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Teaching Nanoscience and thinking nano at the macroscale: Nanocapsules of wisdom

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Abstract

One of the challenges for Nanotechnology is education, which is considered as a bottleneck for Nanotechnology development and implementation. This work contributes to nanoscale education by designing a wide variety of cutting-edge documentaries which assist high-educational level students in learning the underlying concepts of Nanoscience, the last advances and future prospects. In addition, documentaries seek to bring and disseminate the scientific activity of Nanotechnology to society. In this sense, the secondary goals of the proposed approach nanotech activity are: 1) Transfer of knowledge generated in the nanotechnology field and 2) The promotion of scientific culture and innovation between the public objectives. Based on the results observed in students' assessment and You Tube metrics, it was concluded that the developed of nanoscale based documentaries enabled a fast and efficient comprehension of complex concepts related to Nanoscience and Nanotechnology. In addition, the opinion of You Tube audience is highly promising and shows that You Tube and documentaries are an excellent channel to disseminate Nanoscience to society.

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1. Introduction

Nanoscience and Nanotechnology refer to the study, manipulation, engineering and application of matter, particles and structures on the nanometer (nm) scale ($1\text{ nm}=10^{-9}\text{ m}$). Important properties of materials, such as the magnetic, electrical, optical, thermal and mechanical properties, are determined by the way molecules and atoms assemble at the nanoscale. Nanoscience and nanotechnology are at the forefront of modern research and they are considered the new revolution for 21st century.

Nanoscience education is still emerging, and unlike other areas of science education, there are some gaps to fill about how to teach the crucial ideas of Nanoscience and Nanotechnology (Blonder, 2012). It must be promoted new developments in nanoscience education materials as well as research into how graduate or even PhD students best learn nanoscience concepts to succeed in teaching the basics of nanoscale (Greenberg, 2009).

The continuous advance of nanomaterials science and its unprecedented application in more than 1800 nanotechnology-based consumer products, indicate that nanomaterials are crucial to develop new applications: biological tagging, medical diagnostics and treatment, solar energy harvesting, catalysis and electro-optical applications. Then, given the expected economic and social impact of nanotechnology products and the fact that many areas of application are still scarcely explored, it can foresee that industrial use of nanomaterials will continue to increase in future. However, one of the 'grand challenges' for nanotechnology is education, which is considered as a bottleneck for the development and implementation of the field (Roco, 2003). It is even foresee the situation where we may have the research results for new nanoapplications but without having skilled workers to translate them out of research centers (Roco, 2003).

Nanoscience and nanotechnology scientific disciplines are situated at the interface between physics, chemistry, biochemistry, biotechnology, materials science, medicine, microelectronics and computer science. Control of these disciplines therefore requires an academic and multidisciplinary scientific education. Then, it seems reasonable that a multidisciplinary scientific education is crucial to provide industry and research institutes with top quality experts. However, the physical infrastructure in nanoscale science is still in formation, being the multidisciplinary education one of the bottle necks (Roco, 2003). In general, the students use to have difficulties to understand the underlying scientific principles that lead the unique properties at the nanoscale (Muniz, 2014). And, what is more important, teachers also have difficulties in implementing high quality nanoscience and nanotechnology educational material to produce a deep understanding of nanoscience concepts (Greenberg, 2009). Considering the previous facts, there is a need of both thinking small and providing educational tools to assist in the knowledge transfer.

Online videos are considered to be useful in areas of science where records of complex laboratory demonstrations, or physical/chemical phenomena might be more effectively communicated than would prose (Kousha, 2012). For instance, the use of images and documentaries and the ability to share them through the World Wide Web has revolutionized scientific procedures, enhanced our ability to discover new things and offered new opportunities for education (Pasquali, 2007). Video is a valuable teaching tool because it can be used to show students things that would be otherwise hard to transfer in a limited period of time. In fact, an increasing number of scientists uses video to present their results at scientific meetings, during lectures or in their publications as online supplementary material. Then, it seems clear that the use of movies to understand the concepts and phenomena occurring at a world where the scale is far beyond our dimensions could ease Nanoscience teaching.

Consequently, this work has the main goal of contributing to nanoscale education by designing a wide variety of cutting-edge documentaries, named "Nanotechnology capsules", which assist high-educational level students in learning the underlying concepts of Nanoscience, the last advances, as well as the future prospects in new topics ranging from properties of nanomaterials to their societal impacts. In addition, "Nanotechnology capsules" seeks to bring and disseminate the scientific activity of Nanotechnology to society. In this sense, the secondary goals of the proposed approach nanotech activity are: 1) Transfer of knowledge generated in the nanotechnology field and 2) The promotion of scientific culture and innovation between the public objectives.

Next, it will be described the methodology applied and the most interesting information about the Nanotechnology capsules and their educational benefits.

2. Materials and Methods

This study was carried out at the University of Zaragoza, Spain, during two academic years (2014-2016). A total number of 110 people were involved in this study: 1) 25 Chemical Engineering master students, attending the optional subject “Nanomaterials” given on two days for a total of 4 hours a week during the spring semester. 2) 85 people with different level of education, ranging from secondary education to PhD.

This work comprises three parts: 1) Selection of a variety of advanced research themes for Nanotechnology capsules script writing and digital recording. 2) Nanoscience divulgation to society and teaching method. Divulgation to society was carried out using public media (radio and newspapers). The teaching method study examines how the teaching methodology influences student learning using two different teaching methodologies. The first is a traditional method where the blackboard and PowerPoint slides were used to teach the underlying scientific principles that lead the unique properties at the nanoscale, the second is a method based in the Nanotechnology capsules, where students were taught using the visual media prepared in this work and afterwards they were asked to follow a list of activities and questions to be graded. 3) Survey and student assessment.

Many academics are now using YouTube for recording and disseminating course lectures (Pasquali, 2007). Most studies about academic uses of YouTube videos have focused on educational applications or have used YouTube videos as a dataset for scientific research. The use of YouTube videos is gaining interest in the scientific community, being also cited by academic publications and scientific peer-reviewed journals (Kousha, 2012). A set of ten documentaries have summarized the last advances in Nanoscience and Nanotechnology. The documentaries were deposited for free access in a YouTube channel named “Catedra Samca de Nanotecnologia”. The documentaries were bilingual to reach audiences both in English and Spanish. The metric applied to determine the success of the Nanocapsules videos was done by the evaluation of an audience survey and counting the views that each video has over time. These data have enabled to have the statistics analysis from each nanocapsule. In the teaching methodologies students learning were evaluated during the lessons (evaluation of a list of activities) as well as in an end-of-term test using a total number of 50 multiple-choice questions. Specifically, 25 questions were used to test student knowledge acquisition when the teaching methodology based on Nanotechnology capsules was used and 25 questions were used to test the traditional procedure.

3. Results and Conclusions

Nanotechnology capsules were elaborated according to three main fields at the nano scale: 1) Nanomaterials and applications (Figure 1), 2) Promising nanofields (Figure 2) and 3) Biomedicine and sensors (Figure 3). The following sections described the most interesting facts related to the Nanotechnology capsules.

3.1. Nanotechnology capsules related to nanomaterials and their applications

Carbon based nanomaterials are a reference in Nanoscience and extensive research efforts are being made to utilize these materials for various industrial applications. The Nanotechnology capsule entitled “Graphene” (Figure 1) reports the most interesting data related to graphene and it is presented as a unique material with properties that have never existed in any other material. New insights in the production techniques and applications are considered in this capsule (<https://www.youtube.com/watch?v=4oW0Izqi7zU>). Scientists involved in carbon nanomaterials production described in the capsule entitled “Carbonaceous nanomaterials and nanotubes” the most important properties of carbon based nanomaterials such as carbon fullerenes, nanotubes and nanofibers, as well as the stages governing their growth (Fig. 1) (https://www.youtube.com/watch?v=gZfwb__Tjc0). The number of applications based on nanomaterials is drastically increasing; here we present two applications where the role of nanomaterials is crucial to fulfill the expected requirements. The Nanotechnology capsule entitled “smart textiles” summarizes the most remarkable properties of nanomaterials in textiles field (Figure 1). Large production of those textiles is described by engineers with emphasis in how nanotechnology can be scale from lab to large scale production (<https://www.youtube.com/watch?v=93d6hdyX3BM>).

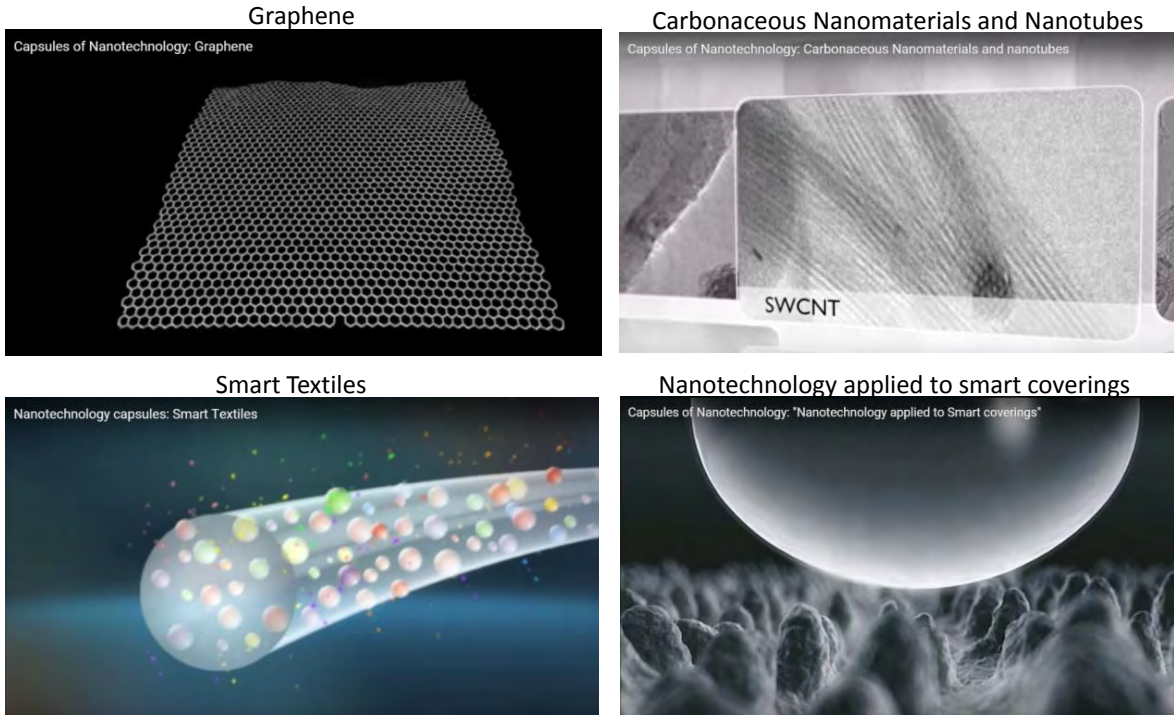


Fig.1. Nanotechnology capsules related with synthesis of nanomaterials and their applications.

On the other hand, the Nanotechnology capsule entitled “Nanotechnology applied to smart coatings” (Figure 1) describes how today's surfaces can become smart surfaces thanks to the research that is being carried out in the field of Nanotechnology: surfaces that are able to clean themselves or self-repairing in the case of the generation of a crack on their surface (<https://www.youtube.com/watch?v=wMt--ICWE18>).

3.2. Nanotechnology capsules related to nanophotonics and nanomagnetism

When light interacts with structured materials at a nanometric level, new properties emerge with an enormous technological interest. Their study is the field of Nanophotonics. Students use to have difficulties to understand the underlying scientific principles that lead the unique behavior of light on the nanometer. Consequently, the

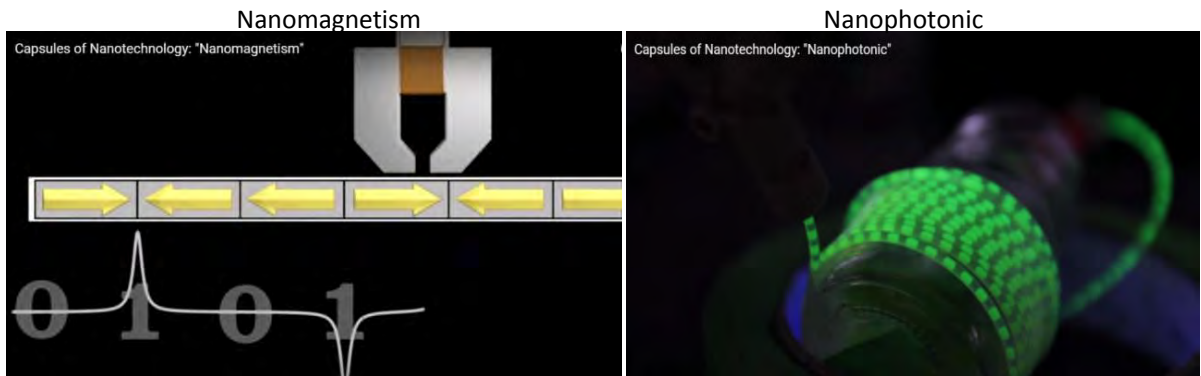


Fig.2 Nanotechnology capsules related with Nanophotonics and Nanomagnetism

Nanotechnology capsule entitled “Nanophotonics” describes the basics and key statements of this field (Figure 2). For instance, Prof. Liz-Marzan describes how the light can interact with nanoparticles to promote the interaction with cancer cells and permitting the detection of the diseases at a very early development level (<https://www.youtube.com/watch?v=wsSH0rPwnEc>). Similarly to Nanophotonic capsule, the capsule entitled “Nanomagnetism” states the advances and future prospects of this field which is focused in the study of the magnetic behavior between a sample with nanometric dimensions and magnetic field (<https://www.youtube.com/watch?v=PCjrdCZyoAk>).

3.3. Nanotechnology capsules related to biomedicine and molecular detection

Nanotechnology is causing a revolution in the field of medicine. Considering the enormous potential of this field and the increasing need of skilled scientist, four different Nanotechnology capsules review the most overwhelming advances in the biomedicine field (Figure 3). The capsule entitled “Nanotherapy and nanodiagnosis: diagnostic and therapeutic applications of nanoscience” describes few examples of Phototherapy and gene therapy treatments, using simulations to ease their comprehension (<https://www.youtube.com/watch?v=bDr3n5ZJ978>). On the other hand, the capsule entitled “Nanosensors” graphically described how nanobiosensors take advantage of the special properties of the nanoparticles to detect substances of interest, making use of their physical and chemical characteristics. This technology enables to make progress in the early and non-invasive diagnosis of diseases, the determination of pollutants in water, or the detection of antibiotics or allergens in food. (https://www.youtube.com/watch?v=pnToLYyc_Gs). An array of inter-connected sensors can be assembled, originating an “electronic nose”. The capsule entitled “The electronic nose” shows how the identification of smells is going to have important repercussions in different fields. In health, it can permit the diagnosis of infections and diseases such as asthma, diabetes, Alzheimer’s or even cancer (<https://www.youtube.com/watch?v=pKueJLJeVc>).

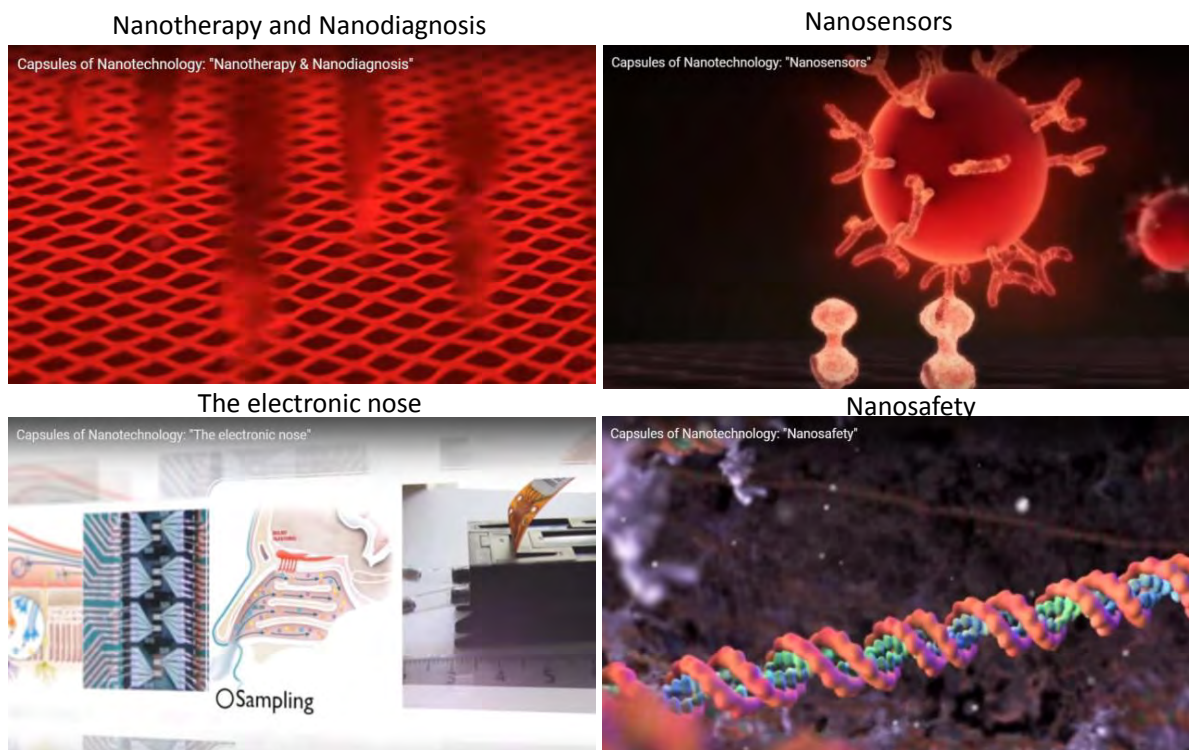


Fig.3. Nanotechnology capsules related with Biomedicine and Sensors.

Finally, the Nanotechnology capsule entitled “Nanosafety_ nanotechnological applications in product safety” highlight the fact that certain nanoparticles are able to pass through biological membranes and can even reach the nucleus of the cells is representing revolutionary advances in therapies against diseases such as cancer, but at the same time it poses questions in terms of the possibility of the environmental nanoparticles being able to cause harm in the organism.(<https://www.youtube.com/watch?v=H-ytxlLF9dk>).

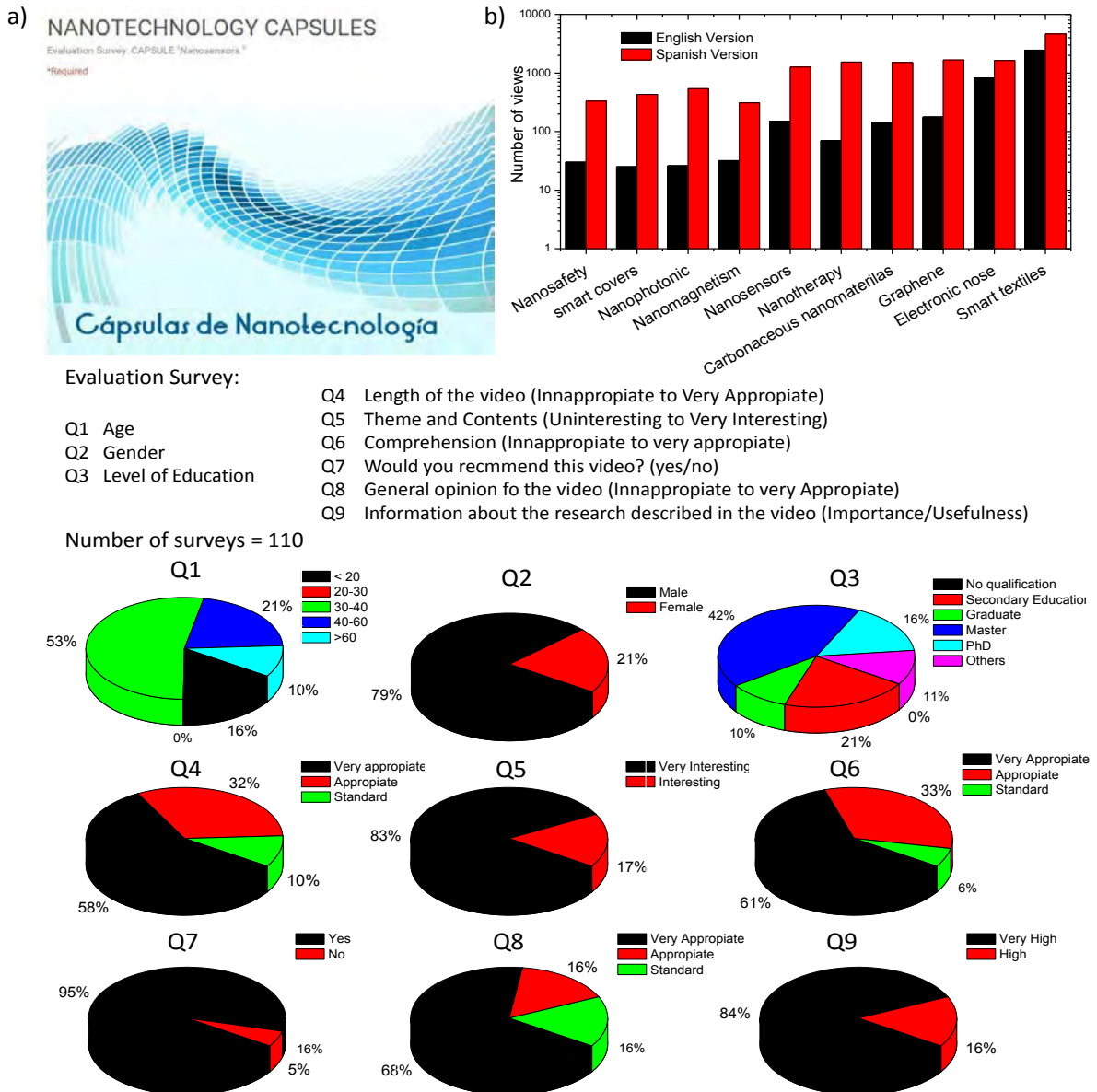


Fig.4a) Evaluation survey to You Tube Nanotechnology capsules and statistics. b) Number of views per Nanotechnology capsule

Figure 4-a shows the survey to evaluate the audience opinion about the capsules. It can be highlighted from the YouTube movie metrics that the total visualization time was 55.615 minutes and the mean visualization time per capsule was 3.10 minutes. It means that the scientific content of those capsules with duration longer than 3 minutes were not efficiently transmitted to the audience. The results obtained from the evaluation survey show the effectiveness in the elaboration of the visual media, since the quality, comprehension, usefulness and importance of the capsules was mainly considered as very appropriate. Figure 4-b shows the number of views of each capsule. YouTube metrics depicts that the majority of viewers were located in Spain, Mexico, Peru, Colombia and USA; being the Spanish version the most widely visualized. The difference in the number of views between capsules was mainly due to a different in the uploading date. On the other hand, comparing student assessments between the traditional and the capsule based methodology, the highest achievement was obtained with the visual media. Students also highlighted that the time required to understand the underlying nanoscale concepts and phenomena was shorter using the nanocapsules, obtaining more fruitful information.

4. Conclusions

Based on the results observed in students's assessment and You Tube metrics, it was concluded that the developed of cutting-edge documentaries helped to ease the student's comprehension of complex concepts related to Nanoscience and Nanotechnology. In addition, the opinion of You Tube audience is very positive and shows that this is an excellent channel to disseminate Nanoscience to society.

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