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Grau de Química

Treball Final de Grau

Metals with history, history of the metals. A workshop in Learning Service (LS) approach.

Metalls amb història, la història dels metalls. Un taller de divulgació en clau Aprenentatge Servei (ApS).

Òscar Vidal Blay

June 2019

UNIVERSITAT DE BARCELONA

B:KC Barcelona Knowledge Campus
Campus d'Excel·lència Internacional

Contar la ciencia de forma amable, de forma cercana, de forma que lo pueda entender mi tía la de Cuenca, que no tengo.

Santi García Cremades

M'agradaria expressar el meu agraïment:

Per començar als meus dos tutors, la doctora Elena Xuriguera i el doctor José Antonio Padilla per la seva dedicació i atenció, i les seves magistrals aportacions que m'han donat peu a uns resultats ben satisfactoris i un molt bon aprenentatge. Als meus pares per la paciència que han tingut en els moments on tot semblava enfonsar-se, i a tots aquells amics que m'han ajudat, o que simplement han tingut el detall d'escoltar-me una vegada i una altra quan els hi feia el taller.

REPORT

CONTENTS

1. SUMMARY

This Final Project has been divided into three sections. In the first section talks about the Learning Service approach, LS and scientific divulgation, as well as the methods of carrying it out, focusing specially on the audio-visual method (internet videos, blogs, TV shows, etc.), and important divulgators from our own nation and from abroad.

The second section starts explaining the process of creating a survey with the objective of defining and understanding the needs of the public for who the Learning Service workshop will be conducted; whom in this case are high school students, hence the workshop would be adapted to their level of knowledge. After this, the second section talks about the process of creating such workshop, starting with the selection of the topic, going through all the ideas and suggestions that have been discarded, until reaching to the final design of the workshop.

In the third section, the actual activities of the workshop are covered, focusing on presentations of metals such as copper, iron, gold and aluminium. In the first part of this section, the unifying thread is talked about, moving then to all the activities conducted for each one of these metals, giving some touches of their inherent properties.

Keywords: Learning Service, scientific divulgation, workshop, Periodic Table, metals, properties

2. RESUM

Aquest Treball de Final de Grau està dividit en tres seccions. A la primera secció s'ha parlat de l'Aprenentatge Servei, ApS, i la divulgació científica d'avui dia, tant de les diverses maneres de dur-la a terme, centrant-se sobretot en els audiovisuals (vídeos d'internet, blogs, programes de televisió, etc.), com dels divulgadors més importants del nostre país i a nivell europeu.

La segona secció comença explicant el procés de creació d'una enquesta, per tal de definir i conèixer les necessitats del públic a qui va dirigit l'ApS, que en aquest cas es tractarà d'estudiants de secundària, i poder adaptar un taller d'acord amb el seu nivell i capacitats. Per altra banda es parlarà del procés de creació del taller esmentat, començant per la tria del tema, passant per totes les idees i propostes que han estat descartades, fins arribar finalment al disseny final.

La tercera secció està dedicada a l'explicació del taller, i al posterior enfoc en la presentació dels metalls coure, ferro, or, i l'alumini. En un primera part es presenta el fil conductor, i tot seguit les activitats realitzades per a cada un, tot fent una pinzellada d'algunes de les propietats inherents més importants d'aquests elements (conductivitat, magnetisme i redox).

Paraules clau: Aprenentatge Servei, divulgació, taller, Taula Periòdica, metalls, propietats.

3. INTRODUCTION

This Final Degree Project (*Treball Final de Grau, TFG*) as it focuses on Learning Service, LS, aproach (*Aprenentatge Servei, ApS*), but more specifically, in scientific outreach This project is not a bibliographic approach; it's main objective is to design a workshop as a tribute to the Periodic Table., according to the fact that this year is the International Year of the Periodic Table, IYPT, because it is the 150th anniversary of its creation, by the Russian chemist Dimitri Mendeleev. For this reason, the General Assembly of the United Nations has proclaimed 2019 as the International Year of the Periodic Table [1]. The main objective of this initiative is to recognize the crucial role played by the elements and chemistry, in sustainable development when it comes to providing solutions to many of the challenges facing society and to inform a wider audience about its importance.

In addition to this, the year 2019 coincides other several anniversaries of important events in the history of the periodic table, such as the publication of a list of 33 chemical elements classified in metal, non-metals and earth gases by Lavoisier in 1789 or the creation of the periodic table by Mendeleev 150 years ago.

Furthermore, this workshop pretends to be conducted during the Researcher's Night in Barcelona, as well as in schools, youth centres, and any kind of event that I have been able to attend.

3.1. LEARNING SERVICE

In general terms, LS is based on learning while you are teaching, and doing any kind of service for the community. According to the official web page of ApS in Catalunya [2]:

> *"L'aprenentatge servei és una proposta educativa que combina processos d'aprenentatge i de servei a la comunitat en un sol projecte ben articulat en el qual els participants es formen tot treballant sobre necessitats reals de l'entorn amb l'objectiu de millorar-lo."*

In other words, the Learning Service approach is not only a good learning strategy which improves the knowledge and studying techniques of the students, but it also intends to become a

social and educational movement. In order to achieve that, this approach promotes an environment of cooperation and teamwork as well as an inclusive attitude.

The three principal objectives of the LS approach are the following [3]:

1. To link academic knowledge with practical activity
2. Offer a formative experience that at the same time has social utility
3. Contribute to the formation of citizens and future professionals

A great advantage of this approach is that it is very useful, and not only to the students, but to the teachers as well. It helps the students (coming from any age and academic year) to study, it improves their motivation towards the subject, and it promotes their personal development. On the other hand, it helps the teachers in evaluating the student's skills, it encourages good mood within the classroom and it provides an innovative teaching method.

It is very important to emphasize on the fact that the ApS approach works with transversal skills; this allows it to be practiced both inside as well as outside of the classroom.

3.1.1. What is not Learning Service?

Once illustrated what exactly is ApS and its scope, it is important to make clear what ApS is not, through the comparison with other pedagogic techniques [4].

According to Pablo Alto there are four blocks (Figure 1):

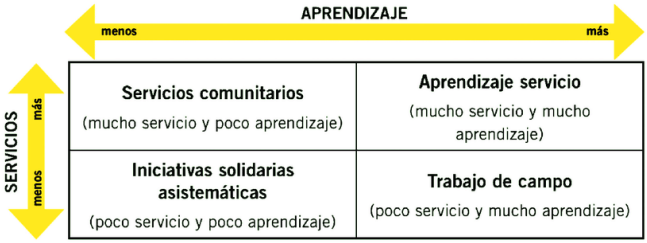

Figure 1. Service-learning quadrants
(*Pablo Alto, 09/04/19, ResearchGate Creative Commons)*

The table above shows these four blocks and set them up depending on if they are more focused on Learning or Service.

Just as it was expected, LS is located on the top right-hand corner, where both Learning and Service have more contribution. When Service is more important than Learning, we are talking about volunteering activities and community service. On the other hand, when Learning is more important than Service, we found something like work camp or bibliographic researches. Finally,

when learning and service have not too many importance, we can see solidary initiatives and sporadic activities.

3.2. SCIENTIFIC OUTREACH

The scientific outreach in Spain has always been slower than the English one since they started much earlier than the Spanish one. However, it has improved considerably in the last year. There are many scientists who engaged their lives to spread their knowledge, either on-line (talks in YouTube channels, Twitter, Instagram, etc.), on the television, newspapers, journals, magazines, or even though on life, in events and fairs doing interactive workshops, like the one which I am working on it.

3.2.1. YouTube

This media is experimenting its peak, due to it has been adapted to the change of the society, and more specifically to the young society. Nowadays people do not watch as much TV as before. They prefer to watch series or films on internet platforms, in which they are not obligated to see a certain program, and it is possible to choose. Therefore, in YouTube something similar it is happening, and the ones who are not chosen, disappear.

YouTube is a virtually inexhaustible source of information, not just fun videos and entertainment. This platform can be tremendously didactic, since the fact of enriching the explanations with images, facilitates learning and understanding, and even more if the possibility of pausing the lessons at any time is considered, it becomes a perfect source of lessons. Nowadays there are as much active scientists as online divulgators who use this platform to create their own channels and use them as a tool to spread their knowledge.

In Spain, some of the most important channels are *CdeCiencia* (Martí Montferrer) [5] and *Robot de Platón* (Aldo Bartra) [6] regarding general contents, *Derivando*, (Edu Sáenz de Cabezón) [7] and Santi García Cremades [8], which are specialised in maths, and finally *QuantumFracture* (Jose Luís Crespo) [9] and *Date un Voltio* (Javier Santaolalla) [10], talking about physics. On the other hand, some international channels are *Veritasium* (Derek Muller) [11], which is a channel of science and engineering videos featuring experiments, expert interviews, cool demos, etc., *Minute Physics* (Henry Reich) [12], which offers very clear explanations on very curious topics

related to physics, based on drawings and some images, and *Sick Science!* (Steve Spangler) [13], who makes experiments which could be done at home.

As Jose Luís Crespo says in his video *"Hablando sobre la Divulgación en YouTube con el Robot de Platón y CdeCiencia"* [14], this platform allows to use videos, which are a very valuable support. Furthermore, it is very easy to access, and it is known by everybody. Another important characteristic is that can reach a young audience very easily, which is very important for science, because as younger we are, faster we learn, and it is easier to get interested in new things. Santi Cremades says [15]: "It is a social need to increase the scientific culture".

Even so, they had to redefine the popular meaning of the word "YouTuber" has. Until recently, YouTubers were the people who comment films or videogames, and increasingly, scientists have been adopting this position, so that nowadays, there are also scientific YouTubers.

Another factor that has made it difficult for scientific videos to become a popular source of information is mystery and conspiracy videos. Anyone with a YouTube account can publish a weird theory (which are usually catastrophic or paranoid), and people believe that.

This results as a handicap for real scientists; it is easier to believe a crazy idea such as the "Earth is flat" or "aliens control us", rather than an actual scientific fact such as "Earth was formed from an explosion that took place millions of years ago" or that "human beings' descent from the monkey kind".

3.2.2. Scientific blogs

Another important platform for scientific outreach is the blogs. These are websites, and usually free, where people can write their ideas, experiences and discoveries, but also videos, conferences, publications, etc. They are used as a personal diary where the author or authors publish their content of interest allowing readers to comment and give their opinion on such content.

The advantages and disadvantages of this platform are of big similarity to those of YouTube since both are online ways of communication.

According to Sara Asensio in Lifeder [16], some of the important scientific blogs in Spain are:

Ciencia Online

This blog contains all kinds of scientific information, and it is mainly made for the use of teachers and student, but anyone with a scientific interest can read it. It was created on 2007 by Lorenzo Hernández Villalobos, a physics and chemistry teacher of high school, and as he says on the web site [17]:

"CienciaOnline es un blog personal dedicado a hablar sobre ciencia. Sobre la ciencia que nos crea curiosidad, la que nos crea inquietud, la que hace que nos preguntemos por qué son las cosas como son y la que cambia la percepción del mundo que tenemos."

Lorenzo Hernández

Fogonazos

Another very famous scientific blog in Spain is this one created by Antonio Martínez Ron, a journalist specializing in scientific issues. This is one of the oldest and most visited blogs in the field of natural sciences. It collects and analyses news on science topics, explains curiosities and recovers its interventions in the TVE Órbita Laika program, focused on scientific dissemination [18].

Naukas

Naukas is a Spanish web platform that hosts a hundred blogs devoted to scientific dissemination. Its slogan is *"Ciencia, escepticismo y humor"*. It is a common project of Miguel Artime, Antonio Martínez and Javier Peláez (all of them brilliant divulgators), with the support of hundreds of Spanish scientists and journalists [19].

3.2.3. Events and fairs

This kind of divulgation is very different from the ones before. Basically, consists on activities executed for institutions which are dedicated to the scientist research. The organisation and realisation of the activities made during the event, as well as the planification and execution are entirely on charge of the members of the responsible institution. The conferences or workshops may be short-lived or may last several full days.

On the one hand, some of the most important European events are:

Researcher's Night

European Researchers' Nights are public events dedicated to bringing researchers closer to the public. They showcase the diversity of research and highlight the impact of research on our daily lives. The aim is also to motivate young people to embark on research careers. The events promote how researchers contribute to our society by displaying their work in an interactive and engaging forum.

The Researcher's Night is held annually on the fourth Friday of September throughout Europe. This has been a popular event since 2005, and this year the event take place on the 27th of September [20] [21].

Youth Mobile Festival, YoMo

It is associated to the Mobile World Congress, and this year was the third edition. Designed for students from 8 to 16 years old, YoMo Barcelona 2019 featured educational exhibits, live shows, interactive workshops, deep dive presentations and a wide range of hands-on activities.

The students interact with over 100 universities, research centres, institutional bodies, outreach specialists and business and industry leaders from the Science Technology Engineering Art Mathematics, STEAM, industry [22].

On the other hand, some examples of local events are:

Fira Ciència Barcelona

This event is coordinated by the Barcelona Science program. Each year in spring, a lot of entities organize activities to bring scientific and technological knowledge to society through a two-day festival, with conferences and workshops, and involves more than a hundred research centres, universities, companies, associations and professionals of scientific divulgation [23].

The result of the great effort translates into thousands of citizens who visit the festival every year, interested in the advancement of knowledge and attracted by the wide range of activities aimed at all types of public.

Festa de la Ciència UB

It is celebrated throughout an entire morning (in the beginning was during the whole day), at the Historic Building of the Universitat of Barcelona. It is filled with all kinds of practical and scientific activities, such as demonstrations of researchers, workshops, games, etc.

The aim of the festival is to make the research carried out at the University of Barcelona, UB, accessible to types of audience, in a playful and innovative way, while at the same time vindicating the relevant role of science in all areas of life. The programmed activities and workshops aim to promote the discovery of the science that surrounds us and stimulate the ability of the participants to adopt a reflective and scientific attitude in any situation [24].

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Figure 2. Festa de la Ciència Poster
(Universitat de Barcelona,18/05/19)

Finally, there are also national events, such as *Desgranando Ciencia, BCNspiracy* or *Naukas.*

3.2.4. TV Programs

Television has always been a channel of historical disclosure, since documentaries are the usual version of the divulgation. Two national important programs are:

Quèquicom

Quèquicom is a weekly program of scientific dissemination broadcasted by Corporació Catalana de Mitjans Audiovisuals, SA, CCMA, since March 2006, directed by Jaume Vilalta, and presented by Jaume Vilalta, Fina Brunet and Pere Renom [25].

It has the intention of providing the audience with basic knowledge for understanding the nature and scientific-technical aspects of this society and, at the same time, facilitate the communication of scientists with citizens. In short, Quèquicom aims to awaken curiosity towards science as a way of interpreting reality. Quèquicom comes from the program *Punt omega,* and this, in turn, from the *Més enllà del 2000*.

Figure 3. Quèquicom logo
(CCMA, 21/05/19)

Órbita laika

Órbita Laika is a late-night show of popular science and humor broadcasted on the Spanish network La 2, which commenced its weekly broadcasts on December 7th, 2014. The name of the program is due to the dog Laika, who was the first terrestrial living being to orbit the Earth. It was created by the *Fundación Española para la Ciencia y la Tecnología*, FECyT, and it has been presented by many different people. Ángel Martín started, then came Goyo Jiménez, and this year is presented by Eduardo Sáenz de Cabezón [26].

Each chapter is devoted to a different topic: physics, artificial intelligence, sex, climate change, etc.

3.2.5. Other scientific outreach

Famelab

Famelab is an international contest of scientific monologues started in 2005 thanks to an original idea of the Cheltenham Festival [27]. Its main objective is to promote the dissemination of science by introducing new talents of divulgation through an innovative format, the scientific monologue. At the national level, after two preselection stages, only 12 participants are chosen, of which 8 will go to the final. The winner of this final, will represent each country, to facing the other national winners in an international final.

Since 2007, thanks to the association with the British Council, Famelab has become global, with competitions held in more than 30 countries in Europe, Asia, Africa and the United States [28].

TED Talks

TED is a non-profit devoted to spreading ideas, usually in the form of short, powerful talks (18 minutes or less). TED began in 1984 as a conference where Technology, Entertainment and Design converged, and today covers almost all topics, from science to business to global issues.

TED is owned by the Sapling Foundation, a private non-profit foundation. The foundation was established in 1996 by publishing entrepreneur Chris Anderson.

The goal of the Sapling Foundation is to foster and the spread of great ideas. It aims to provide a platform for thinkers, visionaries and teachers, so that people around the globe can gain a better understanding of the biggest issues faced by the world and feed a desire to help create a better future [29].

4. OBJECTIVES

The main objective of this project is to learn how to design, prepare and carry on a workshop in Learning Service approach, inspired in the Periodic Table As this year is the international year of the Periodic Table, this workshop will be included on the Researcher's Night 2019.

The workshop expects to introduce many different properties of some metals, through the ages of the history, and it will be designed to be aimed at high school students, as well as being accessible to a non-specialist audience.

Another objective is to know more about the divulgation, how it is nowadays, the different types of outreach, and even more what exactly means to be a divulgator.

5. METHODS

5.1 SURVEY OF THE YOMO EVENT WORKSHOP *KEEP CALM AND MATERIALIZE YOURSELF*

For the YoMo 2019, the Materials Science Department, of the Universitat de Barcelona was presenting a workshop called "*Keep Calm and Materialize yourself*". The workshop was divided in four parts, and the students could move from one to the other depending on their interests. The first one talked about superconductivity, the second one about hydrophobic recovering, the third about recycled cements, and the last one about biomaterials.

Since the main goal of this Final Project is to design this kind of workshop, in a Learning Service approach, through conducting a survey to the public assisting to the event, it would be possible to know about their needs and concerns, and therefore adjust the workshop accordingly. By the way, this would be the first year polling the public and getting some feedback, in order to improve the workshop.

Moreover, this survey may be used in other workshops, like for example the one which is going to be created in this project.

There were very few instructions for do the poll. Basically, it had to be short, easy and fast to do (due to it had to be done in situ during the event, after each workshop) representative, focused to youngsters between eight and sixteen years old, and designed for people who came in groups.

The first platform used was the website *Typeform* [30], but eventually, Google Form facilitates the execution of the survey and the subsequent processing of data, so it was the chosen for carry on the poll.

After some research about how to make a good pol [31] (for instance, almost all the questions should be closed [32]), an outline called *"Enquesta YOMO"* was made. It was set out as an individual survey, which provides me a lot of valuable information, but it was not functional, due to the students came in groups, so I had to change it.

SECTION	QUESTIONS
FIRST	1. *De quina escola veniu?* 2. *Quina edat teniu?*
SECOND	3. *Quina és l'àrea que més t'agrada de l'escola?*
THIRD	4. *Quina assignatura t'agrada més?*
FOURTH	5. *De què t'agradaria estar treballant quan siguis gran?*
FIFTH	6. *Qui d'aquí havia sentit a parlar de la Ciència de Materials o algun dels conceptes que heu vist en els tallers?*
SIXTH	7. *Com puntuaríeu el taller?* 8. *Quants heu descobert que us agrada la Ciència de Materials?* 9. *Quants us plantejaríeu ser en un futur Enginyers de Materials?*

Table 1. Sections and questions of the survey

The survey was formed by six sections (Table 1). The title of each section would be the question itself, what is thought to be the question, would be the different options to choose (some of them accompanied by a small description) and finally the options of the answer will correspond to how many people pick each one of the proposed alternatives (Figure 5).

The questions of the first section were thought for make a first contact with the students (Figure 4). First, asking them the school where they were studying, while using the occasion to write down how many students were doing the survey, as well as the workshops they were participated using the following legend:

a = Superconductors
b = Hydrophobic Recovering
c = Recycled Cement
d = Biomaterials

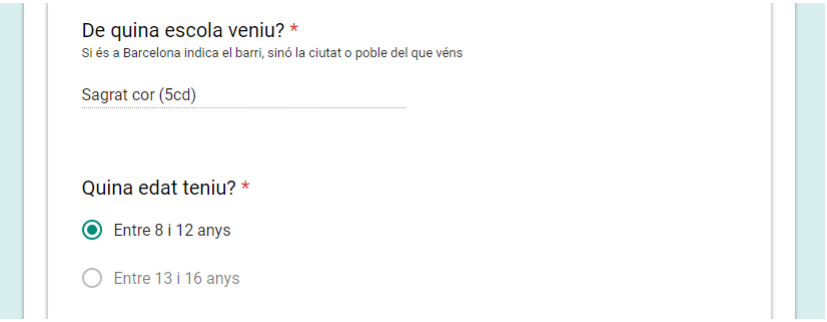

Figure 4. First section. First and second questions of the survey

In the example above, five students came to the workshop, from the school Sagrat Cor, and they did the workshops of Recycled Cement and Biomaterials.

Only the second and the third sections were different for both ages. This was because the subjects in primary school are very different from the subjects of the secondary, and in this way, the information will be more valuable.

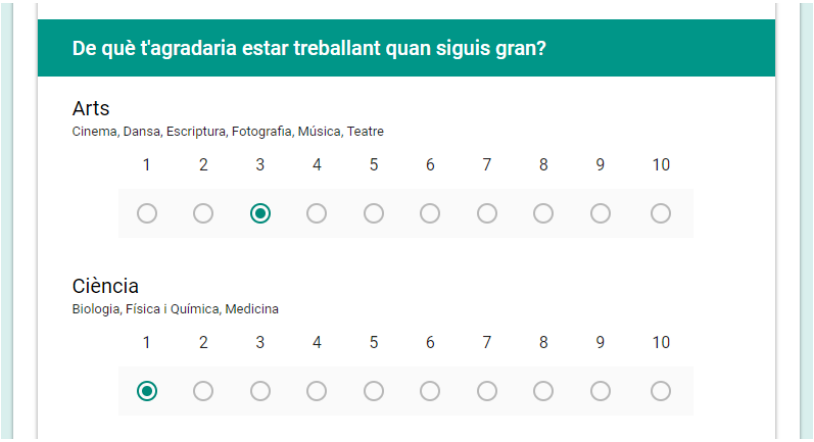

Figure 5. Example of the design of the survey. In this group, 3 students wanted to work in something related to arts, and 1 student in something related to science

5.2. PREVIOUS RESEARCH

Once starting to face the workshop, two different areas had to be worked. First of all, what the workshop should talk about, and secondly how a divulgator should be [33].

5.2.1. Science Disseminators

This research consisted in searching for different divulgators, learning their methodologies and write down the things they do that I could get some initial ideas.

There are as many ways to divulgate as divulgators are, so here there are just some of them, the ones which were considered more relevant and get more ideas (Table 2).

As a result of all this research, some techniques chosen for divulgation are creating mystery (Crespo), use humour (Aldo, Cremades), choose a main theme as a common thread and talk about all its related concepts (Martí), work with easy examples (Sáenz), use friendly and daily language (Cremades), add some technicisms, and explaining them (Crespo, Sáenz) and producing illusion and curiosity (Altozano).

It is necessary to mention in this section the television program Quèquicom [25], since it has been a very useful source of inspiration for doing and designing the workshop, due to its educational standpoint. Its concise explanations and varied topics were very helpful to prepare and design the workshop.

DIVULGATOR	CHARACTERISTICS
Martí Montferrer **(CdeCiencia)** [5]	- Starting with an initial question which answers in the end - Explaining general and quotidian concepts in a very simple way - Throughout the video, explaining the concepts (sometimes with a transcendental way) related to the first question - Finishing the explanation with an open ending
Aldo Bartra **(El Robot de Platón)** [6]	- Explaining apparent simple contents, but complicating them looking for the exception - Maintaining an apparent seriousness but occasionally making jokes, generating a relaxed and grateful atmosphere
José Luís Crespo **(QuantumFracture)** [9]	- Talking about the most complicated concepts of physics, but using colloquial language and detailed explanations - Always maintaining the suspense
Santi García Cremades [8]	- Communicating in a very dynamic and fun way, sometimes using music - Being aware that dissemination is necessary, calling on all the scientists to disseminate their knowledge
Edu Sáenz de Cabezón **(Derivando)** [7]	- Explaining everything very clearly, slowly, and adding examples of everything - In a relatively complicated concept it seems that nothing said has any meaning, until at the end of the explanation, where something said illustrates the audience - Brief, decisive and clear
Jaime Altozano [34]	- A musician, deserving a special mention since his explanations, as well as the topics are very interesting - Really clear and understandable explanation, even the concepts seems to be complicated

Table 2. Characteristics of some important divulgators

5.2.2. Process of the creation of the workshop

First of all, it has to be decided to whom will be the workshop, and as in the YoMo event, It would be students of secondary school. At these ages they have a basic knowledge that would allow to complicate a little bit the workshop, but not too much as if they were in university.

Then it must be thought the workshop, which does not last more than 30 minutes. Due to the wideness of the topic, a brainstorming was made [35]. The most important ideas are written on the following list:

- Home: Chemical products and daily process (kitchen, toilet, etc.)
- Copper, silver, gold, and other common transition metals
- Elements than has been replaced by others, for many reasons as price, healthy, toxicity… (Hg, Pb, Fe, W, etc.)
- Aluminium (metal, oxide, applications, etc.)
- Electronic devices: Mobiles, laptops, etc.
- Oxygen compounds (water, ozone, hydrogen peroxide, etc.)
- Glasses and silicates
- Some important group of the periodic table

The first options discarded were the four last ones, since they were too complicated to carry out in a workshop or just did not seem interesting enough. Then, the first option was eliminated due to its strong deviation from the main topic which is the Periodic Table. Talking about replaced elements was also discarded, because to get hands on these elements was a difficult task. In the end, two final ideas remained, and both were related to metals. Therefore, a new global idea was designed. It consisted on creating a route through the Periodic Table, talking about many different metals.

The next step was to define the basic ideas: where should it start, which elements will be talked about, which experiments will be performed and how to move from one element to the other.

The first proposal was starting from iridium. This element is in the middle of the Table, and this give a wide variety of paths. Regarding the question of “How to move from one element to the other”, the most attractive idea was to use a chess figure, the horse. This chess figure has the most unique movement, but also the most restrictive. This was an advantage and disadvantage at the same time. On one hand, there are limited elements that it can step into due

to this restrictiveness, which would help to narrow down the alternative elements to look into. However, on the other hand, some options are not so common elements, which are not interesting enough for a workshop.

The four metals that may appear on the workshop were copper, iron, gold and aluminium, and, in order to maintain that initial idea, a route had to be designed through the Periodic Table, but it was very difficult to move from iridium to such metals. Hence, the starting point had to be changed; the best element for introducing the workshop is the one responsible of life: Carbon. Thus, using this element as the starting point and maintaining the chess movement of the horse, a somewhat chronological order of discovery can be followed through the elements.

The number of existing metals is so vast that it is impossible to talk about each of them. Thus, the main elements of each historical period were chosen. The selected metals for representing each historical period are (Table 3):

YEAR OF DISCOVERING	METALS
PREHISTORY	Carbon, sulfur, iron, copper, silver, gold, antimony, mercury, lead
1700 – 1800	Platinum, strontium, titanium, beryllium
1801 – 1820	Palladium, iridium, cadmium
1821 – 1840	Silicon, aluminium, bromine

Table 3. Elements organized according to their year of discovering [36]

So far, there were 19 elements, and there were too much, because the workshop could not last more than 30 minutes. Only in ancient times there were copper, silver and gold, apart from others also very important. In order to reduce the time of the duration, the other three groups were discarded, changing the perspective of the work again.

The new proposal was to talk about the metals which have been discovered throughout history, and still today have a fundamental importance, such as, copper, steel, gold and silver, and also about aluminium. Therefore, the figure of the horse would not need either.

This idea showed a more feasible unifying thread through the element based on a chronological order only, leaving out the chess method.

After discarding the initial idea, another brainstorming had to be done to see if some new life motive through the metals could be used. These are the most relevant suggestions:

- Itinerary over the history

- Jumping from one element to the other
- Using the metaphor of an electric copper thread as the “unifying thread”
- Arrange all the elements by their physic and chemist properties

It appeared again the idea of the chronology, and even though the other ideas were also suitable, they were discarded, to use history as a unifying thdread.

6. RESULTS AND DISCUSSION

6.1. YOMO EVENT: SURVEY OF *KEEP CALM AND MATERIALIZE YOURSELF*

6.1.1. Execution of the survey

The initial idea was that the groups would be quite numerous, but the first group that approached was made up of three students. Looking around the hall, it was easy to foresee that the students will come in groups of a maximum of 5 or 6 boys and girls, so some changes in the questions were needed in situ. This was the first setback of the day. The way in which the answers were set out would not be representative, since the answers were focused by groups of between 5 and 20 people.

After this incident, the hours went by, and the polls went well. They were dynamic, short, and easy to carry out (Figure 6).

As a curiosity, a group of foreign students from Ireland came to the event and participate, so all the workshops and the poll had to be translated, and they left satisfied.

Figure 6. Conducting the survey

Figure 7.Conducting the workshop

Once finished the morning, started arriving the students who came in the afternoon. There were less people, and with the supervision of the members of the workshop I did the workshop about hydrophobicity (Figure 7). At first, I was hesitant, since it was the first time I did a divulgation act. I thought it was part of my work, and then I jumped in. I tried to do just exactly what I saw during the morning, and it went very well. After the explanation, I took advantage of the fact that they were listening to me and I was doing the survey.

This meant doing less surveys, but on the other hand it meant gaining a divulgation experience.

6.1.2. Analysis of the survey

The survey was done to 34 groups (of which 10 were elementary students and 24 of ESO), between 2 and 5 people. A total of 125 students, 45 from 8 to 12 years old, and 80 from 13 to 16 years old (Figure 8). It came to this workshop around 350 people, so, not all of them did.

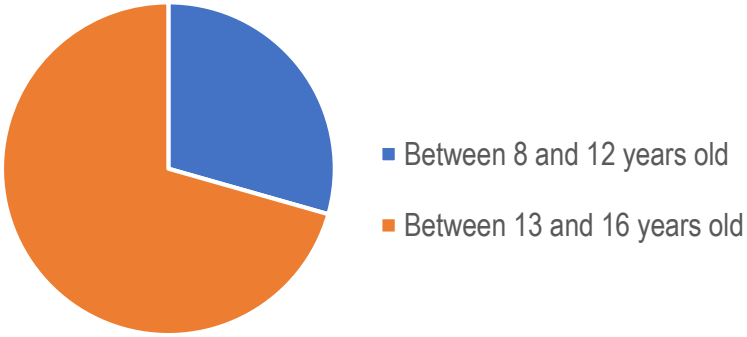

Figure 8. Percentage of students of each age

Although all the questions were the same for all ages (apart from the third one, which was asking their favourite area on school), for a better analysis, the answers will be separated in the two ranges of ages, and the obtained data will be represented on various pie charts.

6.1.2.1. Students between 8 and 12 years old

In the first place, for the students from 8 to 12 years old, the most liked areas were "Science" and "Art", what serves as an indicator to see that in primary there are two types of well differentiated interests (Figure 9).

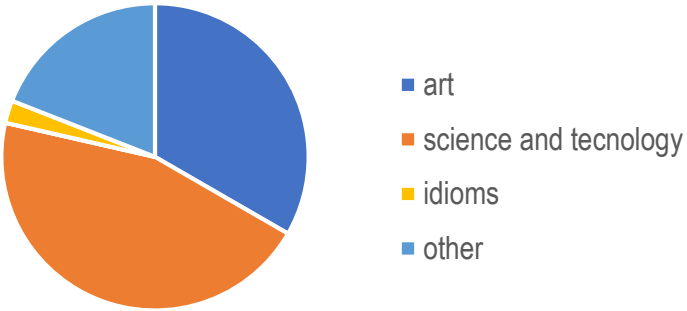

Figure 9. Areas of the school chosen for the students between 8 and 12 years old

On the other hand, regarding the professions (Figure 10), there is a big variety of the choices, and it is notices that the option which predominates is the non-defined question. At this age, for most of the people is too early to know what they want to be. Even so, following the tendency of the first question, the two most chosen professions are from science and engineering.

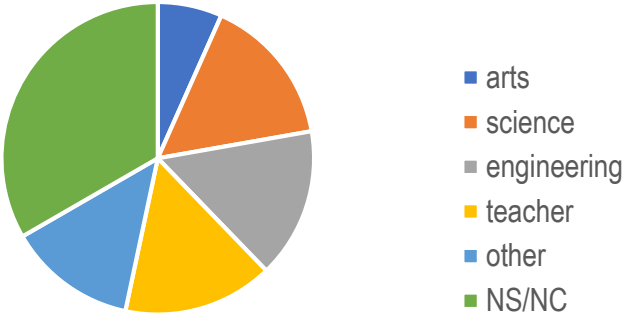

Figure 10. Jobs chosen for students between 8 and 12 years

Facing the lasts questions, this was interesting because the students were asked of their previous knowledge of the main topics of the different workshops, and most of them did not know nothing (Figure 11). The concepts were specific, and these results were expected.

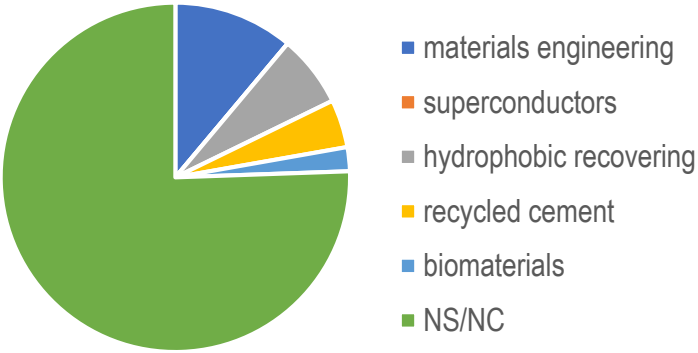

Figure 11. Previous knowledge of the students between 8 and 12 years old

Finally, in the last question the students were asked how much they liked the workshops, and, even if they knew it before or no, how much they like the science materials (Figure 12).

Apart from that, if they could contemplate dedicate to something related to this discipline. Almost all of them were satisfied and enjoyed the workshops they took part, and around 71% percent like the engineering, of which a 48% could consider working as a science material engineer.

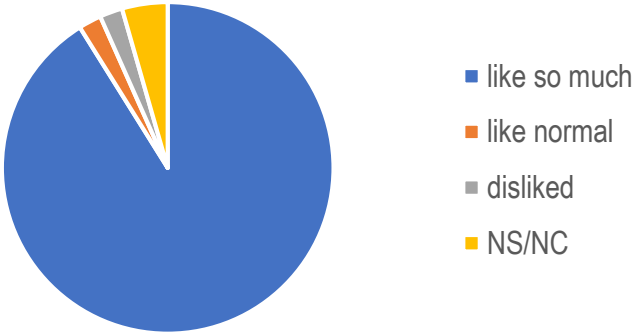

Figure 12. How much the students between 8 and 12 years old liked the workshop

In summary, primary students are too young yet to know what they want to do in their future, as well as for having previous knowledge of Materials Science, and concepts related to this discipline. Even so, this does not mean that the workshops are not suitable for them, since most of them left satisfied, with new knowledge acquired

6.1.2.2. Students between 13 and 16 years old

For students from 13 to 16 years old, as it was expected (due to it is a scientific event, and it is more possible to find scientific students) the most chosen area was "Science", around 40% of the students picket it out, followed by "Engineering" with 20%, this in total sum 60%, so it fits with the focus of the event (Figure 13).

This might also be because at this age, only students with a certain interest in science and engineering are interested in this kind of activities. All the rest just walk away.

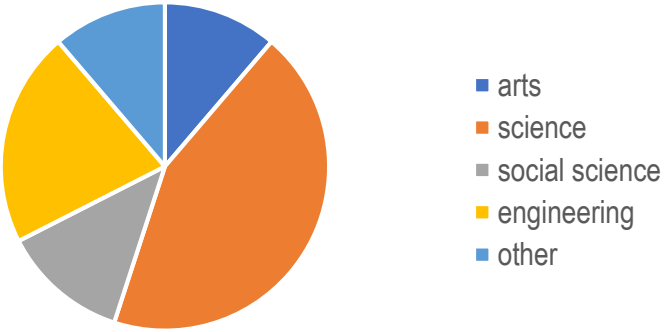

Figure 13. Subjects of the school chosen for the students between 13 and 16 years old

Looking the professions (Figure 14), in comparison with the younger students, clearly predominates people who intend to be a scientist, followed by people who want to work as an engineer. There are approximately the same people who want to work on something artistic or as a teacher. A job that I expected to come out, but it did not, was youtuber, since nowadays it is a job that all children know. As a curiosity, only one boy chose the sport option.

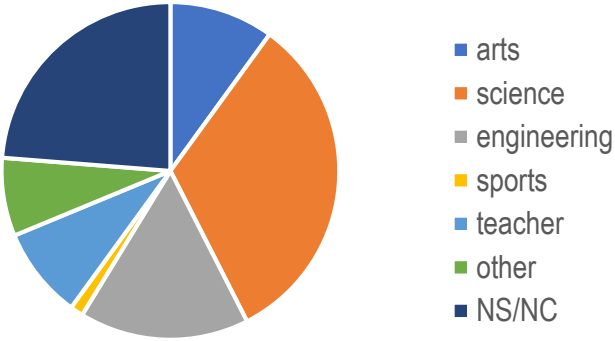

Figure 14. Jobs chosen for students between 13 and 16 years old

In relation to their knowledge of Materials Science and Engineering (Figure 15), 10 of all the 24 groups, knew (or had heard) some of the concepts. One interesting observation is that the same people knew something about materials engineering and concepts related to superconductors or hydrophobic recovering, which a priori could be concepts very unpopular, like the two other workshops, of recycled cement and biomaterials.

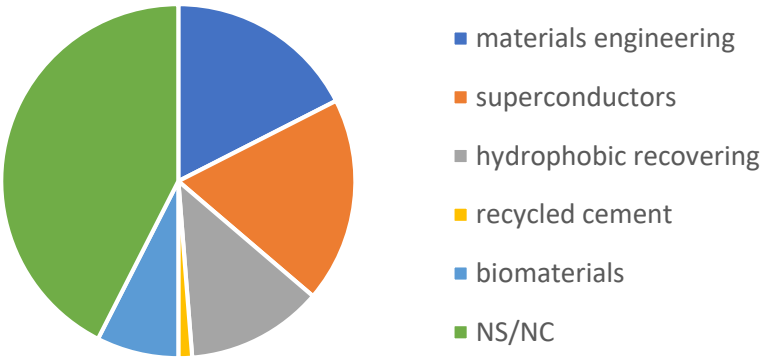

Figure 15. Previous knowledge of the students between 13 and 16 years old

This leads us to the block which evaluate the satisfaction degree (Figure 16). Most of the students answered that they enjoyed the workshops and finally, around a 88% of the students liked the discipline, and a 36% of them answered that they could consider being materials engineers.

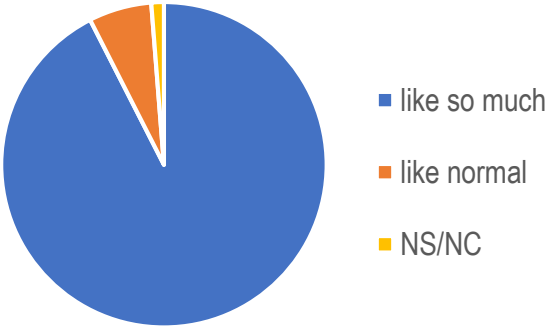

Figure 16. How much the students between 13 and 16 years old like the workshop

For the older students, they are old enough so that the subjects and works of sciences and engineering stand out as preferred subjects. The previous knowledge is also bigger, which was completely expected, and the satisfaction degree is as high as for the primary students.

One interesting aspect to comment, is that there are more secondary students who liked the materials science than primary students, but, there are more kids which could consider working as a science material engineer. This could be because the younger students do not have yet the enough knowledge, which makes them enjoy the Materials Science as much as the older ones. On the other hand, the fact of having contemplated less what they are going to work in the future, they have a better predisposition to consider new ideas, such as materials engineer.

6.2. WORKSHOP: *METALS WITH HISTORY, HISTORY OF THE METALS*

From the beginning the workshop has been contemplated as much as interactive and visual as possible, with very simple activities, and directed towards a non-specialist public. The workshop will talk about four different metals, which are copper, iron, gold, and aluminium, being introduced by the carbon. Experiments and graphic explanations more suitable for this workshop

had to be thought. As there are four different metals (apart from carbon), the workshop will talk about many different properties, choosing the most suitable for each element.

6.2.1. Life motive of the workshop *Metals With History, History Of The Metals*

The workshop will starts talking about the carbon. First of all is necessary to mention that carbon is the principal component of the organic matter, forming its main structure, and is the reason because the matter burns. The idea is to show how a combustion works and compare the combustion of organic matter with the combustion of a metal (due to the main theme of the workshop are the metals). This short and introducing experiment, would help with the first contact with the audience, and then to continue then with the principal metals of the workshop.

The first three metals of the history of being used and produced are copper, bronze (an alloy of copper and tin) and iron (steel), in this order. The copper was the first due to its lower melting point, and the relative ease to getting extracted. Taking advantage of this concept, the melting point, the second activity will be a funny experiment using the temperature of melting of iron and gallium, which melting point is around 30 ºC [37]. Someone in the audience will take one piece of iron and one piece of gallium (its melting point is around is around 30 ºC) in each hand, and in a few minutes, the gallium piece starts to melt.

After that, it continues with copper. First it was used for the tools and weapons, but it was replaced as soon as a more resistant metal appeared. This new metal was also copper, but mixed with tin, forming bronze. The ones who started using bronze start producing better tools and weapons, due to the improved physic properties, and it will be demonstrated.

After many years, scientists discovered a better property of this metal, which introduced it again in the life, the conductivity. It is one of the most conductor, and it is thermal as well as electric, so the first experiment will consist on show how this conductivity works.

Continuing with the history, the workshop will move from copper to steel, which is made of iron and carbon. Actually, almost all the iron on the Earth is steel. This alloy is known for having a big resistance and great mechanic properties. Apart from that, one important characteristic of the iron is the magnetism, and the compass is a popular object, known for using the magnetism. Therefore, a compass will be made.

Iron and copper are useful, but the world is ruled by the money, and the metals with which the coins are made are first the gold and second the silver.

Gold has a very poor reactivity (it is one of the most noble metal in the Periodic Table) much lower than the reactivity of silver, therefore, it is more expensive. According to that, there will be an explanation of why it was chosen to be the money, and then, a simple experiment that is practiced in jewellery will demonstrate its lower reactivity.

To move to the final metal of the workshop, the history will be set aside, and the audience will be asked the following question: "What do you use to wrap the snacks?". It is expected that people who uses aluminium foil say silver foil, so this connect the two metals and, while correcting this hilarious mistake.

Aluminium is the last metal discovered of all of them. Due to its reactivity with oxygen, it is impossible to find it pure in the nature, and the technology was not enough to reduce it until the middle of the 19th century, even though it is the third most abundant element, after oxygen and silicon, and the most abundant metal on Earth's crust. In the begging, produce it was expensive, and it was considered one of the most valuable metal. Nowadays its manufacture has experimented a big decrease of the price and cost, and that makes it one of the most used metals, for example, in windows. Although, few lines above say that aluminium is very sensitive with the oxidation and corrosion. Therefore, a priori it would have no sense. The reason why it is so used is the passivation.

6.2.2. Activities of the workshop *Metals With History, History Of The Metals*

All the chosen metals stand out among the other in one property. Hence, that property will be the one to work with.

6.2.2.1. Carbon

The first experiment (Figure 17) will be based on the different property of wood (organic material) and iron wool in front a flame [38] [39]. To verify it, is going to be the following activity:

1. Weight some matches and write down the value
2. Burn them
3. Weight the ashes
4. Compare the two weights, and notice that the second one is lower
5. Repeat the four previous steps, but with iron wool

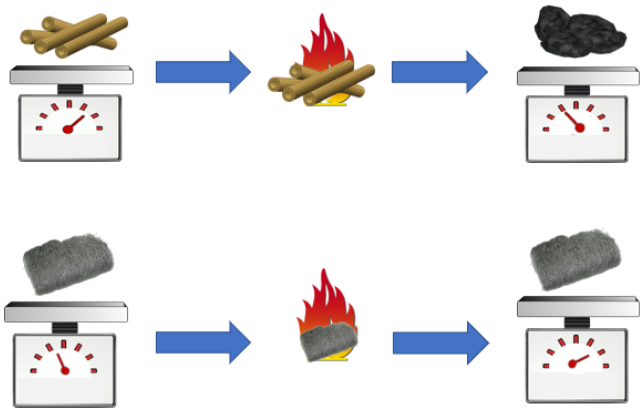

Figure 17. Carbon experiment

The wood is mainly composed of cellulose, hemicellulose and lignin, these compounds are formed by carbon, hydrogen and oxygen that make it a combustible material. Those components burned, forming CO_2 and H_2O, which are gases. That is the reason why second weight is smaller.

On the other hand, the temperature of the wool increases so fast in a few seconds, so a hard oxidation occurs. This high temperature can not be evacuated sufficiently, and then the iron wool gets incandescent. The gain weight is owed to the oxidation reaction, that in case generates a solid product (Fe_2O_3) which remains there.

That is the reason why the weight is bigger.

6.2.2.2. Copper

In relation to the thermal conductivity, following experiment (Figure 18) will be done [40]:

1. Fix two metallic bars, on made of iron and the other of copper
2. Spread some solid wax over them
3. Heat up at the same time both bars, from the opposite side of the wax
4. The wax which is on the copper bar will melt before, just because the heat will reach it sooner than the other, due to the highest conductivity

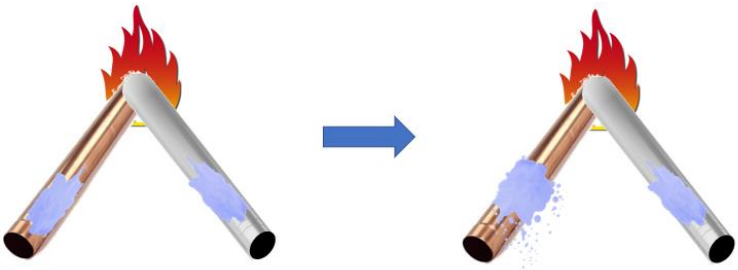

Figure 18. Copper experiment

Metallic solids present bonds that make possible the free movement of the valence electrons, and that gives way to the property of the conductivity [41]. Metals have high thermal conductivity, as well as electrical, but in this case, copper has much more thermal conductivity than iron (Table 5). These high values of thermal conductivity are related to the vibrations of the ned (phonon) and free electrons. In this case, copper's conductivity is five times bigger. Therefore, in the experiment, the wax located on copper is going to melt earlier than the wax which is on iron.

ELEMENT	k (W/m*K)
Iron	80
Copper	398

Table 5. Thermal conductivity of iron and copper

6.2.2.3. Iron

Iron came after copper in the history due to its higher melting point. Furthermore, iron is known by its resistance and its magnetic behaviour. In this part of the workshop it will take advantage of this last property, making a compass (Figure 19), with a needle, a cork and a magnet [42].

1. Scrub a needle with a magnet
2. Put it in a cork (it will act as a support) and fix it with adhesive tape
3. Release the assembly in a pan filled with water
4. Compare it with a compass, and effectively, it works

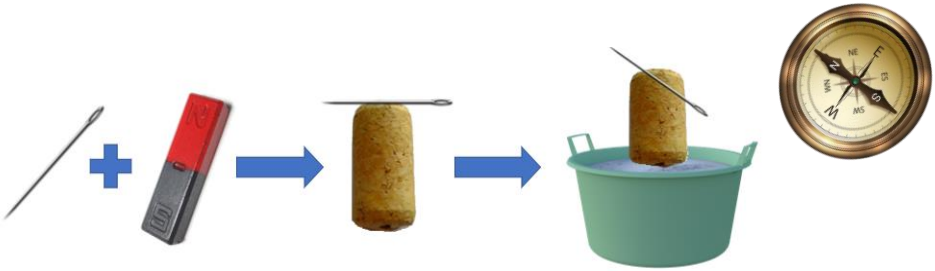

Figure 19. Iron experiment

Iron, cobalt and nickel are the only three metals that when magnetized can produce an intense magnetic field around themselves. That is because they are ferromagnetic [41]. Ferromagnetism is a physical phenomenon in which magnetic ordering of all the magnetic moments of a sample occurs in the same direction and sense, and that involves the creation of a magnetic field around the metal.

6.2.2.4. Gold

The reason why the gold is used for paying [43] [44]:

- Must be solid at room temperature, for practical issues. So, the last column (noble gases) is discarded.
- Should no react easily, and this dismiss alkali and alkaline earth metals
- Lanthanoids and Actinoids are weird, rare and radioactive
- Metals from the fourth and fifth period react with oxygen
- Metals from the sixth also react with oxygen, and some of them and radioactive
- Aluminium (which nowadays thanks to the advance in technology is very easy and cheap to produce it) was very difficult, even impossible, due to its reactivity with oxygen, so in the nature it is never alone as Al, always forming oxides.
- The non-metals are also discarded, because they are very reactive, or gases, or short-lived, therefore, the money would disappear

All these reasons lead to only three metals, gold, silver and platinum. Silver has been used as a coin, but it has an inconvenience: it gets blacken after many uses. Nowadays platinum is more valuable than gold, but its disadvantage is that it is very difficult to extract. The gold, however, is in the nature as gold native and, due to lack of reactivity (it is one of the most noble metal of the Periodic Table). Therefore, the winner is the gold, and the second, the silver. The experiment to demonstrate those reactivities is very simple. Both metals, gold and silver, are

going to be treated with nitric acid. Gold, as due to its lack of reactivity, will remain immutable, but silver will experiment a redox reaction (Reaction 1).

$$3\ Ag_{(s)} + 4\ HNO_{3\,(aq)} \rightarrow 3\ AgNO_{3\,(aq)} + NO_{(g)} + 2\ H_2O_{(l)} \qquad \text{(Reaction 1)}$$

6.2.2.5. Aluminium

The following experiment will demonstrate the effect of the passivation [45]:

1. Introduce copper (II) sulphate in a glass (Figure 20)
2. Add water (Figure 21)
3. Heat the dissolution and shake it (Figure 22)
4. Cover a pan with aluminium paper (Figure 23)
5. Once the solution is hot, put it on the pan covered with the aluminium (Figure 24)
6. Shake and add some sodium chloride if the reaction does not start (Figure 25)
7. In a few minutes it appears some brown solid, which is copper metallic (Figure 26)

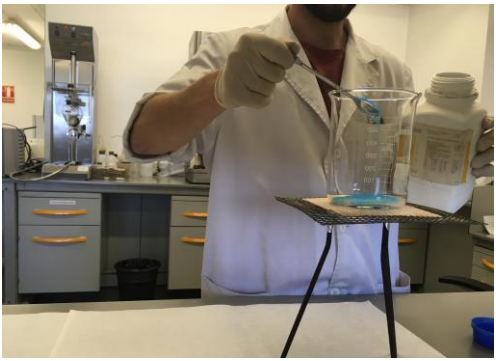

Figure 20. Step 1. Introduce $CuSo_4$

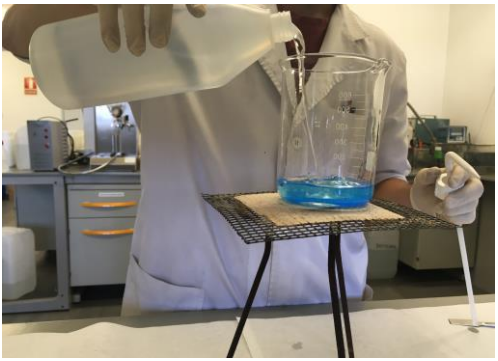

Figure 21. Step 2. Add water

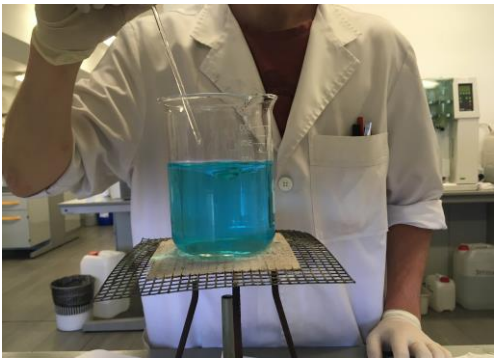

Figure 22. Step 3. Heat and shake the dissolution

Figure 23. Step 4. Cover a pan with aluminium

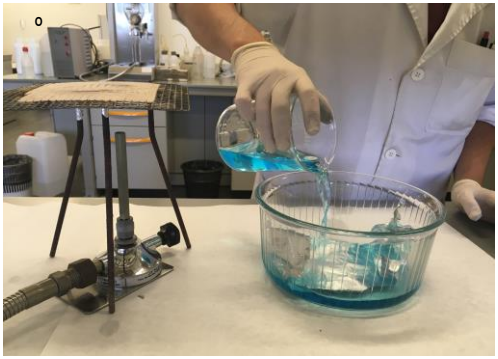

Figure 24. Step 5. Mix the solution with the aluminium

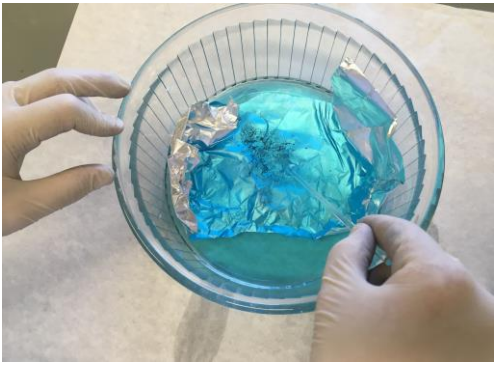

Figure 25. Step 6. Shake and add some NaCl

Figure 26. Reaction non-catalysed finished

Figure 27. Reaction catalysed finished

The redox that is happening is:

$$2\ Al_{(s)} + 3\ CuSO_{4\,(aq)} \rightarrow Al_2(SO_4)_{3\,(aq)} + 3\ Cu_{(s)} \qquad \text{(Reaction 2)}$$

The process (Reaction 2) is already finished, but it was slow, and not much copper was produced. Therefore, if the experiment is repeated, but adding the sodium chloride in the step number two, the reaction will be much faster, and more copper is going to be produced (Figure 27).

The explanation of this experiment is related to different chemical potential of the metals. In this case the chemical potentials are shown in the Table 5:

REDUCTION	Eº (V)
$Al^{3+}_{(aq)} + 3\ e^- \rightarrow Al_{(s)}$	- 1,66
$Cu^{2+}_{(aq)} + 2\ e^- \rightarrow Cu_{(s)}$	0,34

Table 5. Chemical potentials of Al and Cu [46]

Due to the high negative chemical potential of aluminium, it is always oxidised in front of many different acids and oxygen, but, this oxide, with a nanometre thickness, remains fixed to the metal acting as a protector. This phenomenon is called passivation [41]. It involves the creation of an outer ceramic layer, which protect it from the corrosion in many environments. This fits with the fact that aluminium is used in objects which are in contact with the air. Having said that, the salt can interfere with aluminium's ability to re-form a passivating film. Tiny local fluctuations degrade the oxide film in a few critical points, being able the oxidation of aluminium.

6.2.3. The workshop's kick-off

Through the analysis of the surveys conducted, it has been noticed that students from 8 to 16, would appreciate this kind of workshops and activities, in order to develop themselves in the scientific field. Therefore, the workshop *The Four Fantastic Metals* is going to be lunched at the Researcher's Night 2019, in the most appropriate place according to the general theme (CaixaForum, libraries, cultural centres, etc.), as well as in any kind of cultural and scientific events.

7. CONCLUSIONS

Three main conclusions can be obtained from this project; these are the following:

The first conclusion is that the survey was indeed useful enough to conduct the workshop, and it can there for be used in the future for conducting other different workshops. However, it should be improved by making it more dynamic in order to make the poll more adaptable to a bigger number of people.

Another conclusion is obtained from the experiments that were made. It is visible that copper has better conductivity than steel, iron is a magnetic element, gold is one of the most noble metals in the Periodic Table, and aluminium, due to its high reactivity with oxygen, experiments the phenomenon of passivation and it does not oxidise.

Finally, the workshop was also conducted to some people other than high school students (both specialists and non-specialists) which gave joy and new knowledge to everyone who took part of it. Therefore, another observation is that the workshop adapts to the public all kinds of public, keeping all activities the same and changing only the speeches and explanations.

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9. ACRONYMS

ApS	Aprenentatge Servei
CCMA	Corporació Catalana de Mitjans Audiovisuals
ESO	Educació Scundària Obligatòria
FECyT	Fundación Española para la Ciencia y la Tecnología
IYPT	International Year of the Periodic Table
k	Thermal conductivity
LS	Learning Service
STEAM	Science, Technology, Engineering, Art and Mathematics
TFG	Treball de Final de Grau
YoMo	Youth Mobile