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# Grau de Química

# Treball Final de Grau

**NANOTECHNOLOGY AND COMUNICATION: From Nano to the World**
**NANOTECNOLOGÍA Y COMUNICACIÓN: De Nano al Mundo**

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A mis padres, por su constante apoyo y ayuda a lo largo de esta etapa. A mi hermana y mi hermano por dar un punto de crítica, a su manera, *constructiva* y a la vez echar una mano. A mi pareja por aguantarme cada día, ser una pieza clave y animarme a hacerlo cada día mejor. A mis abuelas por cuidarme siempre, una más cerca y otra desde más lejos. A mi tío Jona por aportar su punto de vista como científico al trabajo. A mi colega Ben, por darme consejos sobre edición. A la clase de 2º ESO del IES Lluís Domènech I Muntaner y a su profesor Óscar por la atención y la participación brindada. A su directora y mi maestra, Montse que nuestros caminos se crucen más veces. A Ana y Padi por su implicación y comunicación. Y a "Los de la Barbacoa" y el resto de mis amigos y amigas por su comprensión en mis ausencias y ser mi fuente de desahogo. A todos y todas, muchas gracias.

# REPORT

# IDENTIFICATION AND REFLECTION ON THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

United Nations (UN) set a number of goals[1] to achieve by 2030. These goals are composed of 17 points that can be divided in the 5P's: People, Prosperity, Planet, Peace and Partnership. For this strategy to succeed, we should consider them in every aspect of our life. Therefore, this work has been done according to them. As it is very difficult to cover up all of them in just one thing, this study has focused on two points.

The work is included in the People's P. The obvious goal is Nº 4: Quality Education. This works pretends to improve the quality of the education all over the world by showing different ways of not only science dissemination but communication as well. Above its 10 target goals, this work covers 3 of them: 4.4 as it enhances society skills, 4.7 it remains society of the importance of sustainability by means of Nanotech applications and in 4.C as a consequence of this work targeting not just learns but also teachers to improve their skills.



Figure 1, SDG main goal of this work[1].

The second one would be the 8Th: Decent work and Economic Growth. As for the achievement of knowledge society is concerned, once everyone makes decisions well founded, economics will grow all along. Decent works will start coming up as a consequence of the progress of society.

Nevertheless, in case we consider this work as nanotechnology, almost all the points are acquired thanks to the big potential this field possesses. From point 1 about poverty and what nanotech can bring to everywhere to point 17 that will be affected as society must agree in terms of security and legal affairs that future nanotechnology applications will create.

# CONTENTS

# 1. SUMMARY

In the present study, communication has been mixed with science to obtain science dissemination, as if it was a chemical reaction. These concepts must be well defined. Therefore, the "reagents" are firstly introduced. Subsequently, both the science's field that has been popularised -Nanotechnology- and the ways of spreading information are presented. Nowadays, science faces the problem of nearly neglect. This can be caused by two aspects: the message itself or the other elements of the communication.

Since what is being communicated is really important and affects everyone (science is in everyone's life), the initial hypothesis has to do with how it is spread. After analysing the different options, making a video was the best choice so as to disseminate Nanotechnology. *Introduction and History*, *Applications* and *Moral Debate* are the three tittles of the videos whose objectives are to cover up all aspects.

The importance and the scope that Nanotechnology can provide is reflected. Afterwards, the effect of the videos has been analysed in a High School class. They were played in a speech mixed with questions and interactive activities. The final form evinces that they not only have found the activity interesting, but also it has made them widen their perspective about science. As a consequence of their responses, it can be concluded that a video is an excellent tool to disseminate science. Moreover, when it is blended with a participatory class higher results of interest about it are obtained and it attracts attention from new generations to science.

**Keywords**: Communication, Science Dissemination, Nanotechnology, Applications, Video

## 2. RESUMEN

En el estudio, la comunicación ha sido mezclada con ciencia para obtener divulgación científica, como si fuera una reacción química. Estos conceptos deben estar bien definidos. Así es pues que, los "reactivos" han sido primero presentados. Seguidamente, tanto el campo que ha sido diseminado -Nanotecnología- como las maneras de repartir conocimiento son presentadas. Hoy en día, la ciencia enfrenta el problema del abandono. Esto puede ser debido a dos factores: el contenido del mensaje o el resto de elementos de la comunicación.

Debido a que lo que se comunica es realmente importante y afecta a todo el mundo (la ciencia está en la vida de todos), la hipótesis inicial tiene que ver con cómo se divulga. Después de analizar diferentes opciones, hacer un video fue la mejor elección con el fin de diseminar Nanotecnología. Introducción e Historia, Aplicaciones y Debate Moral son los tres títulos que tienen los videos cuyo objetivo es cubrir todos los aspectos.

La importancia y el alcance que la Nanotecnología nos puede proporcionar queda reflejado. Más adelante, el impacto de los videos ha sido analizado en una clase de instituto. Se reprodujeron en una charla mezclada con preguntas y actividades interactivas. La encuesta final evidencia que no solo han encontrado esta actividad interesante sino que también ha ensanchado sus miras sobre la ciencia. Como consecuencia a sus respuestas, se puede concluir que el video es una herramienta excelente para divulgar conocimiento científico. Además, cuando se promueve junto a una clase participativa, obtenemos mejores resultados por lo que hace al interés sobre ellos y atrae la atención de nuevas generaciones.

**Palabras Clave**: Comunicación, Divulgación Científica, Nanotecnología, Aplicaciones, Vídeo

# 3. INTRODUCTION

In this Final Project (FP), I try to explain nanotechnology and science dissemination and how I manage to mix them. I have first analysed the results of a survey made by *Fundación Española para la Ciencia y la Tecnología* (FECYT) about science in several groups of people[2]. It is reflected that although science is a field in which Spanish society is interested (3.09/5), it is not the top 1. It is in top 6 (Figure 2), under medicine and health that makes sense after the pandemic and unexpectedly above sports. Another interesting fact that inspires this work is that 54,1% (Annex 1) of our society do not believe that positive scientific aspects are better than negative ones. This disregard is one of the problems I want to deal with.
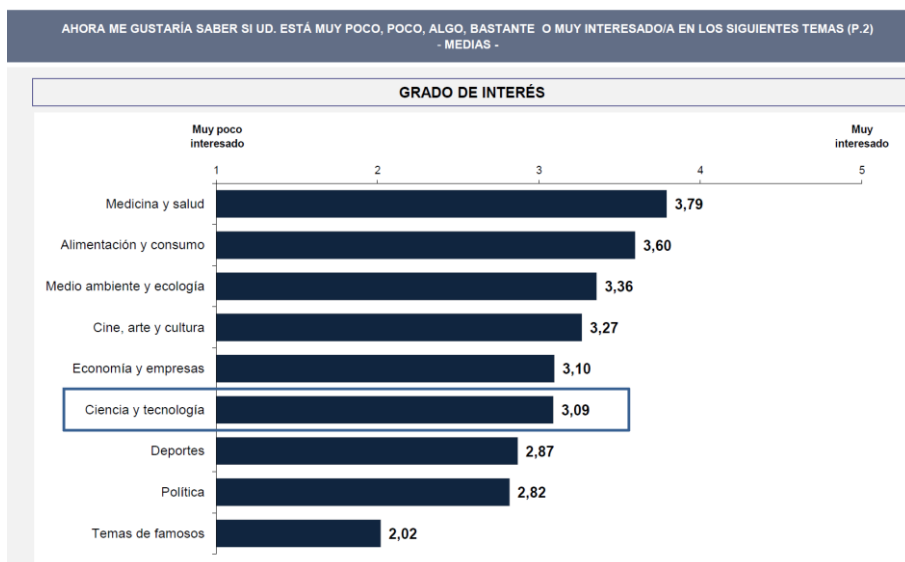


Figure 2, Society interests[2].

Along this introduction what science can improve and what communication can provide is reflected. There are no plenty studies about scientific disseminations, therefore one of the things that make this work valuable is its shortage. This is not the only reason why I made this FP. Being a chemist (or almost a chemist) and, talking about communication provides this work the perspective of one of those who have always lived around reagents and numbers as opposed to those who opine about scientists without never stepping in a laboratory.

## 3.1 SCIENCE AND SOCIETY

Science is a big topic everyone is familiar with. It is a concept that includes all the knowledge that has been obtained through testable explanations and prediction, better known as the scientific method. As this work comes from a scientific degree, this part is focused not on what science is and what the scientific method requires but on why it is important and what it should improve in order to get better.

### 3.1.1 Impact of the Science on the Society

Thales of Miletus, Nicola Tesla, Marie Curie, Margarita Salas…These are some of the names that have made a really important impact on how science has changed society. From the mere fact that made first humans burnt themselves in the pursuit of learning how the fire worked to the study of the space that is still ongoing; almost all forms of development have come from science. Not only chemistry, physics, biology… have helped humanity, but also social sciences like psychology have. Being a scientific means wanting to analyse and study every inch of ignorance that arise on oneself. Let's imagine the fact that Archimedes had never wondered why the water of his bath overflowed, or that Newton had never wondered why the apple fell. As they wondered those things, a prediction was done then and all the necessary calculus. There were more things needed than just theories, because without a real application they become useless.

### 3.1.2 Science Needs

Science is not just about thinking and guessing. As everything in life, resources are the basis that allows things to work. Resources include both money and workforce. Using the examples shown before, Archimedes could convert his thoughts into consistent application as he worked for the King and Newton had Halley's financial support, who was a very rich astronomer. Even Tesla would have been a much greater investigator if he had had better business mind and more money. It is a pity that making science is so expensive, that in order to earn funds you must convince rich people. It is complicated for a devoted scientific to have its own financial support if they have been working and studying for a long time without clear incomes.

The other important resource science needs is to attract people, especially young people, to be interested in science because it is what, at the end, the ones that change and improve the world. As seen before, science is not on the top 3 of Spanish society interests so this has to

change in case science wants to get better. The more people are interested and well taught, the more findings and theories will arise.

### 3.1.3 Where to improve

For science to improve, it is needed to get more people involved. This can be made in two ways, improving what is being communicated or improving how it is being done. As the first one is so wide and has many fields, scientists should focus on the second one. Only a 17,7% of the survey respondents (Figure 3) want to be able to debate about science.
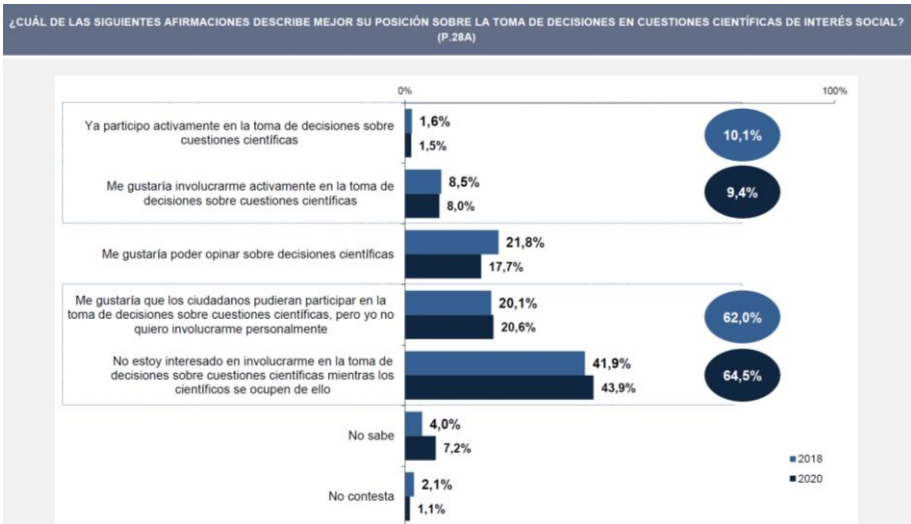


Figure 3, Society position about scientific themes[2].

There could be many reasons that support this statement: the ignorance about what science provides, the unawareness of the importance of its benefits, the fear of them being wrong and criticised or science being difficult, or even because they do not give enough relevance to the tool that makes us evolve. All these reasons must be fixed and mixed with an improvement on communication so that science reaches the greatness and its maximum potential, that it is still far from it.

### 3.1.4 Nanotechnology: Huge Potential

Science is a system of knowledge acquirement that comprehend a vast range of fields. The first ones were studied in the Prehistory, some of them were born in the Ancient Era with the introduction of the wheel and most of them appeared in the Modern Era. Despite the fact that

there has been a long time since the first "study", not all the questions that past society made to themselves have been answered properly. However, science is constantly getting new disciplines, therefore it never ends.

*"I know that I know nothing"*

This popular quote that Plato attributed to Socrates in his apology back in s.IV b.C, is still useful for today's civilization. Freshly made discoveries are the ones that tend to be more worthy in terms of not having been exploited yet. Nanotechnology seems to be the latest one and it also covers a great deal of areas of application.

Nanotechnology, also known as Nanotech, is a branch born in s. XX and explained more thoroughly in Chapter 5. It is going to be the future of humanity as it can be applied in medicine, transport, spacecrafts, sports, electronics, fabrics, health products and almost everything you have in mind. No one has ever seen this potential anywhere and it is thanks to its capacity for creating nanorobots which can be programmed to do whichever task we want (not tiny robots, but programable beings made of carbon fibers) and, because its potential capacity of creating new materials using fresh air as raw material. It is new, it has potential and society is not aware of it[3], therefore it meets all the requirements needed to be a good discipline to be popularised.

## 3.2 COMMUNICATION

### 3.2.1 What it is

The other topic that must be introduced is communication. Society is constantly communicating in several ways and the fact that there is not only one way of doing it is what differentiates us from the rest of animal species. Bats and whales establish contact between them by using frequency waves that can travel long distances. Bees dance in order to let other bees know where the nectar is and to alert from enemies. The list of how animals communicate is extensive, but humans are at the top. Humans' communication comprehends all the explained ways and we have perfectioned it throughout time. Therefore, the real challenge we face is not whether we are able to do it, but to choose the most suitable option for each case.

Communication is constantly changing. It has varied a lot from back in prehistory when families sat around the leader listening to the news about the tribes, to the appearance of printing back in 1440. Nevertheless, it is not necessary to go back that long: less than 60 years ago, the primary way of communicating was a mediocre telephone (comparing to those we have

nowadays). The creation of internet has driven us to a world where we can be in touch with someone in the other side of the planet. It is not a crazy idea to think about the possibility of communicating further in space or even between different moments of time in 100 years. That is why mastering communication is something society must do in order to evolve.

The last 10 years reflect the importance communication and how social media have affected our lives. Nowadays, we read the news in Tweeter rather than in a newspaper, we listen to music in Spotify or YouTube rather than in CD's or we watch films from our home in Netflix or the latest streams in Twitch. The main communication channel is WhatsApp or Instagram. These are a vast range of possibilities that allows us to get as much information as possible. Sometimes this information is mistaken, and we communicate in a wrong way. Therefore, in order to avoid misinformation (Appendix 1), having a critical spirit towards these loads of incomes is compulsory.

### 3.2.2 Knowledge society

A knowledge society refers to the type of society that is needed to compete and succeed in the changing economic and political dynamics of the modern world[4]. It will be built providing society is well educated. Being in a good educational standard lets society rely on their knowledge to drive economy in terms of innovation, dynamism and entrepreneurship. In order to follow this path, governments and firms must cogenerate laws and availability for everyone to every aspect of knowledge. This knowledge must be understandable and catchy to those who expect ruling the world in the terms of a knowledge society. Here it is where scientists present themselves as these disseminators that society needs.

### 3.2.3 Science Dissemination: Theory

Science dissemination is very powerful tool to spread information because it provides a means for the experts in a topic to explain it in a more engaging and simple way. In order to know whether it has been used correctly, the audience is needed to be tested via some type of form or exam.

As introduced above, science dissemination helps scientists to share their findings and their knowledge to a considerably high number of less expert people. As what has been done before, the definition we could find about disseminate is to broadcast a message to the public without direct feedback from the audience. It serves the purpose of communicating and if it is done in the best possible way, it could reach objectives like promoting love for science or getting funds. Both

targets are equally necessary for humanity to develop new devices and improving the standard of life.

Those who pursue to cause a great effect in their audience must take in to account several things. The first ones answer the question: how it is explained. The style used in the message must be precise and as straightforward as possible. Writing down or broadcasting the information using an easy grammar would let the receiver focus on what he/she is reading. A direct work without ambiguities leads to a much better understanding without constant guesses about what the writer does really want to express. Einstein once said : "Keep things as simple as possible, yet not simpler". It is important not to lose neither formalism nor consistency in our pursuit of simplicity.

The other ones are the ones related to which means have been used to communicate. We are constantly being bombed by hundreds of different types of communication, not all of them being either fair or suitable for each case. For us to identify the best way to spread the message, the first thing we should do is to analyse the audience and try to find which one fits better. The range of possibilities we have is huge. It can be split in two: the written ones and the spoken ones. All the scientific books that have been published, from those which are used to teach to those which are bought to have fun, are ways of science dissemination. Articles, handbooks, journals… are other types of scientific works but these tend to be less informational.

On the other hand, we have spoken ways of popularising information. The most typical ones are symposiums or talks from informational perspective. There are also the oldest ones as they "existed" back in the ancient Greece when the speeches were performed in front of everyone in the Agora. In order to update them, associations like FameLab[5] or TedTalks[6] promotes these talks all over the world by making them compete. Another typical channel of communication of the modern era is to use videos as a way of making these lectures perdurable. Videos can be both recorded at the same moment during the pep talk and recorded at home with more time and preparation, there are millions of videos posted on Youtube that show this both ways of recording. Not only the first one but also the second one enlarges the reach of the message. It is highly important since the more audience, the more resources (both personal and monetary), as explained before. Nowadays using social networks like Tik Tok or Instagram in an audio-visual way or Tweeter in a more written way will magnify in a billion times the repercussion of the idea. YouTube also is like an information amplifier and youtubers like Veritasium[7] exemplifies it very

well. A youtuber is a person who makes videos and post them on YouTube following a schedule. They sometimes explain some important things that we would not be aware of if it was not because of them. As the youtuber named before did, they can reach 85 million views and approach interesting facts to society, that is one of my desires with this work but with nanotechnology. Spanish scientific youtubers have also a great impact in Spain like Quantum Fracture[8], who reach 2,6 million views talking about atoms.

### 3.2.4 Science Dissemination: How it IS done vs How it SHOULD be done

This society's need explained before must improve because otherwise achieving the goal of reaching a knowledge society will be very difficult. Nowadays, science is exhibited as a luxury available to few who are the smartest or the most intelligent people or even the richest ones. It is usually portrayed using complicated and rare words not because it is needed, that sometimes it is, but because it separates people in those who understand or will be capable of and those who will never be able to do it. As a student I have heard comments about the extremely difficulty of my career or other science careers from people coursing law or economics. With these words I do not pretend to discredit my career but to enlighten that is less complicated than what people tend to think.

The way of teaching and the perception of the society about science is something, we as scientist, must reconduct. Both aspects can be done by means of science dissemination and during this work is what I have tried to show. The strategies that are carried out nowadays are both old-fashioned and a little discriminatory, as explained before. Books with just formulas and boring classes should be redirected to practical things students can touch and that show real applications. More time in laboratories during first educational ages or more excursions to see new exhibitions would help these upcoming generations to get attracted. For example, a new way of teaching that is arising nowadays is to explain or teach facts via social media like TikTok that allow to do it in an entertaining way. The other thing that should be improved is the way of explaining not just the channel. Making the grammar simpler and finding the proper words to explain more complex concepts should be a thing scientists consider before addressing to the audience. Not everyone to whom a scientist speaks is a scientist. Therefore, we should not presume that all the words said are understood, despite being in a first instance easy for us.

## 3.3 MOTIVATION FOR THIS FINAL PROJECT

At a first glance, the outcomes from this work are very clear: to know more about Nanotechnology and taking out the fear of it. Nevertheless, this work is not based on nanotechnology neither it pretends to be. This work aims to reflect the importance of contributing to a knowledge society by disseminating a non-common scientific topic such as those involving nanoscience to a non-specialized audience. It also tries to point out the different paths scientists have to spread their studies.

"Publish or perish". Yes, it is definitely true that publishing in articles and in journals and having references is what will give credibility to the study. However, making the projects readable and understandable for everyone is as important as publishing them in order to bring science, or in this case nanotechnology, to a 40% of people instead of the actual 4%[2]. Providing we are able to communicate new and intriguing findings in an optimum way, awareness of the importance of science will rise exponentially.

Communication is one of the foundations of our society and it is what really differentiates us from other animal species. As it is said before, knowing how to explain things is so important that marketing people is starting to be very requested nowadays. Although whoever communicates has to be good, the topic must be very attractive. Nanotechnology is a science's branch that has the potential to determine the future of humanity.

This FP can be very useful not only in theory terms and explaining how to do them but also it could be useful for entities to spread Nanotechnology. It is supported by the Institute of Nanoscience and Nanotechnology of the University of Barcelona (IN$^2$UB)[9]. The material attached to this work would be able to be published in the in the organization web page and used as an educational tool for the several activities that the institute performs each year. This is one of the reasons why I chose this FP.

In order to sum up the facts explained, I would say that science has 2 actual problems. Those are the difficulty that the public attributes to science and the outdated manners we scientist use to spread information. These obstacles dispel our society from a knowledge society. This can be solved using science dissemination and its tools that approach science to citizens. To do so, this study explains why the best way is the creation of three videos about Nanotechnology to spread it. It also shows the preparation of both the videos and the class and ends up evaluating its impact by means of a survey.

# 4. OBJECTIVES

For your firm to succeed, it is better to have objectives in a narrow scope rather than the willing to gather every possible aspect. As I am not an entrepreneur but a scientist, I have tried to get as many things as possible from my work, like a chemist would do while trying to take the most out of a reaction and considering all the subproducts.This work has 3 main objectives:

The first one is to create three informational 5 minutes videos about what nanotechnology is, its history, how it affects our live nowadays and in the future. For them to have a greater impact, they have been played along with a speech.

The second objective is to analyse the impact of these videos in a non-specialised group of 13-14 years old. This point is extended in Chapter 6 when explaining the unique characteristics that this group possesses.

The last but not least is an objective that leaves the work an open door to improve. It is a reflection about new ways of approaching this topic to society and how science dissemination can be better.

The FP also wants to approach nanotechnology to society by means of science dissemination. It can show scientists how to communicate their research, and in the best expectations, it can help to produce new scientists. This work tries to highlight the importance of the union between both communication and science by means of a rising discipline that is about to explode like Nanotechnology.

# 5. NANOTECHNOLOGY- PAST, PRESENT & FUTURE

There are two basic things that are compulsory to cohabit in a communicative action: the message and the channel, one won't have sense without the other one. There are other important aspects that appear throughout the work. In this chapter, the Message is explained, and it is the past, the present and the future of Nanotechnology and, in Chapter 6, channel will be presented.

As it is a rather new branch of expertise, a purely good definition has not been settled in the scientific society yet. From a scientific point of view, it has been interpreted in several ways. The National Institute for Occupational Safety and Health (NIOSH)[10] says:

> *Nanotechnology is the manipulation of matter on a near-atomic scale to produce new structures, materials and devices.*

It is quite general, and it uses the word *near* so is not very accurate. The National Nanotechnology Initiative (NNI)[11] narrows to a scale of 1 to 100 nm and adds a little more information:

> *Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100nm. Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.*

This initiative also involves certain activities such as measuring and manipulating nanoscale matter which can be very attractive. There are loads of definitions in internet representing the amount of things Nanotech is able to do. Nanoscience is "a discipline at the cutting-edge of scientific knowledge"[12] and this provides these multiple interpretations.

In order to define it in the best spreading way, it has been divided. On the one hand, there is the prefix "*Nano-*" which relies to the scale. Nano means $10^{-9}$ or what it is the same, one divided by one thousand millions (9 zeros). An example of this magnitude would be to compare the peak of Elon's Musk fortune[13] (340.000.000.000 \$) to 300 \$ (less than what a PS5 costs)[14] or to compare the length of the Burj Khalifa (800 m)(Figure 4) [15] to the average of hair diameter (0,057 mm)(Figure 5) [16].
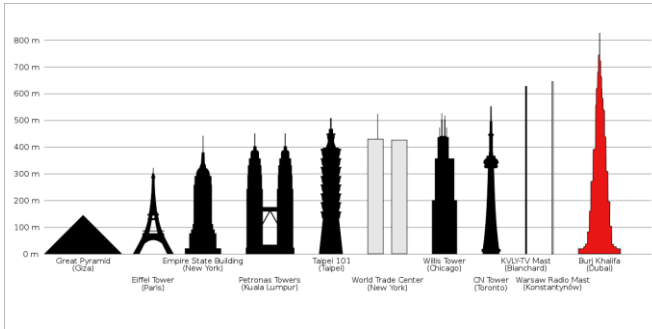
Figure 4, Height Comparison of Burj Khalifa[15].



Figure 5, Thickness of a hair compared to a coin *(Own Image)*.

On the other hand, there is a much more known word like "-technology". Etymologically speaking it refers to the study (-*logía*) of an art or skill (*tékhnē*)[17]. As it is commonly known, it is the application of scientific knowledge for practical purposes. Consequently, both terms signify the study of the skills at nanoscale.

It is very important to know why it is necessary for the audience to know about Nanotech, therefore, to point it in a timescale is needed. Richard Feynman is considered to be the father of Nanotechnology. Years before this concept was conceived by Norio Taniguchi in 1974, as a consequence of his symposium (Figure 6) [18] entitled "There's Plenty of Room at the Bottom" back in 1959. He theorised about manipulating atoms long before "seeing" them back in 1981 with the

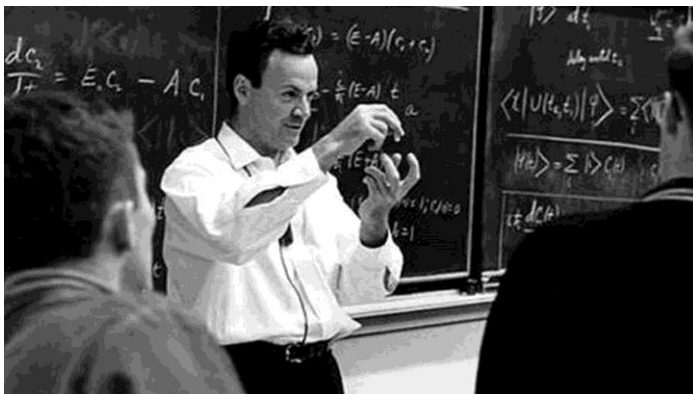development of the Scan Tunnelling Microscope (STM) and when modern Nanotech is believed to begin.



Figure 6, Feynman's Symposium when he said the quote mentioned[18].

This glance at history let us situate in time with the purpose to comprehend better the scientific basis of this field. Nanotech has an enormous potential thanks to all the different characteristics nanoscale gives to materials in comparison to bulk materials, which has not been leveraged yet. Its size allows reactions to go faster as there is more surface. The more surface there is, the faster it will go because atoms will be more prone to achieve an optimal position. This size can also lower melting points hundreds of degrees or it can enhance quantum effects.

As the NNI reflects about nanoscale*: properties such as melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity can change as a function of the size of the particle*[11]. Gold nanoparticles are a clear example of how much scale can change properties as they interact differently with light in comparison with bulk material. It gives nanotechnology a very distinguishing beauty among other disciplines(Figure 7) [19].
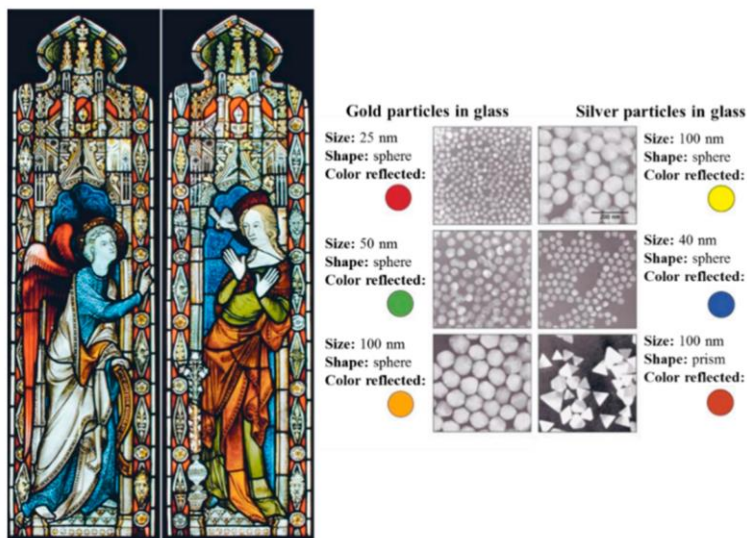
Figure 7, Stained glass from Stained Glass Museum, Britain and colour due to size of gold particles[19].

Another interesting fact about these particles is that they can minimize pore size that results in making solids storage more liquid or gas (as aerogels) or making walls more insulating. Functionalizing materials by bonding them with nanoparticles is something that widens even more the range of Nanotech. These new nanocomposites can end up being the target of new drug deliver agents or be the means used for creating polymers to make lighter spacecrafts. As it is not a work about nanotechnology but about science dissemination; I will only enumerate some other characteristics before focusing on why it is important to be spread. Sharing the size in which much of the biology reactions take place, having the possibility of creating nanorobots or being able to build an object atom by atom (nanoassembly processes) are some of the bases Nanotech possess to have such a great potential.

All these properties would be a miss if they have no real application. Nanotechnology covers a huge range of areas, from advances in medicine or in health care[20] to those in military equipment or aerospace[20]. Nowadays there are plenty of unknown areas where nanoparticles appear. For example, titanium dioxide nanoparticles, $TiO_2$, absorb ultraviolet (UV) light and reflects all the colours that are in the visible spectrum so that makes this material perfect to be used in both sunscreens. It can be used as white paint as well because it reflects all the colours in the visible spectrum[20]. It sometimes may be the reason why our skin has white residues after applying sunscreen[20]. Another relevant element in nanoscale that is being used these days is

silver. Silver nanoparticles have more silver ions[20], and it makes them a very good antimicrobial agent that we can find in a low-cost filter mixed with carbon nanotubes.

Something that cannot be missed while talking about Nanotechnology are carbon nanocomposites. Almost all live forms are carbon based, therefore that can give us an idea of how versatile it is. Since the discovery of buckyballs, also known as fullerene, that happened back in 1985 by Richard Smalley, Harold Kroto and Robert Curl[21]; a great vary of carbon nanoparticles have emerged. From carbon nanotube (Figure 8h) to diamondoids (Figure 8a) (not diamonds), going through graphene (Figure 8b, just one layer).Those are some of the structures carbon atoms may shape up[22]. This makes them to be considered in many fields as every composition generates different properties. They can be used by the National Aeronautics and Space Administration (NASA)  to build lightweight spacecrafts because of their strength due to de covalent bonds between them or as a better substitute for copper as an electrical wire as a consequence of their changing orientations.
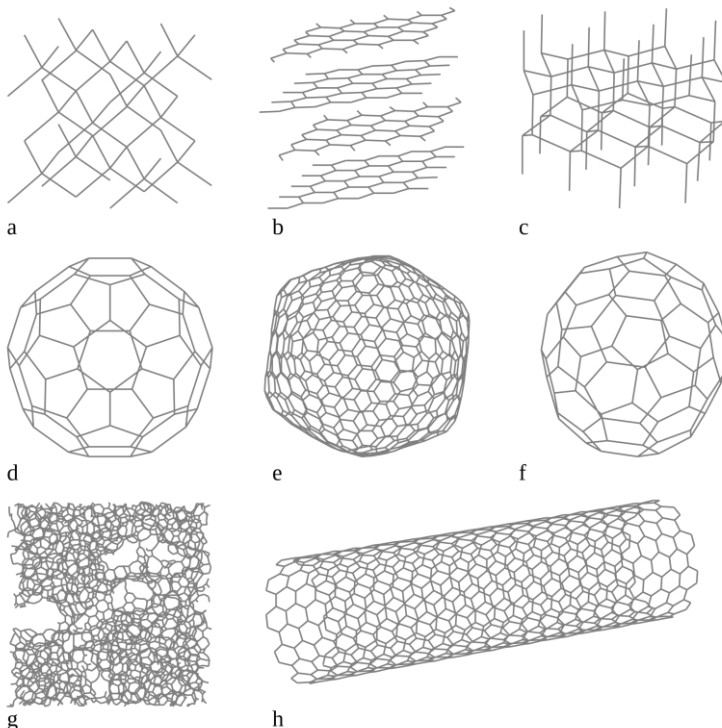


Figure 8, Eight allotropes that pure carbon can take: a) Diamond b) Graphite c) Lonsdaleite d) C60Fulleren e) C540 f) C70 g) Amorphous carbon h) single-walled carbon nanotubes[22].

Yet it is true that only the tip of the iceberg has been sight. Not just millions but an infinite of possibilities Nanotech can reach one day. There are two important aspects that, once they are acquired, the doors of the Nano will be knocked down. The first one is the possibility of making nanorobots that was pointed out before as a source of great potential. Providing one day society will get them, repairing either cell damage or cancer; even improving and lasting life will become more than just hypothesis; just as we have seen in science fiction. The second one is about molecular replication and its availability to anyone and anywhere. It would be a change in world economy and a change in everyone's mind.

Nevertheless, all that glitters is not gold. That why, when discussing about Nanotechnology, there are few challenges that must be faced.  All the current applications and the hypothetic ones must go hand in hand with providing a safer and a healthier future and that is why agencies such as Food and Drug Administration (FDA)[23] or European Medicines Agency (EMA)[24], the leading states in nanotech like USA or Japan and big companies must reach an agreement to regulate its use and availability.

In order to sum up this chapter, nanotechnology is a rising field of expertise with enormous potential thanks to its unique properties. It is needed to be used with high responsibility because: *with great power comes great responsibility[25]*.

# 6. DISSEMINATION ACTIVITY DEVELOPMENT

## 6.1 IMPACT OF THE ACTIVITY

As explained before, I have chosen to make three videos to spread what Nanotechnology is, what it is capable of, and which challenges it is facing, or it will be facing. From a wide range of non-scientific people, I took a group of 13-14 years old teenagers in order to make them unleash their stereotypes about science and try to make them be interested in nanotechnology. There were other possibilities that I rejected since they were either too young to comprehend the theme or too tough to arrive to them and analyse the results. They are a group 2nd of Secondary School Studies of IES Lluís Domènech i Muntaner, a High School in Canet de Mar, Barcelona. They have the perfect age because they are not that unskilled, and they have not an important scientific background yet.

The way of presenting them the videos is as almost important as the content of each video. Firstly, I wanted to make them feel important and to highlight that they were the reason I was there. I introduced myself as an alumnus of that Highschool to approach them. It is important to create synergies between both the audience and the speaker and it is easier if both have things in common (In this case, age and that both parts have studied in the same High School). I was asked before starting the class about the reason I had chosen chemistry and what opportunities did it provide to me. Then, I started talking, and asking questions to them about their knowledge in nanotech, what it is and what we can do so as to set the initial point.

After the first video was played, I remade few of the initial questions (Appendix 2) via Kahoot – an interactive form explained in Chapter 7- while I was playing with a tennis ball. I pass to one of the participants to make him answer the next question that was about what the gum pack that I got and what it had to do with nanotech. That is because both objects are related to nanotechnology and can have nanoparticles in them and asking about them helped me to introduce the second video. The span of time between video 2 and video 3 was little, I played the Kahoot again with more interactive parts and few questions more. At the end of the third video, the final Kahoot question was asked with a trophy for the one who won, the chewing gum pack. I made them consider the three final question of the video by asking randomly to them. It was a very special moment where we debated them, but without giving a right answer because there was not. The ending point of the speech, or the initial point in their scientific careers, was settled by asking them how they have felt and what they extract from this speech.

In this last form they completed (Appendix 3, Table 1), the questions about how the procedure of the presentation were included. By the time the bell has ringing, I asked them to take a  photo in order to immortalize the moment, but it is not possible to attach it here due to underage rights.

## 6.2 DESIGN OF THE DISSEMINATION ACTIVITY

Nanotechnology is the mean by of which science dissemination is put at stage. As exposed before, it is not the only channel of popularising and to find the most suitable one is one of the challenges I have had to cope with. As my target being a group of non-scientific people and specially teenagers, the message must be noteworthy and must have the possibility of spreading it both free and easy ways. Regarding these requisites, all the writing ways were discarded, including the Tweeter one. Despite being free and having easiness for spreading, not all young teenagers are in all social media. The audio-visual channels were left, and from all the possibilities a video was the best choice.

A video was chosen because it betters the preparation of a lecture and its dispersion and minimizes the wow factor. The video was thought to be projected in a big screen, in one singular day, therefore a video was better than other nowadays media like Instagram where people are used to surf every day in their own way. Being able to choose the perfect timing for music and effects helped me to make the decision.

The importance of the video relies on how you manage to maintain the attention of the audience. An average presentation tends to have lower attention as the time passes. During the recordings, changes in the tone of voice, asking some questions, or putting some flashy effects of movement and colour are some of the resources used to smoothen attention drops and to reactivate the class. That is why the length of the video was divided in three parts in order to make the presentation more efficient while mixing the videos with questions and comments that loom the attention (Figure 9)[26][27].
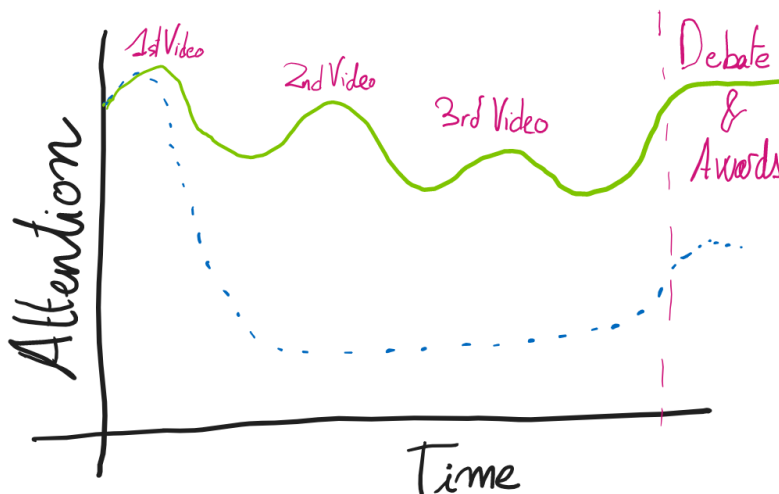
Figure 9. Attention during class: Average vs Optimized *(Own Image). Adapted from reference 26 and based on reference 27.*

As the youtubers mentioned in the introduction do, a good preparation before making the videos is essential. The preparation of the videos was one of the most relevant part of the activity. Providing there is good planification, a lot of time can be saved. Another reason why I divided the videos why because it helped people to choose which part do, they want to learn or to repeat in case they do not feel that everything is necessary. The first part is five minutes long and it introduces nanotechnology and tells its history. It also highlights the milestones nano has reached and who the first nanotechnologists were. It ends up by letting an open question that give entrance for the next video. The following one have to do with the applications nano can have and the most scientific part of the talk: the scientific bases of nanotechnology. These applications generate a moral debate settled in the third video. This one is the most theoretical one and it explains the opportunities nano will be able to provide and how society should treat them in terms of ethics, security and legal aspects.

This work has attached the three videos (Appendix 4) in case someone wants to watch them. Nevertheless, I would rather left record of the most exciting part of each video. In the first one, I would say that even though the timeline was very hard worked, the story behind the filming of the promenade and its result is the best. The second one is related to the scientific basis. It is how the pill was dissolved and its taught fact about reaction rate. As far as the third one is concerned,

throwing questions at the end and giving the opportunity to debate has been a good way of finishing the videos. Don't you think so?

## 6.3 OUTCOME OF THE DISSEMINATION ACTIVITY

The work done before will not be as useful as it could be if we don't analyse its results. I have approached the analysis of the speech in two ways: the things the students have learnt and how I can improve it.

From the first one (Appendix 3), they have found the talk both interesting and entertaining. I agree with them because I think good synergies were created as a consequence of the dynamism and the participation during the class. Almost 40% of the audience, including their teacher, used the word didactic to describe their experience (Figure 10). Their initial idea of Nanotech and its concepts could have been better. Nonetheless, it had good aspects since they spoke about "little things", "robots"  and "something very difficult to make real". The videos and the discussions during them are the reasons that have helped them smoothen their thoughts.
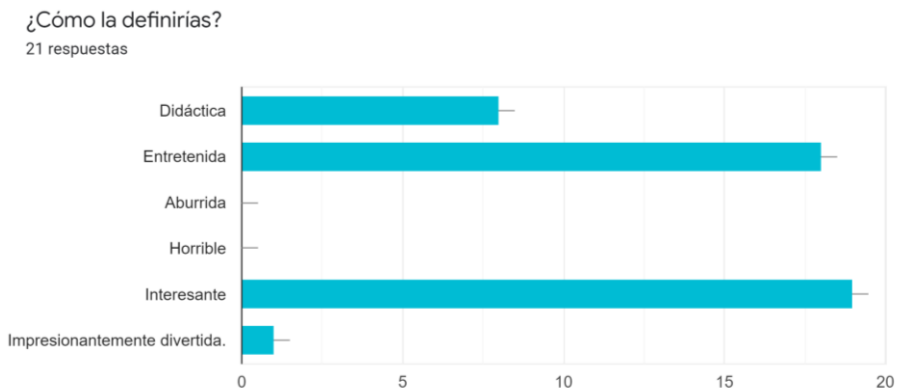


Figure 10. Definition of the Speech with given words + Free Answer *(Survey Results-Appendix 1)*

In a scale from 1 to 5, over 95% of the attendants (20/21) graded the speech with a 4 or above (Figure 11). It matches with their written impressions, some of them using the same words as before like "interesting" or "enjoyable". There were more thought-out answers that spoke about nanotech being in "another world". The capability of making nanorobots or just realising its potential are other things they have acquired.
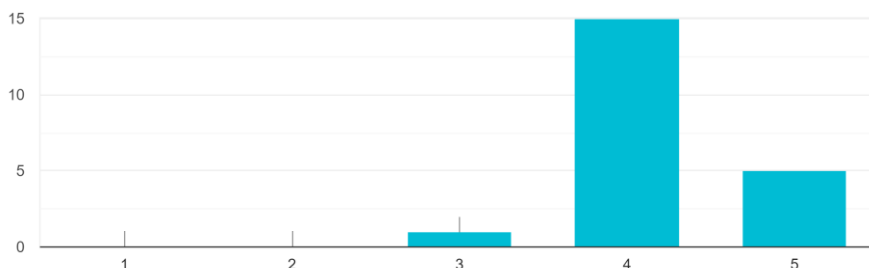
¿Cómo la evaluarías?

21 respuestas



Figure 11. Evaluation of the Speech from 1 to 5 *(Survey Result- Survey Results-Appendix 1)*.

There was a particular moment of the speech that I felt like a teacher. It was not neither when I explained why I have chosen chemistry nor when I spoke about science dissemination and why it is important. It was during the time span between second and third video, after playing the Kahoot. There were two questions most of them failed. The first one was the one that helped me to make them better. It was question number 4 (Appendix 2, Q4). It talked about the reaction rate and some of them had pretty good ideas about how it happened but not accurate. Accuracy is one of the most important things a chemist should consider, otherwise his/her results could vary a lot. They let things out like: "because there is more space" or "because they are smaller", they even tried to connect it to Nanotech by guessing "the smaller, the faster". Their ideas were going in a reasonably good way, they just needed this accuracy that I tried to give them. They were almost right but none of them talked about contact surface. The second one was prepared to make them fail; it was a trap (please, take a moment and imagine Admiral Ackbar shouting it). It was last question (Appendix 2, Q7) and the correct answer was "Every answer is correct", but they missed to read all of the answers so more than 75% of them were wrong; only 4 people were correct! I tried to teach them the importance of concentration that I hope it will help them to pass their future exams, not only in chemistry exams but also in other subjects. This part reflects the work being transversal.

The answers that helped me the most were the last ones. They were questioned about what they would change. Almost all of them said "nothing" but I do not rely on those because they can be because of many things: it may have been because by the time they were answering they

were tired; or just to finish the form, or because the lack of critical spirit that is characteristic from young people. It may have been just because they like it very much but, I am one of those who always think that there are always room for improvement.

Despite having prepared the session many times and trying to find the best way to do it, as soon as I arrived, I got several ideas that would have enrich the course of the talk. Here it starts the second perspective I have used to make the analysis. The first thing to change that came to my mind was the place of the session. If I have had options or more time to prepare the scenario, I would have chosen one distribution in which people are in a semi-circumference. I would have placed a table in the middle and in there I would have put not only the objects I have already brought (gums and tennis ball) but also those that I thought of them later, like molecular structures or sunscreen. I think it would have made the session both more scientific and closer to them; it was a sunny day, and several sunscreen brands contain nanoparticles, therefore I could have played with it. Weather is not something I can set, but, with retrospective, there are rather predictable. One of the things I predicted well was the possibility of the class being distracted, that why I tried to get as much attention as possible while I was interacting with them. I did it by making picky questions to those who were more prone to disturbing and giving emphasis that the Kahoot winner would have an award, so they paid more attention. .

As said before, the last question cause that I had to rethink some aspects. Even though most of them told that they would have changed nothing, I preferred to focus on those who pointed out some things. The most accepted and natural comment was that the quality of the video needed to be better. I have received this kind of incomes from other sources as for my mother that I think she thought I have studied audio-visual recordings or my sister that has always something to say. It is correct that the videos could have been better and in order to rectify, I must find the errors. I set 3 types of errors that need correction. The time I have spent doing them is the first one. I would never say it was little time, but it is true that with more invested time, I would have got a better result. The second point is the one I have less power to change it, it has to do with the sources I can reach. I have tried to use entertaining photos and catching videos to compensate this part. Thus, the last part appears. I have tried to disguise this poor media by providing good transitions and effects, but my skills are not the best in the world. This third point can be greater by spending more hours or doing more videos; even having better sources will helped to improve both this point and the second one.

Going back to the survey answers, the opinion I wanted to read the most was the teacher one. I expected it to be the most mature one and the most reasoned. He wrote about how difficult is to speak about delicate issues in front of a group of people, specially to a young audience. Terms such as "Third World" can be assumed as offensive, that is why the teacher suggested me to use the concept "developing countries" to be more neutral. This kind of things are the ones I must perfect to be a good populariser. The other comment he made was not a constructive critic but a compliment for the good tempo the session got. In spite of this praise, I think I could have adjusted a little bit more the time I got just by making them reflect on the different aspects they had already learnt and how much they took to their homes.

Even tough is not common to put it here, I strongly believe that my personal opinion is the best way to close this part. As this is an informative work, I regard both listeners' and speaker's view as an opinion that must be taken into account to achieve a quality conclusion. Since in a communication both parts must be attentive, both opinions are important. I want to reflect my gratitude for this experience, not for the participants that they have been thanked before, but for the happiness I felt. The fact of being listened rather than heard is something I value a lot and it has expanded my feeling for teaching. In order to get better results, some adjustments must be performed:

- Combine the videos and the speech with daily inputs about Nanotech using Tik Tok:
- Use better audio-visual content and effects to professionalize the video.
- Record the videos in English or other language to reach the whole world.

# 7. TECHNICAL SECTION

Although it is a non-usual scientific FP, it is scientific, thus it has to reflect the experimental part of the study. In this Chapter, the technical characteristics of the video and the softwares used to carried out the dissemination activity are explained.

The three videos are recorded in Spanish as a willing to get better feedback from the audience. They are constituted by photos that describe what is being said and, aiming to attract the audience these photos are mixed with videos. The images are draws and real ones. Both photos and videos are taken from internet: Articles, Google Images and YouTube are the main sources. Even tough internet provides a great deal of options, it does not always fit the things I wanted to reflect. Therefore, there were some clips of the videos that were recorded by myself either using PowerPoint to overcome my lack of skills because it is easy to make the transitions or using my mobile phone.

My mobile phone has served two big purposes. The first one was to record the promenade, where I had to do it three times as a consequence of having bad quality when fast-forwarding it or not recording with the proper camera (I used unwillingly the front one). In Figure 12a it can be seen how I managed to record these videos, not doing exactly like that because I want it to be horizontal. Figure 12b shows how a frame of this video is.



Figure 12. a) Assembly of the recording *b) Frame of the video recorded (Own Images)*

As my mobile phone has different recording options, I chose those with less resolution and less frames, technically speaking it was chosen a Full High Definition (FHD) 30 frames per second (fps) camera instead of using an 8K. Against common thought, it is better for the video rendering, and it provides a much more real sensation.

The second purpose was to tape my voice that is the voice-over of the video. I first consider using an actual microphone, but the results that the phone provide me were good. I used pullovers and blankets to get rid of the background noise as the cushion of professional mic does. The final video was first exported with quality to be performed in a big screen and then exported with YouTube quality

The application used for assembling the video is Filmora Wondershare Premium[28]. In a first instance I thought it to be very simple. However, by the time I had finished the first video, I found a great deal of possibilities. The applications used for the analysis are Kahoot and Google Forms. The first one is an interactive form, is a game that shows who the current winner is every time a question ends, the current points or if someone is in a good streak. It is useful for making the audience being attracted. The second one gives the possibility of reaching whoever I want just by emailing them the form. It also creates the graphics shown along the study using the answers and it is useful when analysing the results.

# 8. CONCLUSIONS

For this experiment to succeed not only science but also society must obtain something valuable from the dissemination process. In this study, all of the initial objectives have been achieved in a less optimistic way.

The first one was to approach nanotechnology to society. It has been done but not to society but to a High School class. The next step is to widen the range and try to reach as many groups of peoples as possible, from youngsters to adults that does not know about Nanotech (96% of Spaniard for example). However, as the results explain, this class reflects an arising willing of acquiring knowledge. They have found Nanotech interesting and capable of things they would never have thought of, and they like it. It is important because they are now aware of a discipline that is about to explode and have the tools to understand its development.

The second objective applies to scientists, and it shows different ways of disseminating. Although it is true that other scientists have not proven this way of teaching yet, the work describes in a systematic way with all the tips I obtained from doing it how to reproduce it. This study gets very good results as far as communication is concerned. Not only because of what the teacher said about the tempo, but also what the students declared in the survey about them having joy while learning something. Another indicator that supports this information is that they describe the activity as "quick", so that means that at least it wasn't tedious for them. Although it is not extrapolating as there was a tiny group of people, it provides inspiring results from other studies.

Finally, the union between both communication and science giving science dissemination has been shown. It is something that existed before but that has been approached from the point of view of a young student communicating to other young students. It provides a perspective of nearness that had eased the way of doing it. The science communicated is a highly potential field that has made things more attractive. The following path to take is to make it more daily rather than going class to class to speak about Nanotech. On way of doing, it would be opening a Tik Tok account and explaining the content of the videos divided in 60s clips or even in 15s. It would let the audience arrive easier and proffers more flexibility and repeatability than just one day and one moment.

Science has obtained new approach to disseminate information and society, and in this case the class, has obtained the information and has lost the fear about Nanotechnology and its potential.

In order to finish this FP, I would like to point my personal acquisitions. I have obviously perfected my editing skills as long as I get new ones. Doing the videos also helped me to find new ways of approaching problems in which I am no expert. I am very glad to have worked in English because is something necessary in labour market nowadays as it is finding the most suitable way of communicating, something I have also taken out. Even though working with teenagers and teaching is something I like a lot, the most valuable thing I acquire from this study is the knowledge about Nanotechnology and how it will be able to change society.

# 9. REFERENCES

1. UN's Goals for 2030: https://sdgs.un.org/es/goals (Accessed 9 June, 2022)
2. FECYT Survey. https://bit.ly/3xyOZgc (Last review on 06/09/2021)
3. CSIC: 4% know about Nanotech. https://bit.ly/3QgEbuC  (Accessed 19 May, 2022)
4. OAS: Organization of American States https://bit.ly/3xigNEe (Accessed 30 May, 2022)
5. Official website of FameLab: https://www.famelab.ch/ (Accessed 8 June, 2022)
6. Official website of TedTalk: https://www.ted.com/talks (Accessed 8 June, 2022)
7. Veritasium: https://www.youtube.com/c/Veritasium (Accessed 9 June, 2022)
8. Quantum Fracture: https://www.youtube.com/user/QuantumFracture (Accessed 9 June, 2022)
9. IN$^2$UB https://www.ub.edu/in2ub/ (Accessed 7 June, 2022)
10. NIOSH from the CDC: https://bit.ly/3MAYTlQ (Accessed 19 May, 2022)
11. National Nanotechnology Initiative (NNI) https://www.nano.gov/ (Accessed May 19, 2022)
12. University of Barcelona Official Master's Degree. https://bit.ly/3Mwj8B7  (Accessed 30 May, 2022)
13. Elon's Musk Fortune https://bit.ly/3O1Vi1d (Accessed June 6, 2022)
14. PS5 price in MediaMarkt: https://bit.ly/3zsnZAh (Accessed June 6, 2022)
15. Wikipedia. https://en.wikipedia.org/wiki/Burj_Khalifa  (Accessed June 2, 2022)
16. Serrano-Falcón, C., Fernández-Pugnaire, M. A., & Serrano-Ortega, S. (2013). Evaluación del pelo y cuero cabelludo: tricograma. Actas Dermo-Sifiliográficas, 104(10), 867–876. https://doi.org/10.1016/j.ad.2013.03.00412.
17. Wiktionary. https://en.wiktionary.org/wiki/technology  (Accessed May 19, 2022)
18. El Español, https://bit.ly/3aOEuME (Accessed June 9, 2022)
19. Bayda, S., Adeel, M., Tuccinardi, T., Cordani, M., & Rizzolio, F. (2020). The history of nanoscience and nanotechnology: From chemical-physical applications to nanomedicine. Molecules. MDPI AG. https://doi.org/10.3390/molecules25010112
20. Booker, R., & Boysen, E. (2005). Nanotechnology for Dummies. Wiley Publishing, Inc. (p. 387). Wiley Publishing, Inc.
21 Kroto, H. W., Heath, J. R., O'Brien, S. C., Curl, R. F., & Smalley, R. E. (1985). C60: Buckminsterfullerene. Nature, 318(6042), 162–163. https://doi.org/10.1038/318162a011.
22. Carbon Allotropes, https://bit.ly/3MIiFvN (Accesed June 7, 2022)
23. FDA: https://www.fda.gov/ (Accessed 10 June, 2022)
24. EMA: https://www.ema.europa.eu/en (Accessed 10 June, 2022)
25. "With great power comes…" quote: https://bit.ly/3trNAW5 (Accessed 9 June, 2022)
26. Attention Curve: https://culturacientifica.com/2018/04/12/la-curva-de-la-atencion-una-leyenda-urbana/ (Accesed 30 May, 2022)
27. Bligh, D. (1985). What's the use of lectures? Journal of Geography in Higher Education, 9(1), 105–106. https://doi.org/10.1080/03098268508708932
28. Filmora Wondershare: https://filmora.wondershare.com/ (Accessed 8 June, 2022)

# 10. ACRONYMS

CDC     Centers for Disease Control and Prevention

CSIC    *Consejo Superior de Investigaciones Científicas*

EMA     European Medicines Agency

FDA     Food and Drug Administration

FECYT  *Fundación Española para la Ciencia y la Tecnología*

FHD     Full High Definition

FP       Final Project

FPS      Frames Per Second

IN²UB   Institute of Nanoscience and Nanotechnology of the University of Barcelona

NASA   National Aeronautics and Space Administration

NIOSH  National Institute for Occupational Safety and Health

NNI     National Nanotechnology Initiative

SDG     Sustainable Development Goals

STM     Scan Tunnelling Microscope

USA     United States of America

# APPENDICES

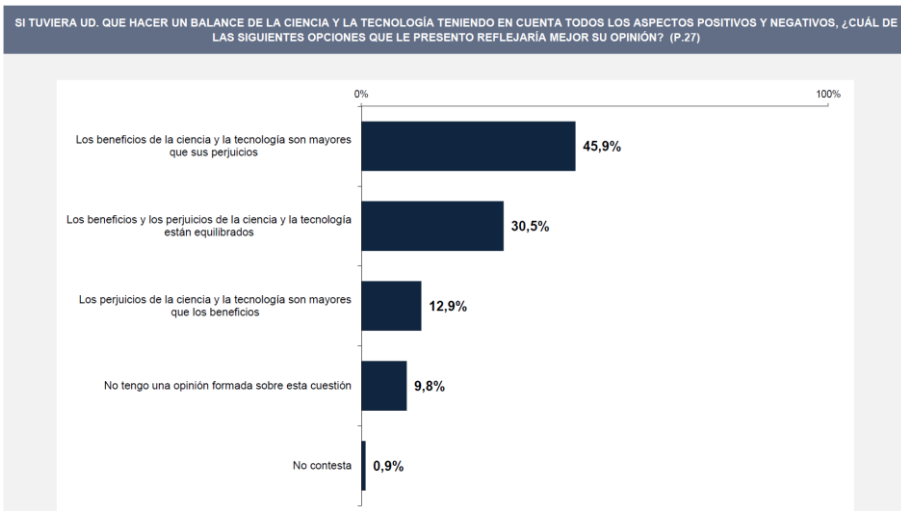# APPENDIX 1: FECYT SURVEY



Figure 13, Society's opinion about Science and Technology
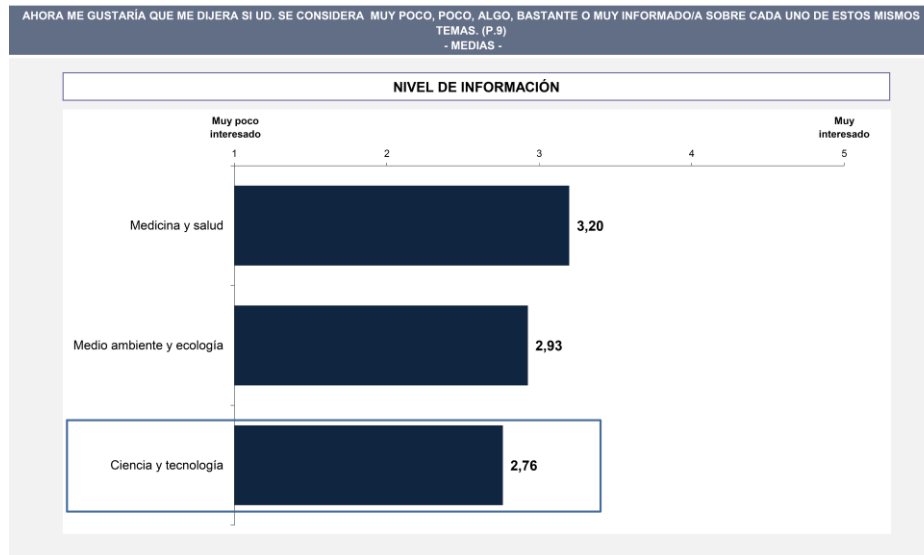


Figure 14, Society's information about Science and Technology

# APPENDIX 2: KAHOOT QUESTIONS

QUESTION1: LA NANOTECNOLOGÍA ES...?  ⭘ 96 %

- A)  ES CIENCIA FICCIÓN TODAVÍA
- B)  LA CIENCIA QUE ESTUDIA LAS TÉCNICAS A ESCALA ✓
     NANOMÉTRICA
- C)  EL DINERO DE ELON MUSK
- D)  UN CONJUNTO DE PROPIEDADES QUE TIENEN LOS MATERIALES PEQUEÑOS

QUESTION2: LA NANOTECNOLOGÍA NACE…  ⭘ 30 %

- A)  EN LA PREHISTORIA
- B)  EN EL SIGLO XX ✓
- C)  EN LA EDAD MEDIA
- D)  DESPUÉS DE INTERNET

QUESTION3: ¿TENEMOS NANOMATERIALES O NANOCOMPUESTOS A  ⭘ 87 %
NUESTRO ALCANCE?

- A)  SÍ, PERO SOLO EN COSAS MUY CARAS
- B)  TODAVÍA NO, PERO EN UN FUTURO HABRÁN MILLONES DE APLICACIONES
- C)  SÍ, MÁS DE LO QUE PENSAMOS ✓
- D)  NO, ¿TU ESTÁS LOCO?

QUESTION4: LA  VELOCIDAD DE UNA REACCIÓN…  ⭘ 96 %

- A)  AUMENTA, AL AUMENTAR LA SUPERFÍCIE DE CONTACTO ✓
- B)  TODAS SON FALSAS
- C)  AUMENTA, AL DISMINUIR LA SUPERFÍCIE DE CONTACTO
- D)  DISMINUYE, AL AUMENTAR LA SUPERFÍCIE DE CONTACTO

QUESTION5: LA POSIBILIDAD DE HACER NANOROBOTS PROVOCA QUE LA NANO TENGA UN POTENCIAL ENORME  87 %

A) TRUE ✓
B) FALSE

QUESTION6: SOLO EXISTEN APLICACIONES "MALAS" DE LA NANO  87 %

A) TRUE
B) FALSE ✓

QUESTION7: PARA ACABAR… LA NANOTECNOLOGÍA ES…  17 %

A) UNA CIENCIA CON INFINITAS POSIBLES APLICACIONES ✓
B) LA CIENCIA QUE ESTUDIA LAS TÉCNICAS A ESCALA NANOMÉTRICA
C) TODAS SON CORRECTAS
D) UNA CIENCIA QUE PRESENTA GRANDES RETOS Y ENIGMAS PARA LA SOCIEDAD

# APPENDIX 3: FINAL FORM & ANSWERS

| Sexo | ¿Cómo la evaluarías? | ¿Cómo la definirías? | ¿Qué impresiones sacas? | ¿Qué mejorarías? |
|---|---|---|---|---|
| Femenino | 4 | Interesante | que es muy curiosa | Nada, me ha gustado |
| Masculino | 5 | Didáctica, Entretenida, Interesante | Que ha sido muy entretenida i interesante | Nada, me ha gustado |
| Femenino | 5 | Didáctica, Entretenida, Interesante | Interesante | Nada, me ha gustado |
| Masculino | 4 | Didáctica, Entretenida, Interesante | Poder hacer robots pequeños | Nada, me ha gustado |
| Masculino | 4 | Entretenida, Interesante | Que es interesante | Nada, me ha gustado |
| Masculino | 5 | Entretenida, Interesante | donde puede llegar la tecnologia | Nada, me ha gustado |
| Masculino | 4 | Didáctica, Entretenida, Interesante | Que la tecnologia esta en otro mundo, es una paranoia y me gusta | Nada, me ha gustado |
| Femenino | 4 | Entretenida, Interesante | Cosas que no sabia que podían suceder | Nada, me ha gustado |
| Otro | 4 | Entretenida, Interesante | La Nanotecnologia pues llegar a ser muy interesante y divertida. | Nada, me ha gustado |
| Femenino | 4 | Entretenida, Interesante | Buenas impresiones | Nada, me ha gustado |
| Femenino | 4 | Entretenida, Interesante | Que la nanotecnologia es muy interesante | Nada, me ha gustado |
| Masculino | 5 | Didáctica, Entretenida, Interesante, Impresionantemente divertida. | No me esperaba que la Nanotecnología fuera así no mucho menos. | Nada, me ha gustado |
| Femenino | 4 | Entretenida | Que es muy Interesante y importante | Nada, me ha gustado |
| Femenino | 4 | Didáctica, Entretenida, Interesante | Buenas, a sido rapido de entender y entretenido | La calidad de los vídeos, Nada, me ha gustado |
| Femenino | 3 | Didáctica, Entretenida, Interesante | Cosas que no sabia | Nada, me ha gustado |
| Femenino | 4 | Interesante | Está muy bien, y he aprendido algo más | La forma de enseñarlos, Nada, me ha gustado |
| Masculino | 4 | Entretenida, Interesante | La tecnologia es mas de lo que pensaba | Nada, me ha gustado |
| Masculino | 4 | Entretenida | Nada, todo a sido interesante | Nada, me ha gustado |
| Femenino | 4 | Entretenida, Interesante | Me ha dado buena impresión | Nada, me ha gustado |
| Masculino | 4 | Didáctica, Entretenida, Interesante | Molt interesant, pot ser eliminar termes com tercer mon, cosa… | El tempo m'ha agradat molt |
| Femenino | 5 | Interesante | Ninguna | Nada, me ha gustado |

Table 1, Survey Questions and Results

# APPENDIX 4: VIDEO LINKS

CLICK IN THE HYPERLINK INSTEAD OF COPYING IN ORDER TO AVOID TECHNICAL ERRORS

VIDEO 1: INTRODUCTION AND HISTORY

HTTPS://BIT.LY/3AJP6B7

VIDEO 2:  APPLICATIONS

HTTPS://BIT.LY/3QGWTKA

VIDEO 3: MORAL DEBATE

HTTPS://BIT.LY/3HA6OOV