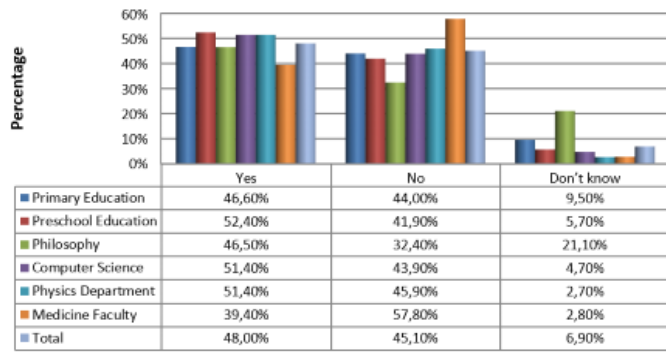
**Questions for Behaviors**

In the 7<sup>th</sup> question: "Would you install a cell phone antenna on the roof of your house?", only 19.4% of respondents gave a positive answer. The highest percentage of respondents who stated that they are negative about the placement of a cell phone antenna was students of Computer Science Department with 85% (Figure 7). A Chi-square test of independence was performed to assess the relationship between the answers to the 7<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(5, n=619)=10,297$ ,  $p=.067>.05$ .

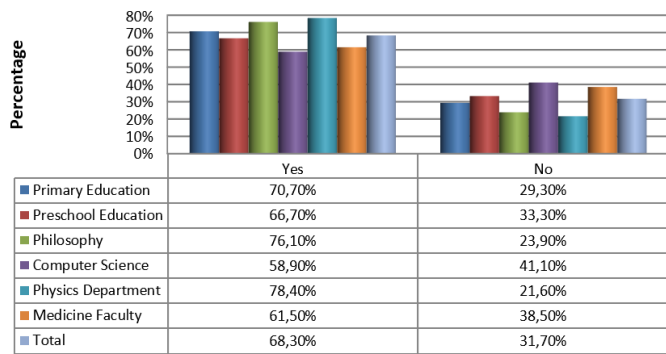
In the 8<sup>th</sup> question: "Would you prefer, within the boundaries of your municipality, or area, to not have cell phone towers?", 41% of respondents answered in the affirmative. The highest percentage of respondents who stated negative in the above question was medical students with 67.9% (Figure 8). A Chi-square test of independence was performed to assess the relationship between the answers to the 8<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(5, n=619)=6,457$ ,  $p=.265>.05$ .

In the 9<sup>th</sup> question: "Would you rather not have wireless networks within the university (classrooms, laboratories)?", only 16.3% of respondents answered positive. The highest percentage of respondents who stated negative in the above question was Computer Science students with 94.4% (Figure 9). A Chi-square test of independence was performed to assess the relationship between the answers to the 9<sup>th</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(5, n=619)=15,745$ ,  $p=.008<.05$ .

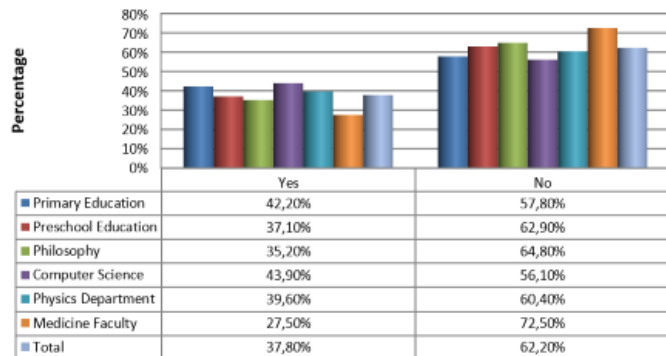
In the 10<sup>th</sup> question: "Is the rate of SAR of a cell phone the main criterion for you when buying it?", only 15% of respondents answered positive. It is important to mention that 49.3% of the students of Philosophy Department stated that they did not know what was (Figure 10). A Chi-square test of independence was performed to assess the relationship between the answers to the 10<sup>th</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(10, n=619)=40,376$ ,  $p=.000<.05$ .



**Figure 11.** Distributing of students' answers to the 11<sup>th</sup> question: "Do you use wired (Ethernet) network to connect your computer to the Internet at home?"



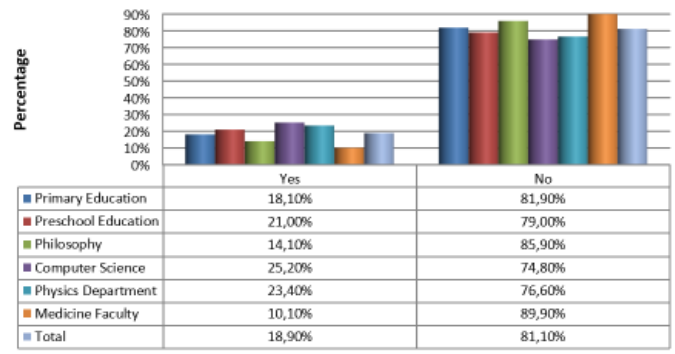
**Figure 12.** Distribution of students' answers to the 12<sup>th</sup> question: "Do you prefer to use wired headphones or speakerphone mode while talking on your cell phone?"



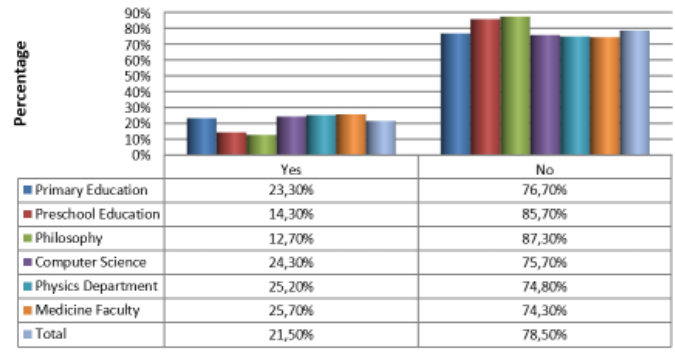
**Figure 13.** Distribution of students' answers to the 13<sup>th</sup> question: "Do you prefer to talk on cord telephones instead of cordless?"

In the 11<sup>th</sup> question: "Do you use wired network (Ethernet) to connect your computer to the Internet at home?", 48% of respondents answered positive. Medical students with a percentage of 57.8% stated that they do not use it (Figure 11). A Chi-square test of independence was performed to assess the relationship between the answers to the 11<sup>th</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(10, n=619)=37,737, p=.000<.05$ .

In the 12<sup>th</sup> question: "Do you prefer to use wired headphones or speakerphone mode while talking on your cell phone?", 68.3% of respondents answered positive. 41.1% of computer science students do not prefer the use wired headphones (Figure 12).



**Figure 14.** Distributing of students' answers to the 14<sup>th</sup> question: "When you don't use your home's Wi-Fi network, do you turn off your modem-router?"



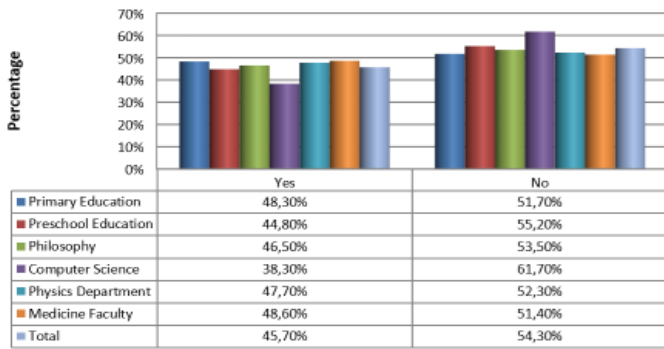
**Figure 15.** Distribution of student answers to the 15<sup>th</sup> question: "When you sleep do you turn off or set your cell phone in 'flight mode'?"

A Chi-square test of independence was performed to assess the relationship between the answers to the 12<sup>th</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(5, n=619)=14,361, p=.013<.05$ .

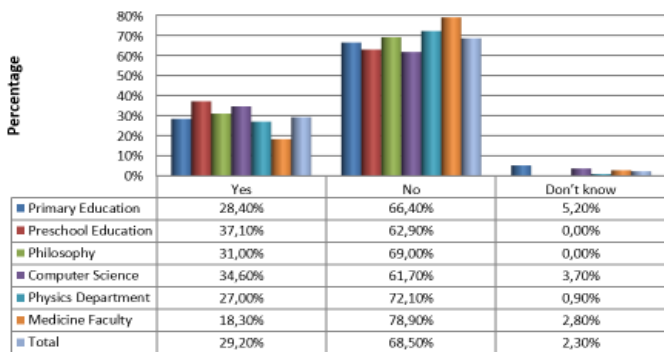
In the 13<sup>th</sup> question: "Do you prefer to talk on cord telephones instead of cordless?", only 37.8% answered positive. Medical students at a rate of 72.5% prefer to talk on cordless phone at home (Figure 13). A Chi-square test of independence was performed to assess the relationship between the answers to the 13<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(5, n=619)=7,958, p=.159>.05$ .

In the 14<sup>th</sup> question: "When you do not use your home's Wi-Fi network, do you turn off your modem-router?", only 18.9% of respondents answered yes. On the contrary, most students do not turn off their modem-router (Figure 14). A Chi-square test of independence was performed to assess the relationship between the answers to the 14<sup>th</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(5, n=619)=11,209, p=.047<.05$ .

In the 15<sup>th</sup> question: "When you sleep do you turn off or set your cell phone in 'flight mode'?", only 21.5% of the respondents gave a positive answer. On the contrary, most students do not turn off their mobile phones (Figure 15). A Chi-square test of Independence was performed to assess the relationship between the answers to the 15<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(5, n=619)=9,277, p=.099>.05$ .



**Figure 16.** Distribution of students' answers to the 16<sup>th</sup> question: "When you do not use your cell phone, do you place it at a distance more than one meter from your body?"



**Figure 17.** Distributing students' answers to the 17<sup>th</sup> question: "When you do not need internet, do you disconnect your laptop or tablet from Wi-Fi?"

In the 16<sup>th</sup> question: "When you do not use your cell phone, do you place it at a distance more than one meter from your body?", 45.7% of respondents said that they do that (Figure 16). A Chi-square test of independence was performed to assess the relationship between the answers to the 16<sup>th</sup> question and the department of the participants. There was not a significant relationship between the two variables,  $\chi^2(5, n=619)=3,277, p=.657>.05$ .

In the 17<sup>th</sup> question: "When you do not need internet, do you disconnect your laptop or tablet from WiFi?", only 29.2% of the respondents answered that they do that (Figure 17). A Chi-square test of independence was performed to assess the relationship between the answers to the 17<sup>th</sup> question and the department of the participants. There was a significant relationship between the two variables,  $\chi^2(10, n=619)=21,595, p=.017<.05$ .

**Correlations Between Questions**

In order to assess whether someone who thinks that the mobile phone emits radioactivity, believes that wireless networks also emit radioactivity a Chi-square test of independence was performed to assess the relationship between the answers to 1<sup>st</sup> question and the answers of 2<sup>st</sup> questions. There was a significant relationship between the two variables,  $\chi^2(4, n=619)=345,214, p=.000<.05$ . Then a CMHT was performed to assess the relationship between the answers to each attitude question and all the other questions of this category (questions 3, 4, 5, and 6). There was a significant relationship between all the questions of this category (Table

**Table 2.** Correlations between attitude questions

	Q-3	Q-4	Q-5	Q-6
Q-3		.000**	.000**	.004**
Q-4	.000**		.000**	.000**
Q-5	.000**	.000**		.002**
Q-6	.004**	.000**	.002**	

Note. \*\*Correlation is significant at 0.05 level; Sig. (2-tailed); & p<.05

2). Correlations with a value of p<.05 are highlighted in gray in the table. This means that if someone considers, for example, electromagnetic radiation dangerous for humans, it is very likely that they also consider it dangerous for animals. The reverse can also be true, i.e., if he does not consider it dangerous for humans, he will not consider it for animals.

In addition, a CMHT was performed to assess the relationship between the answers to each behavior question and all the other questions of this category (questions 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17). There was a significant relationship between most of the questions of this category (Table 3). Correlations with a value of p<.05 are highlighted in gray in the table. It was found that there are no correlations only between questions related to more specific technical issues such as the SAR, and wired Ethernet networks (questions 10 and 11). This means that if someone follows a certain practice or behavior in terms of protecting their health from emitted electromagnetic radiation, it is very likely that they also follow some other protection practices. Of course, this also means the reverse, i.e., if they do not follow a certain behavior, they probably does not follow other behaviors.

The last CMHT was performed to assess the relationship between the answers to each attitude questions (questions 3, 4, 5, and 6) and the answers to each behavior questions (questions 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17). There was not a significant relationship between the questions (Table 4). Correlations with a value of p<.05 are highlighted in gray in the table. Only four couples of questions were found that have significant relationship (question 3 with question 17, question 4 with question 8, question 4 with question 10, and question 6 with question 10). This result shows that, even if someone considers the electromagnetic radiation emitted by mobile phones and wireless networks to be dangerous, it does not mean that they will follow some practices or behaviors in order to protect their health from it.

**DISCUSSION**

Electromagnetic radiation is a very complex subject in terms of understanding it, as found from the literature review and the results of this study. Students' knowledge on the subject of electromagnetic radiation was of a very low level. Even students from Physics Department are distinguished by misconceptions, where electromagnetic radiation issues are subject of extensive study. In the majority of the questions, wrong perception was found, with the surveyed students from Pedagogical and Philosophical Departments, in all cases, they are having significantly less knowledge than medical or computer science students.

In all cases, the answers in knowledge questions are significantly related to the parameter of the department in

**Table 3.** Correlations between behavior questions

	Q-7	Q-8	Q-9	Q-10	Q-11	Q-12	Q-13	Q-14	Q-15	Q-16	Q-17
Q-7		.001**	.664	.027**	.034**	.512	.447	.340	.659	.295	.622
Q-8	.001**		.000**	.361	.105	.783	.004**	.002**	.013**	.023**	.107
Q-9	.664	.000**		.013**	.657	.020**	.000**	.000**	.000**	.000**	.000**
Q-10	.027**	.361	.013**		.006**	.802	.439	.330	.172	.310	.378
Q-11	.034**	.105	.657	.006**		.377	.569	.269	.315	.589	.272
Q-12	.512	.783	.020**	.802	.377		.000**	.373	.006**	.007**	.762
Q-13	.447	.004**	.000**	.439	.569	.000**		.002**	.006**	.000**	.002**
Q-14	.340	.002**	.000**	.330	.269	.373	.002**		.000**	.000**	.002**
Q-15	.659	.013**	.000**	.172	.315	.006**	.006**	.000**		.000**	.000**
Q-16	.295	.023**	.000**	.310	.589	.007**	.000**	.000**	.000**		.000**
Q-17	.622	.107	.000**	.378	.272	.762	.002**	.000**	.000**	.000**	

Note. \*\*Correlation is significant at 0.05 level; Sig. (2-tailed); &  $p < .05$

**Table 4.** Correlations between attitude and behavior questions

	Q-7	Q-8	Q-9	Q-10	Q-11	Q-12	Q-13	Q-14	Q-15	Q-16	Q-17
Q-3	.664	.408	.441	.062	.461	.219	.297	.918	.374	.985	.009**
Q-4	.314	.019**	.449	.013**	.493	.696	.510	.332	.907	.280	.226
Q-5	.861	.179	.899	.076	.203	.877	.336	.551	.787	.839	.494
Q-6	.663	.954	.719	.009**	.643	.092	.721	.636	.928	.640	.038

Note. \*\*Correlation is significant at 0.05 level; Sig. (2-tailed); &  $p < .05$

which they study. There is a significant difference in the perceptions that students have formed on the issue of electromagnetic radiation from cell phones and wireless networks. This effect is mainly due to the differentiation of the study programs that they have followed during their studies in higher education. Of particular interest are the response rates on whether cell phones and WIFI modem routers emit radioactivity. These results agree and confirm the misconceptions that had been found in previous research, about the term radioactivity (Burcin & Ince, 2010).

Students, despite the knowledge they have acquired during their studies, do not seem to use them in their daily lives, thus forming misconceptions. It should be noted that the confusion may be due to the misuse of the term radioactivity by the media such as websites (Burcin & Ince, 2010) which are a means of searching information, for students (Gagan & Rakesh, 2013; Sahin et al., 2010). In addition, anything in which the term radiation is used tends to be considered harmful (Neumann & Hopf, 2012).

Students were found to have a particularly negative attitude towards the electromagnetic radiation from cell phones and wireless networks, as a very high percentage of them consider it harmful to humans and living organisms regardless of the field they are studying. The results of this research are also in agreement with the results of a research conducted on adults by Cousin and Siegrist (2008), where 78% of the respondents answered that mobile phone radiation can have negative effects on people's health. Furthermore, a study conducted by Gautam and Shakya (2016) on 145 college students to assess their knowledge about health risks, about 75% reported that they knew about the cancer risk of cell phones. Also, other researchers have reached similar conclusions (Al-Muhayawi et al., 2012; Kumar et al., 2011; Nasser et al., 2018; Pendse & Zagade, 2014).

Differentiation that agrees with the research of Hassoy et al. (2013), it was found in children's risk compared to adults where it was the least supported concept in the dimension of

mobile phone risk perception. Kristiansen et al. (2009) report that some local governments have banned cell phone antennas in public buildings due to concerns about cancer, particularly brain cancer in children and impaired psychomotor functions.

In the present research, no correlation was found between the students' perceptions and the department in which they study. That is, the knowledge they have acquired does not affect the perception of risk from the radiation emitted by wireless technologies. These results contradict the results of the research of Hassoy et al. (2013), where students' risk perception is influenced by the department in which they study. This differentiation can be traced to the fact that the educational departments of the present research have a similar policy regarding the use of mobile phones within the departments, while on the contrary in the other research it was stated that there was a great differentiation between the departments where they studied, regarding the use of mobile phones. In addition to the risk perception from mobile phones, a risk perception from base stations was also found, which has also been published in research by Blettner et al. (2008).

According to the literature in the majority of cases we would expect there to be a particularly strong correlation between the attitude of the participants and the behavior they will follow (Ajzen & Fishbein, 2005; Armitage & Conner, 2001; Bagozzi, 1981; Glasman & Albarracín, 2006; Kraus, 1995). In this research, knowing the respondents' negative attitude towards the effects of wireless technology on health, we would expect a protective attitude against it, however, we did not find such correlation. Why the attitudes of some information technology users are not closely related to their usage behaviors has been established in other studies where the concept of attitude strength was also introduced (Bhattacharjee & Sanford, 2006). Also, in a survey on knowledge and attitudes towards smoking, although a good knowledge of the dangers of smoking was found, however, this knowledge and attitude did not necessarily translate into health behaviors such as not smoking (Lee et al., 2017).



It is difficult to determine any variable or explanation which accurately answers why attitude does not always predict behavior, because it's a combination of factors that lead this inconsistency. If we would like to answer the above question regarding the inconsistency of attitude and behavior, perhaps we should consider the need of young people for constant communication and socialization at any time (Hassoy et al., 2013). While on the one hand they want to be protected, for example, from cell phone towers, which are the responsibility of others, on the other, when they themselves have to change practices that may affect the way they communicate via mobile phones (switch off WiFi, set flight mode, put device far from body etc.), it was found that they were unable to do. Also, the anxiety of loneliness and stronger need for belongingness are some reasons for people to communicate via smartphones all the time (Kumar & Arulchelvan, 2018; Pearson et al., 2010). Another variable that we should take into account is that according to much research (Bhardwaj & Ashok, 2015; Kamibeppu & Sugiura, 2005; Kumar & Sriram, 2018; Oulasvirta et al., 2012), teenagers are characterized by a high addiction to the use of mobile phones, while also found the increasing addiction over time (Jun, 2016). In addition, we should consider that the possible serious effects on a person's health due to the electromagnetic radiation emitted by wireless technologies, such as cancer, are not immediate (Meena et al., 2016; Singla & Gopalakrishnan, 2019), something that is also seen in the health effects of smoking (Lee et al., 2017). Finally, we should consider that maybe students did not know the recommendations from international health organizations, to not keep cell phone close to head when making a voice call, to prefer sending text messages, to use wired headphones and not put phones next to bed, as protection practices from electromagnetic radiation (Government Advice, 2022). All the above parameters that we have mentioned, may be the reason why the non-correlation of the attitudes with the respondents' behaviors was observed, and actually affect the strength of the attitude, which is the focus of a huge amount of research in psychology and related sciences for decades (Howe & Krosnick, 2017).

## CONCLUSIONS

In conclusion, while research into the effects of electromagnetic radiation on human health continues, it would be important to approach this issue with a precautionary policy until we reach definitive conclusions. On the one hand we need to further investigate the reasons that lead students to such erroneous knowledge and perceptions on the subject of electromagnetic radiation and on the other hand we need to make efforts to inform students about the proper use of technology in order to prevent health problems. Education should provide the necessary knowledge and take care of the development of critical thinking of future citizens. The knowledge and experiences that students gain during their studies at the University should contribute to this direction, regardless of the department in which they study.

### Future Directions

Based on the above conclusions and findings, some directions are proposed for further study and investigation

around the subject of electromagnetic radiation. These directions concern the field of teaching physics (concept of electromagnetic radiation), the field of environmental education (concept of electromagnetic pollution), the field of medicine (investigation of biological effects of electromagnetic radiation), the field of informatics (development and design ICT) and the field of health education (protection and critical attitude towards the use of ICT). In summary, these directions are, as follows:

1. Further research and recognition of alternative ideas around electromagnetic radiation.
2. The development of teaching practices to eliminate alternative ideas about radiation.
3. The development of environmental education programs aimed at informing students about electromagnetic pollution.
4. The development of health education programs, so that students acquire a critical attitude towards their health and use of devices that emit electromagnetic radiation.
5. The design and development of ICT (mobile phones, wireless networks, etc.) aimed at minimizing the emitted radiation.

### Limitations

The generalizability of the study findings may be considered limited because the study participants were sampled from a local area as well as the same educational level. Another limitation could be the respondents' self-reports which may contain some bias. In addition, the survey tool was designed exclusively for the characteristics of the specific sample and the specific limitations during the collection of survey data. Therefore, its application to a sample with different characteristics can be considered precarious.

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