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Inquiry Laboratory Activity: Investigating the Effects of Mobile Phone on Yeast Viability

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ABSTRACT
Practical work as observation and experimentation are vital parts of science education. One way to accomplish this is by applying inquiry-based learning in laboratory activities. Inquiry enhances the development of scientific skills as well as the learning of the scientific concepts. In the present article, a laboratory activity was developed to evaluate the effect of ionizing waves emitted by different mobile phone types on viability of yeast cells. We got yeast cells as a cellular model, since yeast is a eukaryotic cell, as humans are, and many investigations are based on them. The procedure is simple and adaptable to school centers with low resources, using low-cost laboratory material.
In the experimental part, we found a decrease in yeast cells' viability exposed to radiations compared to control cells. Also, different viabilities were found depending on the phone trademark used. Further studies should be done in this line.

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Introduction

Science is based on understanding how the world works. Thus, it is crucial for the learning of science based on observation and experimentation. Students must be aware that the explanations that help us understand how the world works must be based on empirical evidence (Bybee, 2006). So, practical work is a vital part of science education. It promotes that students acquire and understand science knowledge, notice that science is based on evidence, and develop hands-on skills that are essential if students need to progress in science (Abrahams & Millar, 2008). One way to accomplish this aim could be to apply an active-learning strategy such as inquiry-based learning (IBL). Science educators have discussed the definition of inquiry. It is generally agreed that the inquiry enhances the development of science skills and the learning of the scientific concepts themselves (Lunetta et al., 2007). The National Science Education's Standards (National Research Council, 1996) emphasized that science teaching and learning should be focused on developing science inquiry skills, not only learning facts and concepts. Inquiry-based learning corresponds to a pedagogical strategy based on the process of scientific inquiry as to its teaching and learning methodology (Bybee, 2004). In this sense, IBL, as a teaching approach, is a student-centered pedagogy capable of developing the high order skills and improving the knowledge of students. It can also improve the attitude towards science in school and develop an understanding of nature of science (Lunetta et al., 2007). In the guided inquiry model teachers conduct students through the experiments and act as leaders (DiBiase & McDonald, 2015). Inquiry based laboratory activities allow enhancing students' abilities and skills such as posing

questions scientifically, formulating hypotheses, designing, and conducting scientific investigations, developing scientific explanations, and defending scientific arguments (Hofstein et al., 2005; Krajcik et al., 2001; Pedaste et al., 2015).

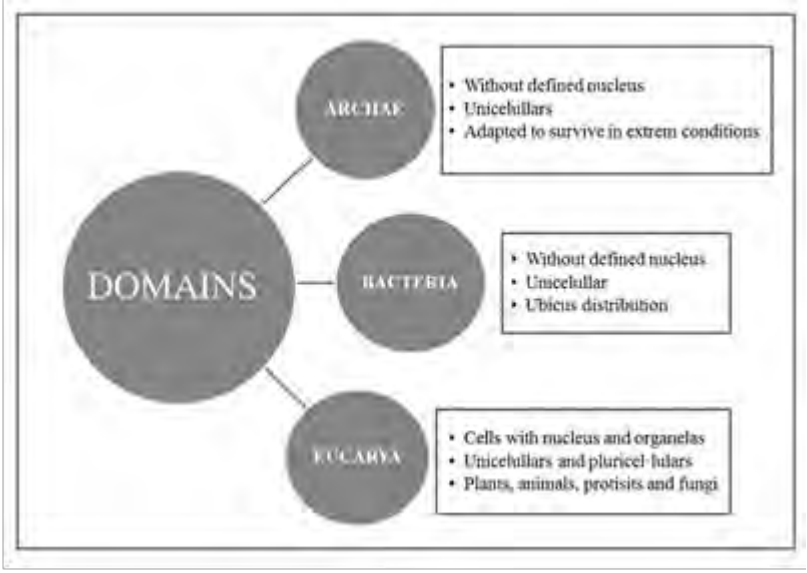
Abd-El-Khalick et al. (2004) claimed that when students participate in an IBL, the academic results improve, especially in science and mathematics. Scientific inquiry involves different ways in which scientists (and in this case students) study the natural world by posing questions and developing explanations based on evidence and data derived from their work (DiBiase & Mcdonald, 2015). Furthermore, applying inquiry in practical science work is the clue to gain scientific literacy (Hofstein & Mamlok-Naaman, 2007). The scientific inquiry is considered a backbone to investigate phenomena, acquire new knowledge, or correct and integrate previous knowledge. The inquiry process includes making observations, identifying problems, formulating questions, developing hypotheses, designing and planning experiments, collecting and analyzing data, summarizing results, drawing conclusions and finally communicating the research. Systematic thinking is required for learners to observe, question, experiment, and control variables throughout the process to validate their hypotheses. Therefore, using the class's scientific method, we will help students develop their scientific skills. Moreover, the scientific method helps students understand science and acknowledges that science is based on evidence and acquire practical skills that are essential if we want students to progress in science (Abrahams & Millar, 2008).

Sometimes it is not easy to find an inquiry activity which motivates students. They are usually interested in knowing how radiations, drugs or toxins could affect people's health, which is difficult to prove with the resources and infrastructures we must develop an IBL in secondary education centers. A good alternative may be to use yeasts as a cellular model to develop these inquiry activities.

Yeasts are mainly used in secondary schools to study the fermentation process, particularly the alcoholic fermentation although very few teachers use them as experimental model organisms (Knabb & Misquith, 2006; Blanco & Nieto, 2015). The yeast is a good/robust experimental model organism because it shares a cellular architecture with multicellular eukaryotic organisms and an easy to grow and handle with a prokaryotic organism. That is why we can use these cells to test the effect of toxic substances or some radiation (Forsburg, 2007). We cannot extrapolate the results obtained in yeasts directly in humans, saying that the effects caused in microorganisms are not the same as that humans would have. However, in research, yeasts are used as the first step to test new drugs and suggest possible effects on human beings.

Figure 1

Domains Classification Organisms and Its Characteristics



Yeasts are well-known unicellular microorganisms since they are the main culprit of bread, wine, or beer fermentation. Usually, the laboratory activities that we can find are related to yeasts as fermentative organisms (Knabb & Misquith, 2006; Blanco & Nieto, 2015). Nevertheless, they are eukaryotic cells like mammalian or plant cells. Yeasts belong to the Eucarya domain, and they share cellular characteristics with major species (Figure 1). In the Eucarya domain, yeasts belong to the fungi kingdom and moulds, smuts, and mushrooms. The most well-known yeast is Saccharomyces cerevisiae which has become a versatile and robust eukaryotic model (Mell & Burgess, 2002; Vojisavljevic et al., 2016).

Yeasts cells share with the other eukaryotic cells the essential characteristics: they have membrane organelles including the nucleus, mitochondria, peroxisome and organelles of the secretory pathway. Six thousand genes compose yeast's genome through the 12 megabase pairs of DNA organized in 16 linear chromosomes (Mell & Burgess, 2002).

Although it seems that human and unicellular fungi organisms do not have many things in common from a macroscopic point of view, from a molecular perspective they do present some similarities (Table 1) as that they share 31% of their genome sequence (Mell & Burgess, 2002).

Table 1

Differences between Characteristics of Bacteria, Yeasts and Mammalian Cells

Characteristics	Bacteria	Yeasts	Mammalian cells
Size	< 1 μm	3-5 μm	10-50 μm
Doubling time	30 min to 1h	2-3h	24-48h
Type of cells	Prokaryote	Eukaryote	Eukaryote
DNA held in linear chromosomes	no	yes	yes
Asexual/sexual reproduction	asexual	Asexual with some sexual behaviors	Sexual
Type of feeding	autotroph and heterotroph	heterotroph	heterotroph
Respiration	some aerobic and others anaerobic	facultative	Aerobic
Unicellular/pluricellular organisms	Unicellular	Unicellular fungus	Pluricellular
% genome shared with human cells	10%	31%	100%
Millions or billions of bases pares in DNA	4 Mpb	12Mpb	2 Bpb
Number of genes	3000	6000	20000

As microorganisms, yeasts could grow in batch liquid culture or isolated as colonies from a single cell on solid media. The optimal temperature for the growth of Saccharomyces is between 27 and 32ºC. However, it can grow in a vast range of temperatures from 12-15ºC (useful to ferment aromatic wine wines) to 37ºC, from 40ºC the growth is inhibited (Alonso-del-Real et al., 2017). Being unicellular microorganisms that divide themselves quite quickly (about 90 minutes) makes it possible to grow large populations to be analyzed. Working with them is less time-consuming and cheaper, so they make the best candidate for educational use. On the other hand, it is essential to bear in mind that this model can never simulate pluricellular organisms' complexity.

In the present work, we present a laboratory activity based on IBL. This inquiry laboratory activity combined two elements: on the one hand, the mobile phone since it is a gadget that is present in the daily life of the students; on the other hand, we have worked with yeasts, as a new organism for students that we will use as a eukaryotic cell model organism. Using elements present in the students' environment provides the learning process with a meaningful sense and motivates students and uses new things to motivate the students.

This article has focused on two goals: first, we wanted to present yeasts as eukaryotic cell model to work in secondary schools; and the second one is to present an example of applying yeast's eukaryotic cell model through following the scientific method using a practical inquiry that we both designed and implemented.

In the last decade, humans have been increasingly exposed to radiation from microwave operating devices; from 2012, mobile phones have increased worldwide. Mobile phones work by sending signals to (and receiving from) nearby mobile towers (base stations) using RF (radiofrequency) waves. RF waves are a type of electromagnetic energy that is classified between FM radio waves and microwaves (http://www.cancer.org). Micro-waves radiation is considered non-ionizing radiation with frequencies between 0,3 and 300 GHz. Cellular phones emit microwaves from 824-850, 900, 1800 to 1900 MHz (Ahmed et al., 2015).

The primary learning outcome of this inquiry laboratory activity is that students will be able to:

- Determine the ionizing wave's effects emitted by different types of mobile phones on Saccharomyces cerevisiae yeasts' cell viability.

Along with the inquiry laboratory activity (Figure 2), the students reach some secondary learning outcomes as a result of their laboratory work; they will be able to:

- Follow the different steps of the scientific method.
- Realize that yeasts are eukaryotic cells that could be used as a cellular model.
- Prepare dilution baths.
- Execute work in sterile conditions.
- Experiment the growth of yeasts in liquid and solid culture media.

In the following figure, we present the elements of the scientific method that were developed to answer our research question:

Figure 2

Steps to Follow in an Experiment Following the Scientific Method

Material and Methods

Students Group

This laboratory activity could be addressed/directed at any course of secondary school. This activity aims to develop scientific inquiry competence and learn how to use the yeasts as a cellular

model. Depending on the experimental design's complexity (maybe adapted into different levels), we could take one course or another. The example of inquiry that we present in this work was applied by students of 16-17 years old.

Reagents and Equipment

Unfortunately, sometimes secondary schools have no infrastructures or material to develop this type of laboratory activities. For this reason, we suggest low-cost materials to substitute the expensive ones, more appropriate for research in a laboratory (Table 2).

Table 2

The Table Shows the Laboratory Material and Their Usage and Low-Cost Material as an Alternative

Laboratory material	Low-cost alternative material	Use
ADY (Active Dry Yeast) *Saccharomyces cerevisiae*	Bakery fresh yeast	Model organism of study
Automatic pipette	Pasteur pipette or volumetric material to get approximate volume values	Precise measure for little volumes
Tub Eppendorf tubes and a holder	Any plastic sterile tubes	Contain the yeast culture to be exposed at different conditions. Should have little volume because one of the tubes must be carried on together with your mobile phone
Erlenmeyer	Glass or glass jar	To content the yeast culture
Beaker	Glass or glass jar	To content ethanol to sterilize the handle
Digralsky handle	We can model with a flame a straight glass bar	Sowing as grass or count viable yeast cells.
Bunsen	You can do a homemade ethanol burner with a glass jar, ethanol, and wick. Also, it can be used a campfire.	To sterilize handles and to create a sterile environment.
Flow cabinet	We can directly use the Bunsen instead of the flow cabinet	To maintain a sterile environment
Petri plate with YPD solid media	Petri plates with YPD media, can be bought directly done or you can do it buying the products separately as indicated in the protocol above	Plastic vessel to content the solid media. Media could be elaborated with concentrated broth and agar (agar can be bought in Chinese supermarkets because they use it to make some typical meals)
Growing stove	It can be let at room temperature or adjust the temperature with a yogurt maker	Yeast can grow at the optimal temperature. If the optimal temperature is not optimal yeast can also grow, even though it can take a little more time
Spectrophotometer	We can count yeast cells with a Neubauer chamber	To measure the quantity of microorganisms we have in the liquid cell culture

The following equipment is required for these practical exercises: a microwave oven (or another method to heat water), an incubator, a fridge, plastic tubes (Eppendorf), Pasteur pipettes, plates, and a marker.

Products: active dry yeasts (*Saccharomyces cerevisiae* 1118, Lallemand S.A., Canada), Glucose (Panreac, Barcelona, Spain), Peptone (Panreac, Barcelona, Spain), Yeast extract (Panreac, Barcelona, Spain), agar- agar (Panreac, Barcelona, Spain).

Some characteristics of the mobile phones used in this laboratory activity are presented in Table 3.

Table 3

Usage, Benefits, Price, And SAR Details of Mobile Phones Used in The Study

Mobile phone	Usage level	Level of benefits	Price (€)	SAR (W/Kg) *max 1.16*
Samsung Galaxy Young II	Low use	Basic functions and some Apps	89	0.92
iPhone 6 plus	Very frequent use	High diversity of Apps	339	0.91
Nokia Lumia 520	Moderate use	Basic functions and some Apps	100	1.08
LG E-460	Moderate use	Basic functions and some Apps	139	0.87
Sony Xperia S	Very frequent use	High diversity of Apps	459	1.1
Nokia 2760	Low use	Basic functions	139	0.53

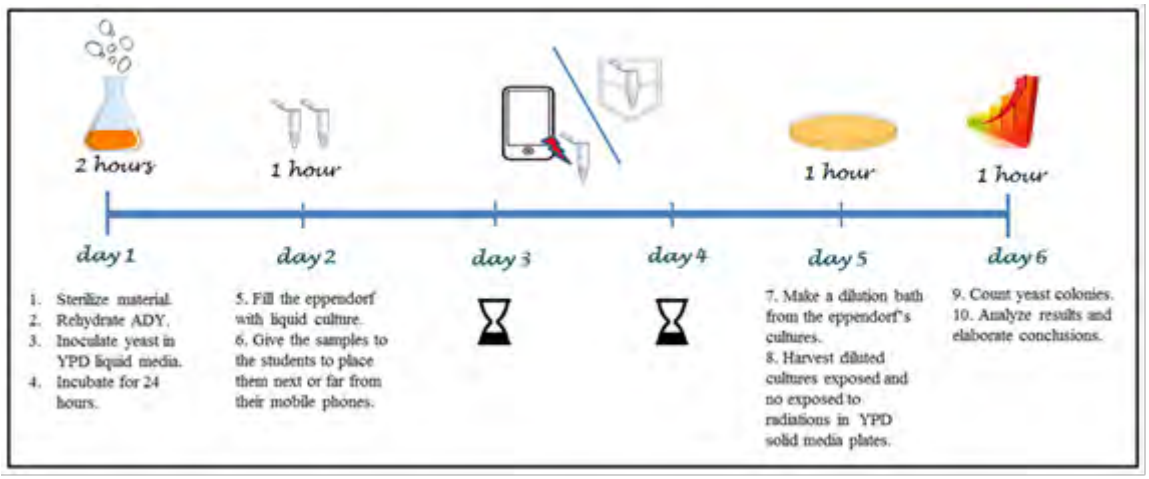
*Note. * SAR (specific absorption rate) that means the amount of RF energy absorbed from the phone into the user's body, expressed in watts per kilogram of body weight (W/Kg).*

Temporization

The temporization of the different tasks involved in the procedure in order to develop this inquiry laboratory activity are detailed in Figure 3.

Figure 3

Temporization of Inquiry Laboratory Activity Detailing Tasks to Do Each Day and Their Time Expending



Procedure

1) Sterilize material (Erlenmeyer, Eppendorf, water to rehydrate cells, culture media).

2) Rehydrate 1 g of active dry yeasts (ADY) from a commercial yeast strain SC1118 for 30 minutes at 37ºC in 10 mL of sterile water, with this; we should have a concentration of approximately 2·109 cells/mL.

3) After rehydration, 1 mL of rehydrated yeast cells (inoculum) is cultured in YPD (Yeast-Peptone-Dextrose) this medium contains 20 g/L glucose, 20 g/L peptones and 10 g/L yeast extract, we used an Erlenmeyer (capacity of 250 mL) filled with 20 mL YPD media.

4) Then, the culture is left to grow for 24 hours, in inconstant agitation.

5) Sterile Eppendorf is filled with 1mL of the yeast culture. The exact concentration of yeast culture is not essential; the key is the good homogenization of the culture and to put the same volume in all Eppendorf to assess we have the same number of yeast cells in each Eppendorf tube.

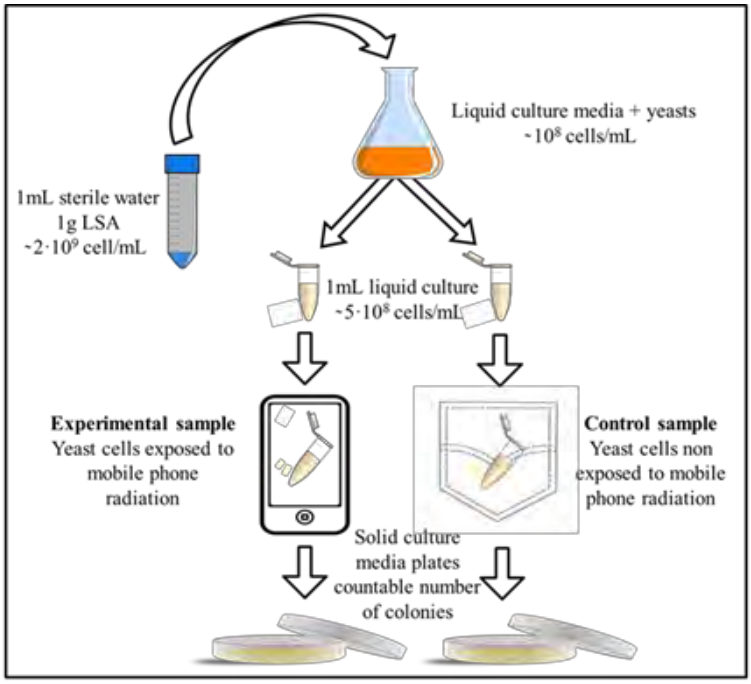
6) Every group of students has 2 Eppendorf. One of them is added with an adhesive tape to their mobile phone near the antenna (experimental group), and the other one must be kept in one pocket or a bag far away from the mobile, which will be the control group. Both tubes should have a similar agitation, similar temperature and they must be as separated as they can be during the incubation period (Figure 4). After the incubation period, 3-4 days after, the samples are taken to the laboratory to be analyzed. We have six samples (one for each mobile phone) with their six controls, respectively. We remark the importance of labelling each sample not to mistake them.

Considerations to keep in mind:

- It is essential to be careful with the Eppendorf. To avoid that they could open accidentally during the incubation time, it could be a good idea to use a parafilm piece to cover the top of the tube. Unfortunately, a tube opened accidentally it would not have negative consequences for students or the environment because this yeast strain is not dangerous. It is used to ferment some food that we regularly consume as bread or wine.
- Not all tubes will grow at the exact temperature. However, the most important is that each student tries to maintain both samples (experimental and control) at a similar temperature to compare them. Although the optimal temperature for yeast growth is 27ºC, they can also overgrow in a range from 15 to 37ºC.

Figure 4

Methodology Diagram to Develop the Experiment



7) If the yeast cultures in Eppendorf are too concentrated, then, to obtain a countable number of colonies when grown in YPD solid plates, preparing a dilutions bath will be necessary. For that reason, it will be necessary to prepare a dilution bath before its harvest (Figure 5). We estimated a total cell number of around $5 \cdot 10^8$ cells because a culture hardly reaches a 10^9 cells population since cells will lack nutrients. We performed successive dilutions until we finally had a countable number of cells to harvest on YPD solid plate (same media as liquid YPD, adding 1.7% of agar-agar).

8) We got 100µL of the last Eppendorf of the dilution bath with a pipette and extended it with a Digralsky handle along the entire plate surface. We repeated the procedure with the 12 YPD solid plates for each of the samples, and we let them at the incubator at 28ºC for 48 hours. A technique duplicate for

each sample is performed; this means that we would need to use 24 plates in total. Each experimental plate must be compared with its control one, and the living cells are calculated by counting colonies. The % of the decrease cell population is measured comparing with control cells growth at the same conditions.

9) Each solid plate should be like their replica, and an average can be calculated. Then, this value should be compared with plates harvested with no radiated cells (control). Then:

$$\%\ survival = \frac{\text{colonies on exprimental plate}}{\text{colonies on control plate}} x\ 100$$

Viable cells could be the average of replicates (plates harvested with the same sample):

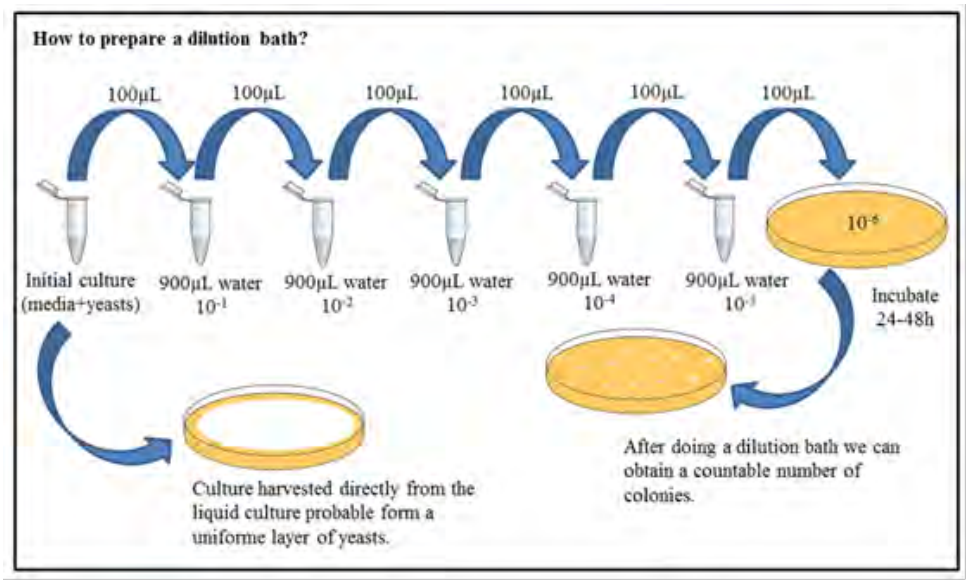
$$colonies\ on\ experimental\ plate = \frac{\text{colonies plate 1} + \text{colonies plate 2}}{2}$$

And the same equation will be applied to calculate viable cells on control plate.

10) Results were analyzed, and some statistics were performed trying to understand how these radiations affect yeasts.

Figure 5

How to Make a Dilution of a Liquid Yeast Culture to Obtain a Countable Number of Colonies



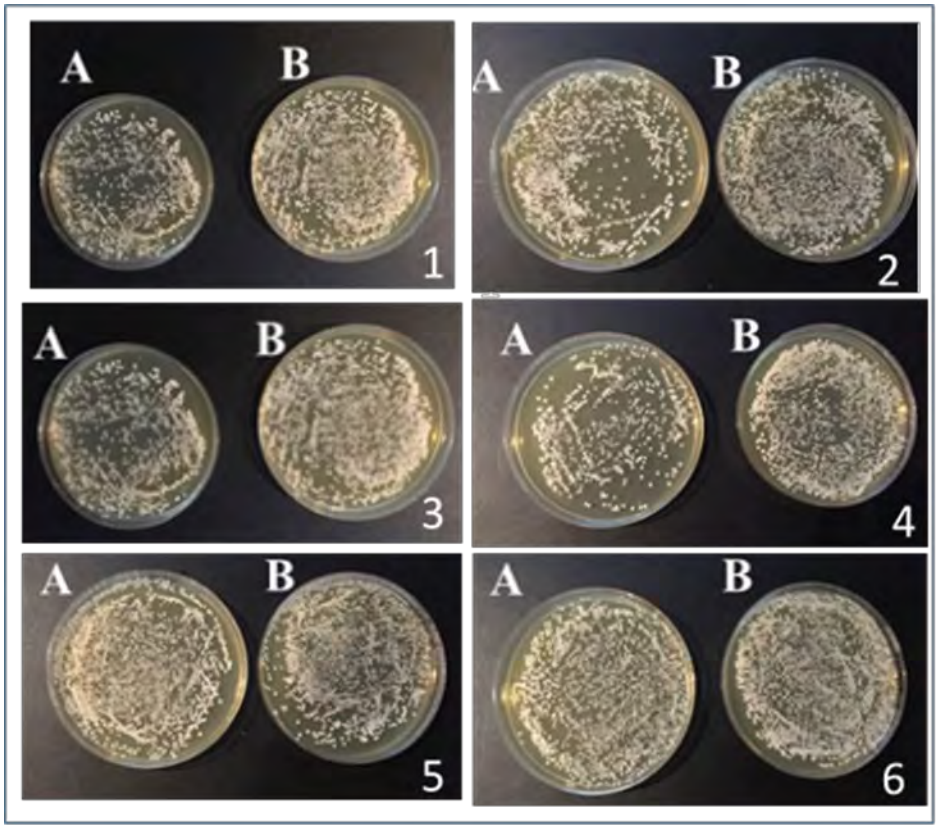
This method consists of counting yeast colonies on solid plates, and it has one biological replicate and two technological replicates. To increase the reliability and validation of these experimental results, more replicates should be taken. Biological replicates are defined as measurements of biologically distinct samples that show biological variation. In contrast, technical replicates are repeated measurements of the same sample that show independent measures of the noise associated with the equipment and/or the protocols (Blainey et al., 2014). Suppose the focus of the article was to assess real values of cell death with phone radiations. In that case, a more accurate analysis should be done, increasing the number of replicates to confirm the preliminary results of the investigation part of this article that we got. There are not a specific number of replicates that should be done in every investigation. More replicates mean more valid results -the number of replicates for each sample, biological or technological, is three. If the value of a sample is very different from the other two, it could be eliminated. Some scientific laboratory requires more to confirm the investigation results.

Results

Yeast cells growth differently on YPD media plates whether they have been exposed to radiations or not. We can observe this effect in Figure 6, where "plates A" are those cultures exposed to mobile phone radiation (1 to 6) analyzed in the present study. On the contrary, "plates B" represent control cultures for each mobile phone. Plates A and B must be compared individually for each mobile phone analyzed. At first sight of figure 6 some differences can be appreciated, being in some "plates A" fewer cells compared to their control plates. Moreover, taking a closer look at the plates, it is evident that, in most of them, the growth difference its significant.

Figure 6

Culture Plates Testing



Note. radiations (A) Cell culture exposed to mobile phone radiations, (B) Control cell culture. Numbers 1 to 6 represent different mobile phones used in this study. Legend: 1) Samsung Galaxy Young II, 2) iPhone 6 plus, 3) Nokia Lumia 520, 4) LG E-460, 5) Sony Xperia S, 6) Nokia 2760.

After counting the colonies in each plate, we have elaborated Table 4 in order to analyze objectively our results. In the following table we relate the number of colonies from the experimental condition with their control group measuring the percentage of survival cells. This percentage is calculated following the formula described in the protocol (point 9). The range of cell survival goes from 95% to 50%.

Table 4

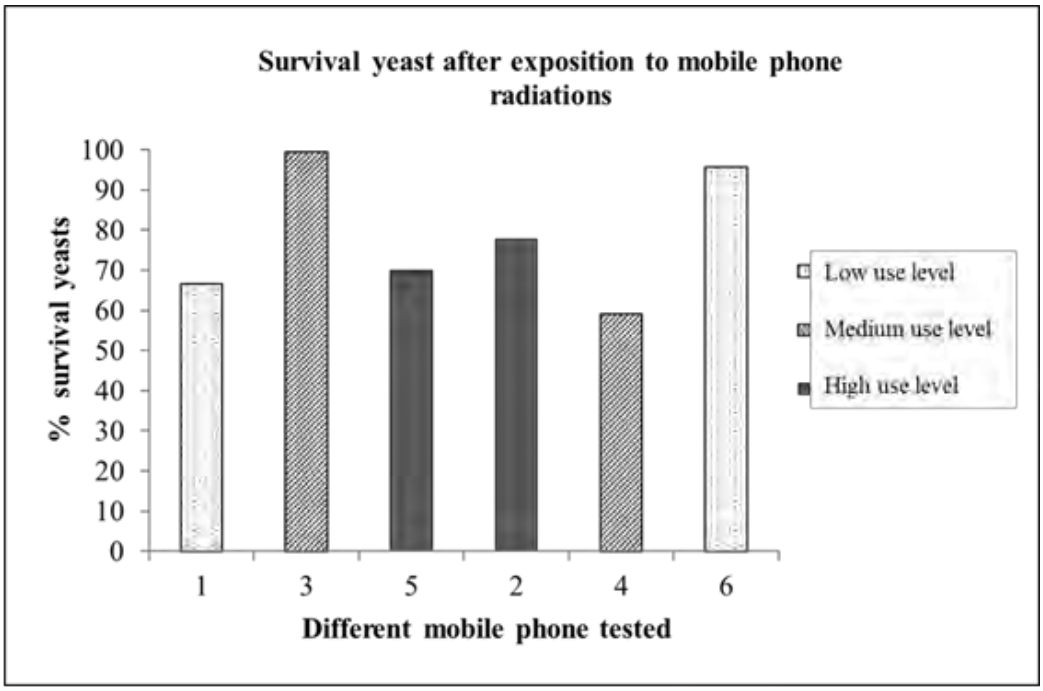
Number of Colonies Grown on a Solid Media YPD

Mobile phone	Viable cells in control samples	Viable cells in experimental samples	% survival
Samsung Galaxy Young II	1006	669.5	66.55
Nokia Lumia 520	1083	1076	99.35
Sony Xperia S	1021	716	70.12
iPhone 6 plus	1345	1047	77.85
LG E-460	920	543	59.02
Nokia 2740	783	750	95.78

Note. plates experimental samples vs. controls samples and percentage of survival relating these two values.

Figure 7

Survival Yeasts Cells (Expressed in Percentage)



Note. After being exposed to mobile phone radiations in comparison to control yeast culture. Mobile phones tested in this experiment were numerated from 1 to 6. Different shapes were used to distinguish between mobile phones with low, medium and regular use.

The values from table 3 are represented in Figure 7 and it can be clearly appreciated how the viability decreases in all cases after exposing yeast cells for 3 days to mobile phone radiations. However, the percentage of mortality depends on the mobile phone brand.

For instance, in the case of Nokia mobile phones (number 3 and 6) the effect on the survival is insignificant. Curiously, they are the only two mobile phones from the same trademark, which are the oldest ones, and this trademark is not producing mobiles nowadays. In both cases, we got a high survival percentage 99.35 and 95.78 respectively. Nokia Lumia 520 had a moderate use, while Nokia 2760 was used with very low frequency by the user. Both cases had survived up to 95%; then cells had a high viability even when exposed to phone radiations, regardless of the model of this trademark.

There is another group of mobile phones, formed by Sony Xperia S and iPhone 6 plus (number 5 and 2, respectively), in which 70.12% and 77.85% of yeast cells population grow in comparison to control cells. These mobile phones have a very frequent use, not only by using their basic functions (calls

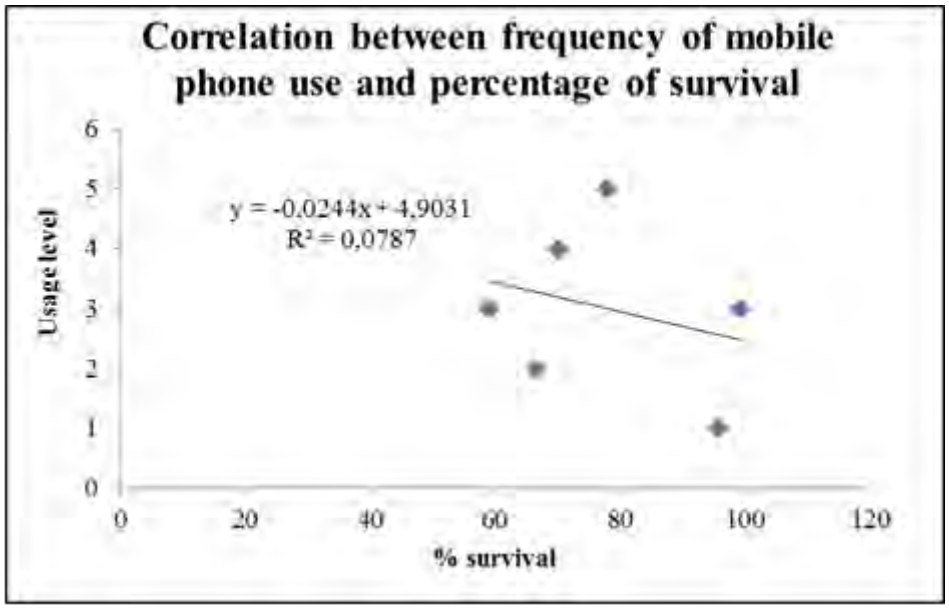
and messages) as well as for other uses like surfing the Internet, message service, games, and some Apps.

Finally, the far more affected yeasts were those that were exposed to radiations emitted by the mobile device Samsung Galaxy Young II (number 1), with a survival rate of 66.55%, and the worst of all, the LG E-460 (number 4), with a 59.02% survival rate. We should point out this last one since it has a moderate use, just for calling, sending messages, and listening to music on punctual occasions.

If we tried to find a relationship between the use frequency for mobile phones and the percentage of cell survival (Figure 8), we did not find a positive correlation. However, this is one of the factors that may affect the yeasts viability.

Figure 8

Correlation Between the Frequency of Use of The Devices and The Percentage of Survival



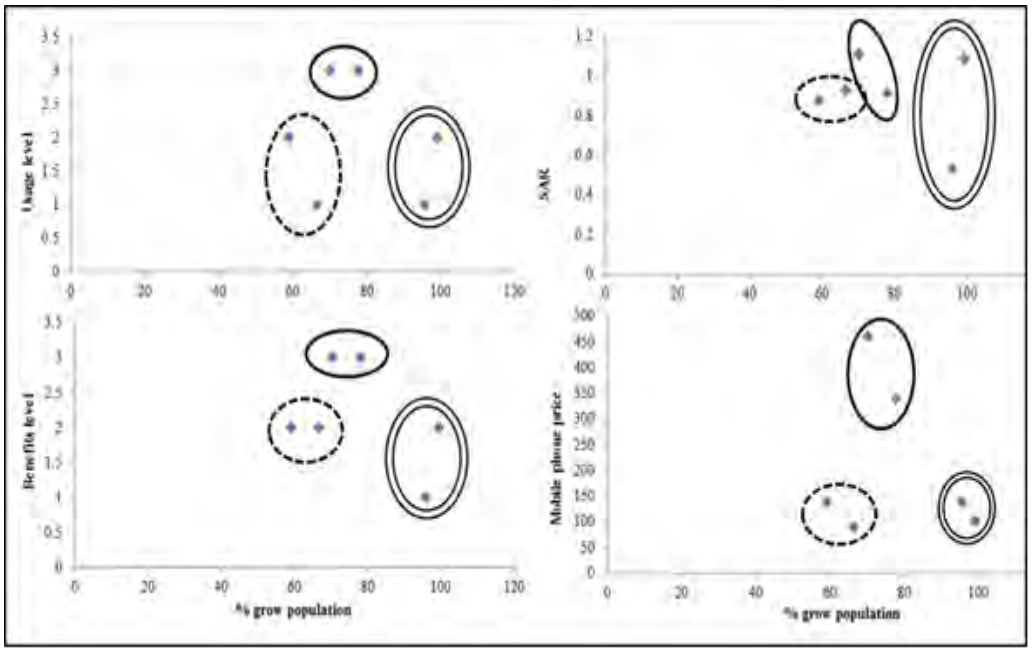
Note. We assume arbitrary vales of each mobile model depending on the frequency of use for each one: iPhone 6 plus (very frequent use = 5), Sony Xperia S (moderate-high use = 4), Nokia Lumia 520 and LG E-460 (moderate = 3), Samsung Galaxy Young II (little use = 2) and Nokia 2760 (punctual use = 1).

Relating the use frequency, the level of benefits, the price and the SAR of the devices with the percentage of surviving yeasts, we did not find any positive correlation. However, it can be seen that mobile devices can be divided into 3 groups, in the 4 cases (see Figure 9):

- The first group is formed by mobile phones Nokia Lumia 520 and Nokia 2740 (both from the same trademark, in double circle), nevertheless they have different characteristics, and the frequency of usage is quite different, the price is lower in both cases and the yeast cell mortality is the lowest. Referred to the SAR level Nokia 2740 has the lowest value for SAR whereas Nokia Lumia 520 has the highest one.
- The second group is composed by iPhone 6 plus and Sony Xperia S devices (continuous single circle). They have lots of benefits, the most expensive price and both presented a very frequent use. In this group the yeast viability is moderate (approximately 70%). Moreover, they presented the highest SAR level. Even though this group has more benefits and high usage, it could be hypothesized that they have a better isolation system.
- Finally, we circle another group (discontinuous line) which is formed by mobile phone devices Samsung Galaxy Young II and LG E-460. They have a quite frequent usage; the price is between the other groups and their viability is the lowest of all mobile phones studied in cells exposed to devices radiations in comparison to control cells. In this case, their SAR level is medium.

Figure 9

Relation Between the Frequency of Use, Level of Benefits and Price of The Device Vs. Percentage of Cell Survival, After Being Exposed to Mobile Phone Radiation for 3 Days



Note. We assigned arbitrary values in function of the level of usage: 1 for mobiles Samsung Galaxy Young II and Nokia 2760, 2 for mobiles Nokia Lumia 520 and LG E-460, and 3 for Sony Xperia S and iPhone 6 plus devices. We assign also numbers depending on the level of benefits: 1 for mobile Nokia 2760, 2 for mobiles LG E-460 and Samsung Galaxy Young II and finally, 3 for the devices Sony Xperia S and iPhone 6 plus.

Discussion

In the present paper, students develop an inquiry laboratory activity, which is the main objective. In this experiment, mobile phones have negatively affected yeasts viability in almost all cases. In 4 of the 6 mobile phones tested, yeast survival is reduced below 80%. These results coincide with those in other studies where different yeast species exposed to microwaves reduced their survival compared to control groups that did not receive radiation (Alsuhaim et al., 2013). Janković et al. (2014) explain that microwaves, emitted by mobile phone devices, may affect microorganisms' growth depending primarily on the frequency of the radiation and the total energy absorbed by the microorganisms. When irradiating live organisms, microwaves could produce two types of effects: thermal and non-thermal effects. The consequence of thermal effect is that the energy microwaves are absorbed by the molecules, consequently, that molecules vibrate faster, producing heat on the cell. Nowadays, the mechanisms of non-thermal action of microwaves are not well understood. However, it seems to be related to changes in functional proteins' secondary and tertiary structure (Janković et al., 2014).

Some experiments with microwave irradiation of various cultures of bacteria and yeasts in a wet environment such as water did not show that the microbes were further killed by microwaves compared to conventional heating at the same temperature (Janković et al., 2014). Numerous studies have well-established microwave sterilization effectiveness. However, the exact nature of the sterilization effect has been a matter of controversy for decades (Gorny et al., 2007). The National Cancer Institute, in contrast to this data, associates cell phone radiations with a cancer risk factor such as age, alcohol, diet, obesity or tobacco use, as they show on their website. The effects of microwave radiation on microorganisms as a physical phenomenon are still not fully explained.

Our study does not have the temperature as a variable, only radiation effects were tested. It can be seen that in almost all cases, RF waves harm cells, for instance, mobile phones Samsung Galaxy

Young II and LG E-460 decrease the survival rate of yeast cells around 40%. However, different mobile phone devices are not causing the same effect; in other cases, survival is almost not affected by the waves.

We tried to relate the percentage of cell growth for yeasts exposed to radiation vs non exposed (control) with different mobiles phones that presented different characteristics. We did not find any clear correlation between them. However, we conclude that all the items studied are involved in the survival percentage.

The fact that generally, mobile phone waves affect yeast cells' survival negatively does not necessarily mean that these microwaves would be dangerous for human's health, due to pluricellular organisms' complexity and genetic metabolic differences.

We should take into account that the results deriving from our inquiry are not conclusive. More investigation must be done to confirm our results. However, it is a good start for students to practice an IBL activity.

Students will know that the in the first step of a real-life investigation, the scientists use yeast as a cell model to test a toxic, a new drug or some radiation effects on them. This would be just the first step of a long journey to reach conclusions about their potential effects on humans. Yeast provides essential information that allows us to develop knowledge about regulation and cell growth (Forsburg, 2007).

Inquiry-based learning is one of the models that challenged the traditional learning concept to combine both learning and practice. Moreover, the IBL offers supportive evidence and explanations for natural phenomena. The Council (2000) claimed that three main reasons drive implementing inquiry-based learning in classes:

- To improve students' scientific skills.
- To engage students in reading, writing, and participating in critical discussions as they learn.
- To encourage students to participate in the critical argument, since the observation of natural phenomena is supported by logical reasoning.

Sometimes, this methodology's application represents an obstacle to many teachers striving to build a shared understanding of what science as inquiry means. We present an inquiry laboratory activity that could help teachers introduce this methodology in their classrooms (Khalaf, 2018).

The inquiry laboratory activity that we present it could be used to achieve different learning outcomes depends on the level that it was applied and students' expertise about the inquiry. This activity may be used for:

- Introducing students in microorganism's management.
- Introducing students in the inquiry-based learning (in that case, a guided inquiry approach will be used)
- Students identify similarities between yeasts and notable species.
- Realizing that yeasts are Eucarya unicellular organism the same as mammals.
- Developing their scientific skills by designing their inquiry. If students work before using the inquiry pedagogy, an open inquiry approach will be used. Students could decide which items are interesting for them and they learn to work as scientists. They learn to apply the scientific method starting by bringing up what questions they want to answer; this way, they are asked to observe their environment and make a question, or in the case of the IBL the teachers bring up a problem to solve. After that, they must think about how they could scientifically answer their question. They ought to design an experiment to give an answer and to be able to respond to the question is necessary to achieve objective evidence that enables the following the acceptation or refusal of their hypothesis. To reach objective evidence, it is necessary to choose a quantitative dependent variable that we could measure directly or indirectly. The inquiry through laboratory activities and practical works is a backbone for scientific literacy.

Conclusions

To sum up, we agree with other authors who assume inquiry-based learning as an excellent pedagogical approach in learning science. These authors reported that inquiry permits developing higher-order cognitive skills, managing laboratory instruments, and collecting and analyzing data (García-Carmona et al., 2017; Simsek & Kabapinar, 2010; Madhuri et al., 2013). Moreover, Kasl & Yorks (2002) suggested that the inquiry approach empowers students to be active learners, resulting in higher quality learning. In addition, Bhattacharyya et al. (2009) stated that the inquiry approach permits students to learn through direct personal experience by connecting their previous knowledge with new information and becoming capable of understanding data. Furthermore, the inquiry-based activity could engage students, increase their enthusiasm, and stimulate their interest in learning science (Taraban et al., 2007; Zion et al., 2004).

As far as we concern, inquiry-based learning is an excellent pedagogical approach to students to learn science in a personal and active manner, developing their scientific skills and learning meaningful learning. The present article is an example of a laboratory activity applying this methodology using yeast as a cellular model. This inquiry laboratory activity is modulated and easy-going that it is possible to adapt to any level of education.

The inquiry and the laboratory protocol presented in this paper are easy-going and adaptable to other conditions or variables. Some changes that we purpose are:

- Different microorganisms could be tested, for instance, comparing different bacteria strains (belonging to bacteria domain) or the effect on yeast cells (belonging to Eucarya domain). To test different kinds of waves (microwaves oven, mobile phone, UHF radios, Wi-Fi waves...) using the wave source as the independent variable and fixing the same microorganism in all cases.
- To test the effect of a toxic or a drug instead of the effect of potentially damaging waves. For instance, we could test the effect of oxidant solutions such as oxygen peroxide or an antibiotic.
- To test different times to use the same microorganism and the same source of microwaves to assess the results are the same every time.
- Students could design their schemes according to their curiosity.

This paper's inquiry activity is an example of practical and interdisciplinary activity, which get students close to how scientific investors work. One of the main problems of scientific practice activities that students develop in class is that they are disconnected from their daily lives. However, the activity described in the present article puts the student at the center of their learning process, by taking decisions and choosing variables, moreover it shows how scientific works bring about the inquiry, and it is an interdisciplinary activity, as most of the investigations require a knowledge of different disciplines is required.

As future perspectives, we would like to evaluate and validate the activity by doing it with secondary school students. Many issues could be measured, (i) to determine if the students gained scientific knowledge through the inquiry, (ii) to analyze whether attitude towards STEM improve, (iii) to assess whether the effectiveness of the survey improves students' scientific skills.

Compliance with Ethical Standards

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

Informed consent was not necessary because this article does not contain any studies with human participants or animals performed.

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