

## **The opportunity to use videos of experiments in chemistry classroom**

### **AUTORES**

#### **Pep Anton Vieta**

Professor de ciències i matemàtiques a secundària al Saint George's School  
Doctor en Química per la Universitat de Girona

#### **Josep Duran**

Departament de Química de la Universitat de Girona  
Director de l'Institut de Ciències de l'Educació Josep Pallach

### **Summary**

Some threats regarding to educational level and interest in science by citizens of our country only can be fought effectively by improving knowledge and the teaching of science at school. Several initiatives are being carried out and interesting proposals are being put into practice with the aim of improving the attention and interest of pre-university students in science as a first step towards improving their learning. Among them, one that is becoming more popular, is the use of the flipped classroom methodology and, with it, educational videos.

In the context of the use of video as a didactic tool, this paper will present the project devised by the Chair of Scientific Culture and Digital Communication (C4D), the Department of Chemistry and the Faculty of Sciences of the University of Girona (UdG), in agreement with the School of Audio-visual and Multimedia (ERAM) assigned to the UdG. "*UAu, això és química!*" (UAU, this is chemistry!) is a tool at the service of chemistry teachers comprised of a collection of short motivational videos that are ideal to begin a pre-university chemistry class.

## Introduction

In the mid 20th century, as a result of technological and scientific excess, society lost the confidence that it had had since the nineteenth century in science and technology being the main causes of social progress. The fear citizens had towards science and technology grew and generated a strong reaction against it, reinforcing anti-scientific and anti-technological positions (Acevedo et al., 2002). Today the two visions coexist. In developed countries, the general perception of trust and gratitude towards research by society is palpable, especially when this implies an increase in well-being and tangible consequences for people's health and technological innovation (FECYT 2015). However, with regard to the possible negative consequences - often unfounded - of the scientific or technological activity on health or the environment, this scientific activity is denounced and distrusted by the public. Additionally, pseudo-scientific currents, such as homeopathic practices in the medical field, do nothing more than nourish esotericism and conspiracy theories against the achievements of science and technology.

On the other hand, regarding the level of knowledge of citizens and especially of pre-university students, a perception of a certain deficit of scientific knowledge is corroborated with the PISA reports. The results of the PISA 2018 report will not be published until next year, so the most recent is the 2015 results. These results show, in terms of science, Spain is close to the OECD average, and though there was a small improvement over previous years, we are still far from the results obtained in Japan, Estonia, Finland or the rest of the northern Europe countries (megd 2018). According to other research the main causes of student disinterest towards science and learning is the presence of a decontextualized teaching of science, not very practical and lacking current subject matter, along with other factors such as non-participatory teaching methods, scarcity of practical lab work and, especially, lack of confidence in success when evaluated (Solbes and Traver 2003).

Taking this scenario into account, the most effective tool we have available to combat the threats of low interest, lack of knowledge and a negative perception of science is precisely the improvement of the teaching of science at school. It is obvious to us that the educational system includes science education, but this is a relatively recent historic event since the institutionalized teaching of sciences began in the late eighteenth century during the French Revolution; almost two centuries after the scientific revolution (Solbes 2002).

Today several initiatives are being carried out and interesting proposals are being put into practice with the aim of improving the attention and interest of pre-university students in science as a first step towards improving their learning. Among them, one that is becoming more popular, is the use of the flipped classroom methodology (Bergman and Sams, 2013). It is a learning model in the context of a semi-presential teaching process where, unlike the traditional pedagogical model, the student begins learning new content by watching educational videos at home or in a space that is not the ordinary classroom. Later, in class and with the personalized support of the teacher, the student carries out activities to assimilate the acquired knowledge.

## Results

In the context of the use of video as a didactic tool, we present the project devised from the Chair of Scientific Culture and Digital Communication (C4D), the Department of Chemistry and the Faculty of Sciences of the University of Girona (UdG), in agreement with the School of Au-

dio-visual and Multimedia (ERAM) assigned to the UdG. "*UAu, això és química!*" is a tool at the service of chemistry teachers in the form of videos that deal with sixteen subjects corresponding to the classical division of chemistry into baccalaureate and first year university courses: from the states of matter to chemical reactions and from the atomic structure to organic chemistry. The videos are short and their structure is always the same: it begins with a daily situation, close to the students, from which a question arises. The chemists, all researchers and professors at the University of Girona, respond from the laboratory with a short explanation accompanied by a visually impressive experiment. In this way, these videos are a good way to introduce each topic in the chemistry class to the students, without having to spend money on infrastructure, chemicals and lab materials. All this is done without risk, in a way close to the students, fun, attractive and with scientific rigor. Awakening student curiosity to know what is happening and what happens can facilitate teaching and learning by students. The videos are available freely in the Catalan portals "*Recerca en Acció*" (Research in Action), *xtec.cat* and *edu365.cat* (Department of Education of the Government of Catalonia) and in *Reacciona.cat* since January 2014 (Duran, J 2018).

The videos begin with an everyday situation (Figure 1), from which a question arises that is answered in the form of a short explanation along with a visual experiment. The answers take place in a laboratory (Figure 2), for those reactions that can be done there, or in an open space, for reactions that generate flames or smoke and that cannot be done in a closed space (Figure 5). The intention was to do experiments that, due to their safety or complexity characteristics, cannot be done in a classroom. Visually appealing, surprising or spectacular experiments have been selected, and have been recorded by audio-visual experts, which ensures the technical quality of the final videos.



**Figure 1.** All the videos of this project begin with everyday situations, starring young people, where chemistry plays a leading role. In this case, the question that arises when the apple browns exemplify an oxidation reaction.



**Figure 2.** The set of the School of Audio-visual and Multimedia, ERAM, became a laboratory for a few days during the shooting of the project.

Below are some of the 16 topics that make up the project. They have been grouped, more or less, by how they are presented to students. We emphasize the question that pique their curiosity and motivates the lesson and the experiment that exemplifies it.

### Homogeneous and heterogeneous mixtures

With regard to homogeneous mixtures the video begins with the situation where a boy is watching a *Western* (Figure 3) in which the protagonist lights a match by rubbing it on a column in the saloon. Is it possible light a match like this? Yes, it is possible because old matches had the two components together in the head.

In homogeneous mixtures, the different substances that form it cannot be distinguished. In this case: red phosphorus and potassium chlorate. Together they are explosive and that is manifested by a domino effect that triggers the violent reaction.



**Figure 3.** An everyday situation as seeing a western on TV can lead us to talk about chemistry, in this case about homogeneous mixtures.

On the other hand, to introduce heterogeneous mixtures in the classroom we use the situation where a couple takes hot chocolate with whipped cream in a bar. The boy, talking like a know-in-all, says: "This is a clear example of two phases of a heterogeneous mixture." And the girl responds: "What did you say? Is that true? "

In heterogeneous mixtures the substances that form it can be distinguished. To show this, the video presents two immiscible liquids: oil and water, which form two phases. The aqueous phase dissolves a small amount of phenolphthalein. A small piece of sodium is introduced, which slowly crosses the oil layer and when it comes into contact with the water, bubbles and the appearance of the colour pink is observed. This is caused by the formation of hydrogen gas and sodium hydroxide which activates the indicator.

### Reactions and chemical kinetics

The chef of a restaurant, after preparing some exquisite dishes, asks: "There is chemistry in the kitchen, no?" Yes, many chemical reactions take place in a kitchen. One could even say that a kitchen is a great domestic laboratory.

Unlike a physical change, in a chemical reaction there is a reordering of the atoms. The most common reactions are presented in this experiment: oxidation-reduction, acid-base, precipitation ... in a spectacular chain reaction.

The video that allows us to introduce the concept of chemical kinetics begins with some young people drinking an ice coffee. When one of them adds sugar after putting the ice cube in the coffee, the other tells him that he is not doing correctly.

When we add sugar to coffee, we are preparing a solution and this will be favoured if the liquid is hot. Kinetics is the part of chemistry that is responsible for studying the speed of reactions, which is affected by various factors, such as temperature. The previous experiment shows the concentration of the reagents in the speed of the reaction.

### From the equilibrium of solubility to the transfer of protons or electrons

The video dedicated to the solubility balance is special because of the environment where it was recorded. In a cave, a speleologist asks the camera about the stalactites' formation process. The laboratory then explains that the area where the cave is made is formed by calcium carbonate. When it rains, small amounts of this compound are dissolved and are transported through fractures, until it eventually accumulates in a particular zone, forming, very slowly, the vertical structure that we know as a stalactite.

When we add a lot of solute to a solvent, there comes a time when it can no longer dissolve. This is when we say that the dissolution is saturated. The experiment that is presented is the surprising precipitation of a supersaturated dissolution of sodium acetate.

Introducing the subject of the transfer of protons took us to the stairs of the Cathedral of Girona where a tourist is observed photographing, up close, the limestone rocks that form the temple and the surroundings, worn by acid rain

Proton transfer reactions, also known as acid-base reactions, are very frequent in everyday life and in the proposed experiment, are displayed by using the colour change of the pH indicator.



**Figure 4.** The clever detective has realized that the bridge has recently been painted. The project has had several collaborators: actors of the ERAM, students of the chemistry department, other groups, companies and individuals.

A *clever* detective observes rust on an iron bridge (Figure 5). He asks the question that motivates this video, related to electron transfer reactions. In all of these reactions, we find two species that react in such a way that one oxidizes and the other is reduced. When the iron is oxidized (it rusts) it passes from a state of oxidation zero to plus three. Because it has gained oxidation states, we say it has been oxidized. At the same time the other reagent, the oxygen of the air, is reduced. An example of this, the beautiful Oscillating reaction of Belousov-Zhabotinskii, is prepared in the laboratory, where reactions of red-ox type cause beautiful and periodic changes of colours.

### **Thermodynamics. Endothermic and exothermic reactions**

A soccer player gets kicked and is injured. The coach puts an instant ice pack on the injury. This leads to the question that leads the video on endothermic reactions. In a calmer situation, a girl is in front of the fireplace and talks about exothermic reactions and how this question relates the fire and chemistry.

A chemical reaction can release energy but it can also absorb it. When this happens, the substances can be cooled or heated. Many of the most spectacular chemical reactions are exothermic, that is, they release energy. Precisely, the video shows there is a violent reaction between two elements: the bromine, a non-metal at room temperature, and aluminium, a solid metallic. It's a very nice experiment to see but it is not recommended to do on your own if you don't have the right conditions for safety and protection (Figure 5).



**Figure 5.** For the videos of "*UAU, això és química!*" a second scenario has been used for the most extensive experiments, which required a larger space. This large room is located inside the ERAM building.

### **Atomic theory, periodic system and chemical bonding**

A couple watches a pyrotechnic display and asks if the fireworks have any relationship with chemistry. This is the situation that leads to the video on atomic theory. The structure of the atoms is presented and it explains how each chemical element, present a different and characteristic emission spectrum, is as if it were a fingerprint. That is, burning an element emits a light of a certain colour. The video concludes by presenting the current atomic theory and how Bohr already postulated that energy was quantified years ago.

To present the periodic system, some young musicians raise the question about the possible relationship between music and the periodic table of the elements. Precisely, one of the first attempts to group the known elements was eight by eight, such as the musical notes. This law was known as Newlands' Law of Octaves.

However, the modern periodic table orders the elements in groups (columns) and periods (rows). The atoms of the same group have similar properties and also observe a periodicity in tendency to increase or decrease, this, throughout a group. The experiment in the video tests the different reactivity of potassium halogenates.

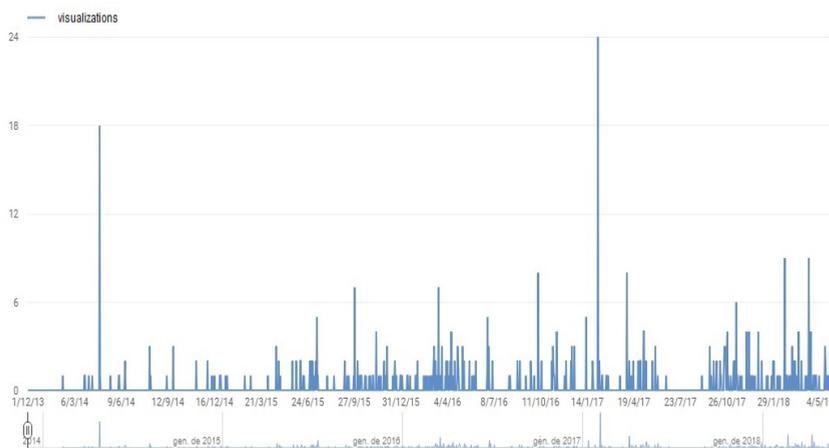
Finally, the interest in chemical bond arises when a boy and a girl are dancing salsa. When they change their dancing to approach each other, they ask themselves if atoms do so, also, or "dance" more or less together.

Different types of chemical bonds differentiate them, the distance between the bonded atoms, the simplest, longest (and weakest) bonds and double bonds, which are shorter and stronger. Both occur in covalent compounds. The video also presents the ionic bond and conducts an experiment where a metallic bond is formed. It is an spectacular aluminothermic reaction which, by the way, is highly exothermic.

### Visualization analysis

These videos can be viewed and downloaded completely free through *YouTube* (Reaccionaexplota 2018) or *Vimeo* (ERAM 2018). Several webpages provide access and promote the videos, such as the website of the project "*Reacciona... explota!*" (Duran, J 2018) or "*Recerca en acció*".

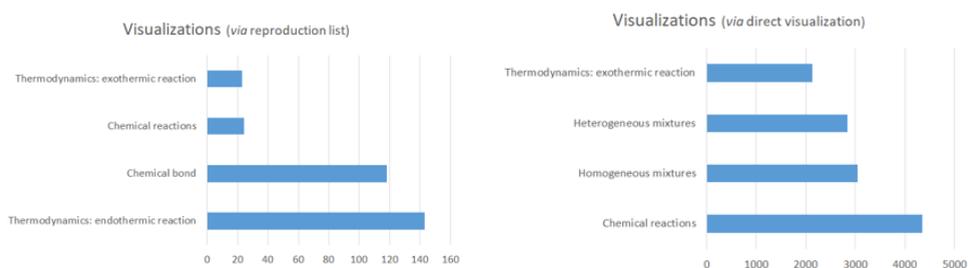
The data collected from *YouTube Analytics* platform shows that the playlist has been started 319 times, with a total of 793 visualization minutes and 490 views. Figure 6 shows the number of reproductions per date, where it can be observed that two dates had the largest number of views: April 2014 coincided with the presentation of the project to the media: newspapers, magazines and in the "*Espai Terra*" program of *Televisió de Catalunya*, and February 2017 coincided with the presentation of a new playlist called "*Ponte Bata*".



**Figure 6.** "UAu, això és química!" channel visualizations, since its creation in December 2013.

At the beginning, the number of views is much more erratic. As time goes by, there are more total views. This may indicate that this resource is being used more and more, and more regularly. Also, it is possible to observe how regularity in the visits is seasonal during the academic year, with the months of July and August seeing little activity.

The number of views through the playlist is indicative of a trend, but only a limited number of visits are recorded. Figure 7 shows the difference between the four most viewed videos through the playlist and the four most watched videos for direct access.



**Figure 7 (a and b).** Comparison between the numbers of visits from the four most viewed videos according to access through the playlist (a) and by direct access (b).

Figure 7 (a) shows that the most visited video is the endothermic reaction experiment, which is not a very spectacular reaction, although there are two factors that may have caused it to be so displayed. One, the protagonists of the video are a football team made up of young people between 16 and 18 years of age. The other, that the experiment is one of the few examples of an endothermic reaction. This last reason could be indicative that the viewers of this video have an academic motivation.

Figure 7 (b) shows that the most watched video has been that of chemical reactions. Once again, this is an eminently didactic video that ends with in a chain reaction, the main types of chemical reactions are acid-base, red-ox and precipitation. It is not as spectacular as the video of homogeneous mixture or that of exothermic reaction. As in the previous example, this data could be indicative of the use as a teaching tool for the videos.

Finally, most people who have consulted the videos have done so with a computer. Only 16% used a mobile phone and 4% tablets. This data reinforces the hypothesis that most of the videos are seen in the classroom or for didactic purposes.

### Use of videos in the classroom with the flipped classroom methodology

New technologies applied in the classroom offer many ways of presenting examples of chemistry to students (Donnelly et al., 2013). There is no doubt that the use of ICT opens a wide range of possibilities, from mobile phones (Williams, Pence 2011) to videos (Wulfsberg, G. et al., 2003). It is in this last case that there is an unattainable source of virtual resources. The network contains countless examples, in many portals, of all the elements of the periodic table, with spectacular, interesting, attractive and encouraging discussions. The videos of the project "*UAu, això és química!*" are added to this list.

The videos offer the opportunity to focus the student on their own learning. Several studies show that when the student is the protagonist of their own learning, the results obtained go beyond simple memorization to higher order thinking and action (Bain, 2006; Swett and Michaelsen, 2012). Modifying the teacher's mentality taught by the student who learns is necessary to achieve relevant learning (Kop, 2008).

A methodology that has not yet been adequately explored and which favours student-based learning is the Flipped Classroom. The name comes from the investment in the traditional

sequence of activities: teaching-study-evaluation by study-evaluation-education. It supposes that part of the content should be sought out of the classroom. Prior to class in this case, the videos are a good source of information, with contrasting content and adapted to the students' levels.

The videos, combined with guided activities, allow more time for face-to-face activities, which become much more representative. For example, the face-to-face activities would include the validation of learning, correction, clarification or extension in cases where the previous evaluation was not sufficiently satisfactory, the promotion of communicative and higher thinking skills. It is therefore a question of promoting understanding beyond memorization (Bergman and Sams, 2013).

A good source of experiments for chemistry subjects can be found on the web page of the *Periodic Table of Videos* project. This web page collects all the elements of the periodic table in videos between five and six minutes long. The quality and international impact of the project, carried out by the University of Nottingham, has allowed them to publish their results in prestigious papers (Haran, Poliakoff 2011a), (Haran, Poliakoff 2011b).

Another good source of experiment is on the Royal Society of Chemistry website, whose videos are very well explained and presented. In addition, all this material is found in English, so that students also practice the cross-curricular competence of the English language.

The *Kopernik* program produced by the "Xarxa de Televisions locals de Catalunya" (network of Local Televisions of Catalonia) can be added to the aforementioned selection. The subjects all corresponding to "L'Experiment" (The Experiment) in each program. The videos can be accessed through the website of the *React...explode!* project and more recently from the "Recerca en Acció" portal. The videos follow the history of chemistry through the discovery of the elements of the periodic table.

## Conclusions

The project title, "*UAu, això és química!*" plays with two elements in the periodic table to make an onomatopoeia exclamation (WOW/UAu). The aim is that this exclamation comes not only from the protagonists of the videos but also from the students who watch them and feel inspired by the experiments. Awakening curiosity to know what is happening and what happens can facilitate teaching and learning by students. "*UAu, això és química!*" videos can become a way of presenting chemistry without spending on infrastructure, chemicals and lab materials, and without risk, in a way the students are familiar, fun, attractive and scientifically rigorous.

According to the statistical data of tracking the various platforms, the videos were viewed more irregularly the first year of publication, while in recent years, the videos have been viewed more regularly. This progression is very positive, and the hope is that the project continues to be consulted.

Among the most viewed videos are two (chemical link and exothermic reactions) that include two very spectacular experiments (termite and bromine with aluminium, respectively). In spite of this, the highest number of visualizations either on the playlist (endothermic reactions) or

direct visualization (chemical reactions), correspond with didactic rather than spectacular experiments. For this reason, we believe that a good part of the views are not for pleasure but for teaching.

The videos are a good tool to be used in a flipped classroom. It's interesting to combine classic content, such as notes, with an illustrative video of the subject. Watching videos of experiments is an easily affordable and great potential tool, if used correctly. They are a good resource to be used in the classroom, since they dynamize the class and make it participative. The fact of having to interpret the chemical phenomena that occur affects certain basic and knowledge-related abilities and skills. In the case of videos in a second or third language, their visualization and understanding adds this cross-curricular competence.

The videos of the "UAU, això és química!" project, will soon be complemented with other videos that will explain how Girona is a city with a lot of chemistry. The good results and wide-welcome the project received make us optimistic to continue working on a new collection of videos.

### Acknowledgments

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## CURRICULUM VITAE

### **Josep DURAN CARPINTERO**

Va néixer el 5 de maig de 1966 a Girona. L'any 1999 es va doctorar en ciències (química) per la Universitat de Girona. La seva recerca s'ha centrat en l'estudi de catalitzadors amb metalls de transició. Des de l'any 1991 és professor del Departament de Química de la Universitat de Girona. Ha estat investigador principal en dos projectes de millora de la Qualitat Docent i ha obtingut la distinció col·lectiva Jaume Vicens Vives a la qualitat docent universitària. És autor de diversos articles de docència i de divulgació científica així com dels llibres "Itineraris geològics per la Costa Brava" i "Passeig per l'invisible: Itinerari químic per Girona" i coautor de "Ciència recreativa comentada" i de "La cultura de los MOOCs". Actualment és el director de l'Institut de Ciències de l'Educació Josep Pallach.

### **Pep Anton VIETA CORCOY**

Nascut a Blanes, bressol de la Costa Brava, el 1986. Professor de ciències i matemàtiques a secundària al Saint George's School. Doctor en Química per la Universitat de Girona (2017), Màster en Formació del Professorat d'ESO i Batxillerat, Formació Professional i Ensenyament d'Idiomes (UdG 2015), Master in Medicinal Chemistry and Molecular Design (UdG 2011), Llicenciat en Química (UdG 2009).