Tutor/s

Dr. Xavier Giménez Font
Departament de Ciència de Materials i Química Física

Grau de Química

Treball Final de Grau

Synchronous Flipped Classroom implementation. Chemistry contents development: Introduction to inorganic compounds and their formulation and nomenclature.
Implementació de la classe invertida síncrona. Desenvolupament de continguts propis de la Química: Introducció als compostos inorgànics i la seva formulació i nomenclatura

Anna Moreno Alamà

January 2019

Universitat de Barcelona

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

Estudiar cuando se tiene la oportunidad es el fondo de armario de la vida.

La Vecina Rubia (@lavecinarubia)

A l'Arancha Herencia i la Mayte Ramos, per seguir ensenyant-me coses després de tants anys. No podria haver demanat millors companyes, gràcies.

A la promoció 2018/20 de Química de Batxillerat de Maristes Sants – Les Corts, espero haver-vos ensenyat tantes coses com vosaltres a mi. A l'equip directiu i administratiu, per la confiança. A l'equip docent, per fer-me sentir una més.

A la família Falcó Vidal, per ser-hi en els bons i en els mals moments, i per l'ajut inestimable durant els dies previs a l'entrega de la memòria.

A tu Aleix, per escoltar-me i fer petits els problemes, per sumar sempre.

A vosaltres, Toulouse i Chanel, per les incomptables hores de companyia. Als de casa, sobretot als meus pares Anna i Manel, per tots els esforços que heu fet sempre per mi i ensenyar-me que de qualsevol situació, per molt dolenta que sigui, puc aprendre i treure'n la part positiva.

Per vosaltres.

REPORT

CONTENTS

1. SUMMARY 3
2. RESUM 5
3. INTRODUCTION 7
3.1. The beginning of Flipped Classroom 8
3.2. What is Flipped Classroom and how to flip a classroom 8
3.3. The new roles of teacher and the students 9
3.4. Why does Flipped Classroom improve the achievement of learning outcome? 9
3.5. Implementation problems with Flipped Classroom 10
4. OBJECTIVES 11
5. DEVELOPMENT OF MATERIAL 12
5.1. The worksheets 12
5.1.1 Analysis of the teaching material 12
5.1.2 Didactic structure 13
5.1.3 Development of worksheets 13
5.1.3.1. *A bit of history* 14
5.1.3.2. *Another way to explain chemistry* 15
5.1.3.3. *Formulation and nomenclature* 16
5.2. The exam 18
6. APPLICATION OF THE METHODOLOGY 20
6.1. Class conditions 20
6.2. Observations during the Flipped Classroom 21
7. RESULTS AND DISCUSSION 23
7.1. Analysis of the worksheet results 23
7.2. Analysis of the exam 23
7.3. Relationship between the worksheets and the exam 29
7.4. Students' opinion 30

7.4.1 About the worksheets 30
7.4.2 About the exam 30
7.4.3 About the methodology 31
7.5. Teachers' opinion 31
8. IMPROVEMENT PROPOSAL OF THE WORKSHEETS 32
9. CONCLUSIONS 33
10. REFERENCES AND NOTES 35
11. ACRONYMS 37
APPENDICES 39
Appendix 1: Worksheets USB
Appendix 2: Exam 41
Appendix 3: Class Schedule USB
Appendix 4: Surveys and results USB
Appendix 5: Improvement proposal of the Worksheets USB

1. SUMMARY

Nowadays, the most common method used by the educational community when it comes to giving classes is the traditional method, where the student must listen to the teachers' explanations for most of the school hours and then do exercises, and get prepared to pass an exam, at home without teachers' help. In a nutshell, the traditional method focuses on the figure of the teacher and not on the students.

Recent developments in cognitive science show that oral transmission of knowledge is the less efficient learning technique, so that it is imperative to seek alternative teaching methods. Active teaching focuses on the students and makes them the protagonists. The Synchronous Flipped Classroom is based on working around the so-called worksheets; the student will have to answer the proposed questions, by consulting information on the same sheets or through the Internet and ask the teacher the doubts arisen.

The content of the WS becomes the critical element of this study. It is essential to adapt the new material to the level of the course and the maturity of the students, in order not to be dense and entail difficulties derived from a sophisticated language. In this work, the teaching material for 1st year High School class on the topic "*Introduction to inorganic compounds and their formulation and nomenclature*" has been prepared.

The present study consists in developing and implementing the WS in two classes of the same High School, with the expectation that students will play an active role in class and encourage teamwork. Thanks to the daily follow-up of both groups, the evaluable material and the surveys, we will be able to extract a series of conclusions that will allow us to improve the teaching material and verify if the students have correctly assimilated the concepts, as well as if there is an improvement of their academic performance.

Keywords: Flipped Classroom, active learning, inorganic compounds, nomenclature.

2. RESUM

Actualment el mètode més comunament utilitzat per la comunitat educativa a l'hora d'impartir classes és el mètode tradicional, on l'alumne ha d'escoltar les explicacions del professor durant gran part de l'hora de classe i després realitzar exercicis, i preparar-se per superar un examen, a casa sense l'ajuda del professor. En poques paraules, el mètode tradicional centra la seva atenció en la figura del docent i no en la de l'alumne.

Desenvolupaments recents en ciència cognitiva evidencien que la transmissió oral de coneixement és la tècnica d'aprenentatge menys eficient, de manera que és imperatiu buscar mètodes d'ensenyament alternatius. L'ensenyament actiu centra la seva atenció en els alumnes i els converteix en els protagonistes. La classe invertida síncrona es basa en el treball al voltant dels anomenats Fulls d'Activitat; l'alumne haurà de resoldre les qüestions proposades, mitjançant la consulta d'informació en els mateixos fulls o bé a través d'Internet, i preguntar els dubtes que li sorgeixin al professor.

El contingut dels FA, esdevé l'element crític d'aquest estudi. És primordial adequar el nou material al nivell del curs i a la maduresa dels estudiants, amb l'objectiu de que no sigui dens i comporti dificultats derivades d'un llenguatge sofisticat. En aquest treball s'ha preparat el material docent per a classes de primer de Batxillerat sobre el tema "*Introducció als compostos inorgànics i la seva formulació i nomenclatura*".

El present estudi consisteix doncs, en desenvolupar i implementar els FA en dues aules d'un mateix Institut, amb l'expectativa de que els estudiants passin a tenir un paper actiu a classe i fomentar el treball en equip. Gràcies al seguiment diari d'ambdós grups, al material avaluable i a les enquestes, podrem extreure una sèrie de conclusions que ens permetran millorar el material docent i comprovar si els alumnes han assimilat correctament els conceptes, així com si s'evidencia una millora del seu rendiment acadèmic.

Paraules clau: classe invertida, ensenyament actiu, compostos inorgànics, nomenclatura.

3. INTRODUCTION

Nowadays, the most used teaching method in the Spanish educational community is the traditional method. This method is based on a professors' monologue in the classroom, being the protagonist during the class hours, and the figure that students must follow and imitate. On the other hand, students must practice the content explained in class hours by the teacher doing a lot of exercises and studying in non-school hours, without supervision and help. The result of this way of teaching is that the students memorize the syllabus and repeat what the teacher explained, without understanding it, since their objective is to pass the exam they carry out at the end of each topic.

The traditional method does not include other sources of information that are not textbooks, since in this way distractions are avoided. In the same way, it does not contemplate the individual abilities and difficulties of each student; it is considered that the method is efficient while the student is able to reproduce what the professor explains. This method forms students with no critical spirit, with the sole purpose of preparing them to repeat a routine without knowing what they are really doing.

Society evolves, and the needs we used to demand are not the same today. For years, the access to information was more restricted, but nowadays the increased use of new technologies allows anyone to access to a large amount of information with just one click.

In this context, the following question is inevitable: What is the need to force students to memorize concepts without really understanding them if they have access to a lot of information on network?

Therefore, the function of professors should be to help students develop new skills in order to face todays' world with guarantees, such as team working or how to contrast information. For these reasons, a new current of education models is gaining strength, and in some countries, it is already being applied.

The fundamental purpose of these learning models is to help students to learn, discovering contents by themselves using tools such as computers or textbooks, in cooperation with

classmates and with the supervision and when needed, the help of teachers. In active learning the student becomes the main protagonist, and the necessity of memorizing disappears.

These models are globally classified under the tag active learning, and some examples are Gamification, Problem–Based Learning, Project–Based Learning or the model used in this study, Flipped Classroom.

3.1. THE BEGINNING OF FLIPPED CLASSROOM

In 2007, Jonathan Bergmann and Aaron Sams, two professors at Woodland Park High School, Colorado, realized that some students were missing a lot of classes, and with the aim of help them, they decided to start recording the lessons. In this way, students could attend inescapable commitments and have access to the lost classes. As a consequence, time in class was used to carry out other activities that would enhance the knowledge acquired by students outside the class. Unexpectedly, teachers saw that this model allowed to focus attention on the individual needs of each student and the qualifications began to increase. It was the beginning of what is today known as FC.

3.2. WHAT IS FLIPPED CLASSROOM AND HOW TO FLIP A CLASSROOM

''The flipped classroom describes a reversal of traditional teaching where students gain first exposure to new material outside of class, usually via reading or lecture videos, and then class time is used to do the harder work of assimilating that knowledge though strategies such as problem-solving, discussion or debates''. [1] There are several models of FC; the term is used to describe any class structure that consists in prepare the syllabus at home and do exercises in class.

The process of flipping a classroom is not easy as is seems. Even though it is a simple idea, we must be careful during the preparation. For the teacher, it will require an effort and an investment of time that does not require the traditional methodology, because the material used in a traditional class, which usually is given to the teacher, does not fit the FC. It is essential to design the material with the objective that students are able to follow it on their own, which means that has to be easy to understand, with lots of examples. New concepts have to be introduced slowly, from minor to greater difficulty, including concepts previously seen. [2,3]

3.3. THE NEW ROLES OF THE TEACHER AND STUDENTS

Implementing an active learning model implies much more than replacing the transmission of knowledge in class. If the teacher establishes a good communication with students, it will be easy to detect the difficulties and the reactions that they have about the material and the syllabus, so they can be assisted immediately. The purpose of the teacher in the classroom will then be, to solve the doubts raised for a better understanding of the students. With this approach, there will be no excuses such as that class hours are not enough to cover the whole syllabus, since during the class hours the key concepts will worked out as well as the concepts that students have not understood.

The teacher will cease to be an expert in knowledge and its transmission to the students to become an expert in designing and facilitating learning tools that allow students to develop skills. The teacher will have to learn to detect and solve problems and to find tools to convey this knowledge. In doing so, a constant follow-up is essential, as well as the students' opinion. During school hours, the teacher should guide the students providing them feedback at the moment that they show difficulties in order to help them overcome these difficulties. Outside the class, the teacher will not only have to prepare the classes but will have to prepare the material, facilitate it to the students and verify that they study it.

On the other hand, the students will have to work the material beforehand at home, which facilitates a greater interaction in the classroom because they have formed an opinion and their corresponding doubts and concerns about a certain topic. Therefore, the students must achieve autonomy to assimilate the concepts and in case of having doubts, they have to communicate them. [2]

3.4. WHY DOES FLIPPED CLASSROOM IMPROVE THE ACHIEVEMENT OF LEARNING OUTCOME?

Active learning models are sources of encouragement and motivation. The FC makes students who do not work daily with the traditional methodology have to do it regularly to prepare the classes.

The relationship between students and their teacher increases, the attention becomes closer and more personalized and for this reason, the progress of the students can be detected in a way that cannot be perceived with the traditional methodology.

3.5. IMPLEMENTATION PROBLEMS WITH FLIPPED CLASSROOM

Almost all failures in the implementation of FC are caused by the drastic change that supposes for the students passing from having a passive attitude and memorising the syllabus to having an active role, to assimilate the topics before going class, to encounter difficulties, to express doubts and to be critical with the material proposed. [2] For this reason, it is important to accompany the students in this transition, since they do not have experience with active learning models.

Additionally, teachers will need to spend more time preparing the teaching material and the classes than in a regular teaching model. Moreover, additional preparation may be needed in order to learn the use new technologies, sources and tools involved in this method, and also to acquire pedagogical skills such as knowing how to convey the advantages of the method and to know how to adequately analyse the responses of the students.

4. OBJECTIVES

The most important and difficult task to implement an active learning method is the adaptation of the traditional material into a new one. So, the main objective of the present study focuses on the development of a new teaching material about the topic "*Introduction to the inorganic compounds and their formulation and nomenclature*" for a 1st year High School chemistry students, with the aim of improving their academic performance. After that, other objectives will be the following:

- Test the worksheets in a High School implementing a variant of FC methodology.
- Prepare a traditional exam to evaluate the worksheets content achievement.
- Revise and modify the worksheets using the observations reported during the experience and the exam qualifications with the goal of increasing the students' productivity.
- Make surveys to the students and the teachers in order to take into account their opinion.

5. DEVELOPMENT OF MATERIAL

The part of preparing the teaching material requires a lot of time and dedication, specially the worksheets. Even if the methodology is Synchronous Flipped Classroom, it is essential to include all the contents that the teacher wants to work on, in order to follow the syllabus structure planned for the academic year. For this reason, it is necessary to be clear about the concepts that will be included on the worksheets.

In this section, it will be explained how the teaching material "*Introduction to the inorganic compounds and their formulation and nomenclature*" for a 1st year High School chemistry students was prepared. Moreover, the preparation of the exam will also be explained, which it is the method to evaluate the students.

5.1. THE WORKSHEETS

The first thing that must be clear to prepare the worksheets is the scope to cover. Due to that, it was necessary to analyse the material that was going to be used initially, written by the chemistry teachers of the High School and discuss with them about the key topics. Once all information was collected, it was time to think carefully about the didactic structure of the worksheets.

5.1.1. Analysis of the teaching material

This section will be focused on the content that includes the teaching material given by the high school teachers and its didactic structure. [4] Taking a look to this material, we realized that more importance was given at the formulation and nomenclature rules and only a few inorganic compounds and its use were mentioned.

It should be noted that the students of 1st year High School had worked on some topics, but it would be normal to think that they forgot the vast majority of concepts since it passed a considerable period of time.

The structure of the teaching material given by the teachers was the following:

1. A list of formulation and nomenclature rules about the inorganic type of compound.
2. A list with examples.

Except for the first section, where the oxidation numbers that the students must know were indicated, the structure was the same for all the different types of inorganic compounds.

Is it useful to give such importance to the formulation and nomenclature rules? Will students be able to assimilate all this theoretical content, or will they memorise everything in order to pass the exam? And the most important question, will the students really understand what the inorganic chemistry is?

5.1.2. Didactic structure

Students are the protagonists in a FC and not mere observers, so it is important to find tools in order to help them to learn and not to memorize the contents. To achieve this goal, the worksheets must have a didactic structure to help them:

- To be self-taught although they are working in groups.
- To connect the concepts with everyday applications.
- To create curiosity and get them to ask themselves to question the why of everything.

To achieve this goal in the new teaching material, the following didactic structure is proposed:

1. Introduction to the elements and its discovery.
2. The necessity to classify the elements and the importance of periodic table nowadays.
3. Awareness that we must know the nature of chemical compounds to explain the events that happen in our environment and avoid accidents.
4. Realization that chemistry is not a stranger and it can be found in many areas.
5. Learning how to formulate and name compounds by mixing the rules with concepts previously seen or presenting new compounds and their use.

5.1.3. The development of the worksheets

In this section, the development of the different worksheets and their content is explained. The material prepared (*see Appendix 1*) is the following:

- ***Worksheet 1: "Introducció. Descobriment dels elements i la taula periòdica" and "La química que ens envolta"***

  It explains the importance of knowledge about elements and chemical compounds as well as the importance of the periodic table and the fact that this process of study and discovery has been long and complicated. It does not only talk about the everyday chemistry and the need to know not only the composition, but also about the nature of elements and their applications.

- ***Worksheet 2: "Formulació i nomenclatura dels elements, ions simples i compostos binaris."***

  It contains the rules of formulation and nomenclature of elements, simple ions and binary compounds and different types of questions to achieve the concepts that are explained.

- ***Worksheet 3: "Formulació i nomenclatura dels oxoàcids, oxoions i oxisals."***

  It contains the rules of formulation and nomenclature of ternary compounds and different types of questions to achieve the concepts that are explained.

5.1.3.1. A bit of history

In the first part of the WS1, *"Introducció. Descobriment dels elements i la taula periòdica"*, the evolution of chemistry is explained as an introductory way. Todays' students have a great deal of information on chemical compounds, their properties, their nature and applications, and have indispensable tools such as the periodic table, [5] and are not aware of the years that have been needed and the difficulty that has entailed.

At the beginning of WS1, students will familiarize themselves with the elements, through a dynamic periodic table that shows them, with their curiosities or characteristics. They will see that some elements have been known for centuries, and others have been recently discovered with the help of analytical techniques.

> Algunes de les substàncies que ara identifiquem com elements químics es coneixen des de l'antiguitat: entre elles es troben el carboni, el sofre, el ferro, el coure, la plata, l'or i el mercuri. Cap al segle XIX, els alquimistes i els seus successors immediats, els químics, havien estat capaços de determinar aproximadament 18 elements.

Figure 1. Extract of the introduction of WS1.

Then, the students will see the need to organize the elements, what criteria and classifications were used and the conclusions that scientists reached. Question 4 (*see Figure 2*) is intended for students to see, for example, that if different elements form a type of inorganic compound with a certain proportion and they have similar physical characteristics, they could be classified into groups.

Qüestió 4. El carboni, el silici, el germani, l'estany i el plom formen compostos anomenats hidrurs amb una fórmula general EH_4, en canvi, el nitrogen, el fòsfor, l'arsènic i l'antimoni formen hidrurs però de fórmula general EH_3. Que et suggereix aquest fet experimental?

Figure 2. Question 4.

In this part of the WS1, some concepts that students have previously seen are introduced, such as the characteristics of metals, non-metals and metalloids (Question 3) or the names of the periodic table groups and its bonding arrangement and trends (Question 5). [6]

5.1.3.2. Another way to explain chemistry

The second half of the WS1, is based mostly on a series of questions that relates facts of our day to day with inorganic chemistry.

The first important thing that students will see is that accidents can happen and that we have to handle chemical products with caution, and most importantly, accidents not only happen in the industry, they can also happen at home. [7,8] The purpose of Question 6 is for students to understand the importance of knowing how different chemical products react. On the other hand, Question 7 is proposed so that students can see that it is important to know the composition of the products, in this case, cleaning products we use.

Qüestió 7. Quin és el motiu per el qual s'ha d'evitar barrejar salfumant i lleixiu? Justifica la teva resposta basant-te en la reacció que es produeix. Quines conseqüències comportaria a la nostra salut exposar-nos a aquesta barreja?

Figure 3. Question 7.

One of the objectives of the WS, as mentioned above, is to get students to wonder the reason why things happen. [9] Therefore, Question 8 becomes an interesting question as students will be able to see that some things that happen to them, without apparent reason, are related to chemical compounds.

Qüestió 8. Per què plorem quan tallem ceba? Quin pictograma assignaríeu al compost químic responsable?

Figure 4. Question 8.

Following the Question 8 dynamics, one of society is main concerns is global warming and greenhouse effect. [10] Therefore, taking advantage of the fact that it is a subject that usually arises in science subjects and media, some greenhouse gases, specifically those that are inorganic compounds, will be introduced. With questions related to greenhouse gases, students will not only become familiar with new inorganic compounds, but also, they will have a broader view of an environmental problem that affects present and future generations.

When students studied in previous years the difference between physical and chemical change, teachers explained that a chemical change occurred when we observed, for example, a change of colour, such as the iron oxidation. Knowing that the vast majority of students are every day in contact with aluminium foil, Question 11 is proposed to them.

Qüestió 11. L'alumini s'oxida? En cas afirmatiu, indica quin òxid és forma i per què el paper d'alumini que utilitzem per embolicar els entrepans no mostra signes de deteriorament com pèrdua de brillantor?

Figure 5. Question 11.

If the students' response is that the aluminium is resistant to oxidation in moist air, Question 12 will help them to remind which are and what are the noble metals. The remaining questions are intended to introduce inorganic compounds used in construction or in medicine. [11]

5.1.3.3. Formulation and nomenclature

Although there are two different worksheets, WS2 and WS3, both were used to teach about the formulation and nomenclature of the different types of inorganic compounds. The reason why this topic has been separated in two parts is that students learnt the large majority of the content included in WS2 the previous year.

The proposed structure of these WS has been based mainly on short introductions, either through a question, an image or a brief text introducing the type of inorganic compound that is going to be studied, followed by the formulation and nomenclature rules with different examples and finally, one or several questions are proposed to practice. [4,11,12]

The main objective of these WS is that students learn to formulate and name the compounds without having to memorize them. The amount of information contained in this syllabus is high, for this reason, the development of this part of the teaching material became extremely difficult, because it was necessary to carefully think the proposed questions and prevent the worksheets from being too dense for students.

La majoria dels ions metàl·lics com el liti (Li^+), el sodi (Na^+), l'alumini (Al^{3+}) o el plom (Pb^{2+} i Pb^{4+}) són incolors en dissolució aquosa, però per exemple, els ions de coure (Cu^+ i Cu^{2+}) tenen un color blau verdós molt característic que de fet, ja vas veure en la imatge 18 on apareix l'òxid de coure(II) que a l'estar format pel catió Cu^{2+}, adquireix aquesta tonalitat turquesa.

Qüestió 15. Els ions de coure no són els únics que presenten coloració en dissolució aquosa: quins colors tenen els ions de ferro, de cobalt, de níquel i de crom? Anomena'ls.

Imatge 25. El catió coure(+2) té una tonalitat blava

Figure 6. Introduction to simple ions, extracted from WS2.

To avoid falling into the routine of the typical formulation lists, which have also been included, other types of questions have been added: from completing tables (Questions 17 and 18) to exercises in which students have to choose between two options and to give the reason for the choice made (*see Figure 7*). If students have understood the rules, they will be able to solve these questions without any problem.

Qüestió 24. Indica quina fórmula o nom de les següents parelles és correcte i justifica-ho.

a) Cl_2O o OCl_2
b) Clorur d'alumini o clorur d'alumini(III)
c) $ZnCl_2$ o Cl_2Zn

Figure 7. Question 24.

In the immediate future, students will use the formulation in exercises, such as the following question (*see Figure 8*). This type of question will not only allow the students to become familiar with the chemical reactions while still practicing, but also they will see the reaction through the proposed video.

Qüestió 32. Una pràctica freqüent als laboratoris de química inorgànica i orgànica és la del "Mirall de Plata". El procediment experimental té diverses etapes, i la primera és la següent:

Nitrat de plata + Hidròxid d'amoni ⟶ Hidròxid de plata + Nitrat d'amoni

Formula els compostos que intervenen en la reacció.

Imatge 41. Mirall de Plata

Figure 8. Question 32 is one of this type of exercises.

According to the teachers, every year the students show difficulties in understanding the formulation of the salts of the ternary compounds. The aim of Question 30, apart from introducing these compounds, is that from the beginning, students realize that these salts were formulated in the same way as binary salts, no matter what the anion has one or two elements.

Qüestió 30. Quin compost creus que es formaria entre un catió Na^+ i un oxoió SO_4^{2-}? Comenta la teva resposta amb la professora.

Figure 9. Question 30.

In the same way that in WS1, some concepts previously seen by the students have been introduced, such as the acid and base concepts (Questions 27 and 25 respectively) or Lewis structures (Question 28).

5.2. THE EXAM

Although a different methodology is applied, it was considered that the best way to evaluate the students was through a traditional exam, since the students are evaluated in this way constantly. As there was not much time available for the exam, it was prepared to do in 30-40 minutes and had a total of five questions (*see Appendix 2*):

- **Question 1:** This question includes a list of chemical compounds seen in WS1 and the students had to match these compounds to one of the affirmations that were given.
- **Question 2:** This was the typical true or false questionnaire, about concepts seen in the different worksheets.

- **Question 3:** In this question a total of five compounds were given and the student had to choose the correct name or formula, between two options and briefly explain their choice. Students did an exercise of this type in the WS2 and it is useful to see whether the students understand how the different chemical compounds are named and formulated or if they have only memorized them.
- **Question 4:** This was the typical exercise of naming and formulating compounds.
- **Question 5:** In this question the student had to define the concept of acid and draw two Lewis structures. The reason of adding this question in the exam was, as mentioned above, the importance of evaluating the students about concepts that teachers consider essential.

6. APPLICATION OF THE METHODOLOGY

In this section, both the class conditions and the observations along the experience will be discussed. The latter is a very important part of the study, since it allows to see if the teaching material is correctly adjusted to the level of the students and if it is necessary to introduce modifications. This study was made in the 1st year of High School chemistry classes of Maristes Sants – Les Corts, in Barcelona.

6.1. CLASS CONDITIONS

It is important to introduce the classes, due of their differences:

- Class 1: The number of students was eighteen. The most remarkable thing in this class was the presence of a newly arrived student who was not yet familiar with the languages in which the subject was taught.
- Class 2: The number of students was seven.

The classroom was the same in both cases, and it was big enough to join the tables in groups of two up to four students. Each group had two laptops.

In both classes, the groups were made by the teachers, with the aim of compensating the groups, and create a great working atmosphere. The exception was the newly arrived student, because he chose the group which he felt the most comfortable.

Usually, there is only one teacher in each class, but during the experience were two. Mayte Ramos and Arancha Herencia were the teachers of Class 1 and 2 respectively, along with Anna Moreno, author of this report. This factor is important because students were able to solve their doubts more quickly if there were more teachers in the classroom, it is also a condition to analyse since the difference in the number of students between one class and the other is remarkable.

The chemistry teachers dedicate a total of 12 class hours to explain all the syllabus. The experience lasted a total of 14 hours in both classes, 13 assigned to solve the different worksheets, where all types of the inorganic compounds are seen, and 1 hour to perform both the exam and the surveys. The class schedule is shown in *Appendix 3*.

6.2. OBSERVATIONS DURING THE FLIPPED CLASSROOM

Students were motivated throughout the experience, especially during the fulfilment of the WS1. Moreover, during the pass of the days, students were more confident.

Teamwork was remarkable, especially during the sessions in which WS2 and WS3 were worked. Students who understood the concepts correctly tried to solve, as far as possible, their colleagues' doubts before asking the teachers.

The main difference between the two classes was that in Class 1 there was one teacher for every three groups and in Class 2 there was one teacher for each group, so that in the latter group students could solve their doubts more quickly. In addition, the work environment was quieter in Class 2.

The speed with which each group worked was different, therefore, when a group did not finish the work established for the session, they should finish it at home.

During the sessions, the most common doubts were noted, as well as the curiosities arose to students. The annotations were the followings:

- **Question 1, WS1:** All groups showed interest when they learned that strontium is used to give colour to fireworks. In addition, some groups looked for other metals that are used.
- **Question 2, WS1:** It was the unique that generated problems. Students had difficulty in understanding it, they did not understand how the electrolysis process worked, or what a reduction-oxidation reaction was. They also had difficulty in reasoning why sulfuric acid should be added, but when the teachers told them that they should reason it according to the conductivity, they understood it. Some students did not indicate the chemical reaction.
- **Question 6, WS1:** Many students did not read the recommended website carefully and made several mistakes, such as saying that the substance that exploited was gypsum or just mention one of two accidents related to ammonium nitrate.
- **Question 7, WS1:** They liked the proposed video, and realized that they should be careful when handling chemical compounds. Some students did not indicate the chemical reaction.
- **Question 8, WS1:** By not paying enough attention when they read, they confuse sulfuric acid with hydrosulfuric acid.

- **Question 14, WS1:** Some students did not indicate the chemical reaction.
- When Class 1 arrived at the **Binary Sales section, WS2**, some students asked to return to the traditional class. This fact will be discussed in the conclusions of the study.
- **Question 23, WS2:** This question was included in consensus with the teachers of the institute with the intention that students remembered the chemical bonding properties. During the pass of the days, it was decided that it was preferable to use the time to practice formulation, so it was not resolved.
- **Question 31, 32 and 33, WS3:** Due to lack of time, the last three questions could not be completed, but were discussed in class. Students saw positively do formulation exercises and at the same time, watch a video about the chemical reaction.

7. RESULTS AND DISCUSSION

This section is divided into several parts, and all of them are essential to improve the teaching material. With the analysis of the worksheets and the exam results, it will be possible to detect which parts of the material have worked properly and which need improvement. In the same way, the surveys made to the students and teachers will allow to see their perspective on the experience and the methodology.

7.1. ANALYSIS OF THE WORKSHEET RESULTS

Table 1 shows the results of the average mark between all worksheets. It is observed both classes got good marks. Moreover, the overall average is an 8.12.

	Excellent (10)	**Excellent (9.9-9)**	**Notable (8.9-8)**	**Notable (7.9-7)**	**Pass (6.9-6)**
Class 1 (18)	1	3	7	6	1
Class 2 (7)	1	1	2	2	1

Table 1. Students' average marks of WS separated by classes.

Even the students had worked during the class, the following mistakes were repeated in both groups:

- They did not indicate the chemical reactions in the exercises that required it.
- To go faster, some students did not read the sources of information carefully and consequently, some answers were incorrect or incomplete.
- Due to lack of time, students had to complete some of the formulation and nomenclature exercises at home, so they could not comment the exercises with the teachers and for this reason, they made some mistakes.

7.2. ANALYSIS OF THE EXAM RESULTS

The results of the exam are summarized in the following page:

	Excellent (10-9)	Notable (8.9-7)	Pass (6.9-5)	Fail (4.9-0)
Class 1 (18)	4	10	3	1
Class 2 (7)	2	3	2	0

Table 2. Exam results separated by classes

There was only one fail in front of 24 passed. It is remarkable to note that Class 2 notes are equally distributed but in Class 1, the 56% of students have obtained a rating between 7 and 8.9.

Each question of the exam is analysed individually to detect where the students had more difficulties. The following tables show the successful percentage for all the questions. The questions highlighted in green are those with the highest percentage of success and the red are those with the worst results.

Question	% of success	Concept
1	**96**	**Relate the compound with its definition**
2	85	Inorganic compounds theory
3	79	Choose the correct formula or name
4	72	Formulation and naming
5	**69**	**Lewis**

Table 3. Summary of the % of success in Class 1

Question	% of success	Concept
1	**100**	**Relate the compound with its definition**
2	87	Inorganic compounds theory
3	84	Choose the correct formula or name
4	**62**	**Formulation and naming**
5	81	Lewis

Table 4. Summary of the % of success in Class 2

Question 1

In both classes this question was the one with better percentage of success. Furthermore, in Class 2 all students answered it perfectly. That means, that the students have learned correctly the applications and nature of the chemical compounds treated in class.

Question 2

Table 5 shows the percentage of overall success. Sections 1 and 6 were answered perfectly, but 52% of students have failed in section 5.

Section	1	2	3	4	5	6	7	8	9	10
% of overall success	100	80	88	96	48	100	92	96	64	92

Table 5. Summary of the % of overall success

If we analyse the percentages in separately, we can see that section 5 is the worst one in both cases, which means that most of students did not know how to differentiate between acid oxide and a basic oxide. The second section with lowest percentage of success, is number 9 in Class 1. In contrast, the percentage of success of the other sections was greater, which suggests that students assimilated the vast majority of concepts asked in this question.

Section	1	2	3	4	5	6	7	8	9	10
% success of Class 1	100	83	83	94	50	100	94	94	59	90
% success of Class 2	100	71	100	100	43	100	86	100	71	100

Table 6. Summary of the % of success, separated by classes

Question 3

If we take a look at *Table 7*, we can see that section E is the one with higher success and this is important to note, because the students understood the need to indicate the oxidation number in compounds that contained elements that can act with more than one state of oxidation.

Section B is the one with lower success. In this exercise the half of the punctuation in each section was given by correctly indicating the name or formula between to options, so the most common mistakes were:

- Justify the choice made based on the discard. In this case, the full score was not given.
- Not justify the chosen option.

Section	A	B	C	D	E
% of overall success	77	66	68	94	97

Table 7. Summary of the % of overall success

If the percentages are separated by classes, it can be seen that in the case of Class 2, the section with the lowest score is not B, it is C.

Section	A	B	C	D	E
% success of Class 1	74	65	69	92	96
% success of Class 2	86	68	64	100	100

Table 8. Summary of the % of success, separated by classes

In this section the students only made one mistake and occurred the same in Class 1 and Class 2. Students justified their choice with the concept of electronegativity, in other words, they said that the correct answer was OBr_2 since bromine is more electronegative than oxygen because bromine is located more to the right of the periodic table, then the element bromine has to be placed on the right.

This error may be mainly due to the fact that the first time the students had contact with the binary compounds was with the old nomenclature implanted by the IUPAC, where the position in the formula was established by the electronegativity of the element, being the oxygen combinations with halogens (except with fluorine), oxides. From the next year the criterion of correction of the entrance exams to the University will follow the new normative. This one establishes that the order in which the elements appear in the formulas follows the position in the periodic table, so that now the binary combinations between the element oxygen and halogens, are halides.

It is important to improve this point of the worksheets, because although students identify correctly the position of the elements in the formula, they had not understood the reason and what was worse, it shows that the concept of electronegativity was not clear either.

Question 4

Since this question contained sections where more than one nomenclature had to be indicated, the correction was based on whether the answer was correct, partially correct or incorrect.

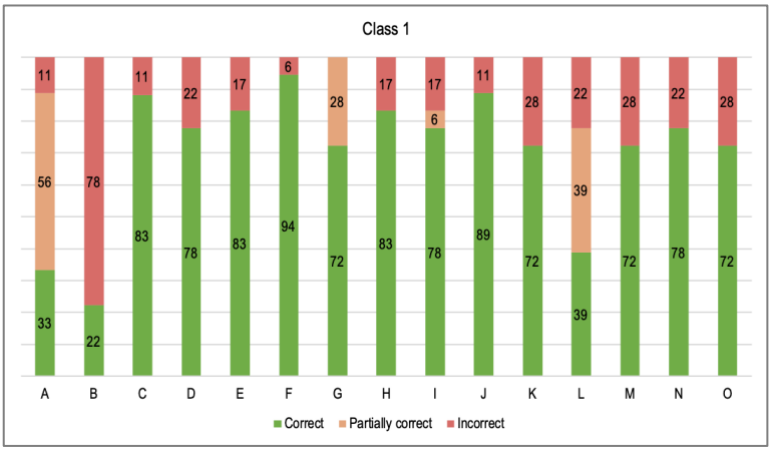
Table 9 shows the percentage of overall success, only including the correct answers. The table shows that the sections A, B and L are the ones with the worst percentage. The conclusions will be discussed jointly with comments on the comparative between classes. On the other hand, the other sections have a minimum of 60% of overall success, which means in general terms, students achieved the formulation and nomenclature rules explained in WS2 and WS3.

Section	A	B	C	D	E	F	G	H
% of overall success	28	24	84	80	84	80	60	80

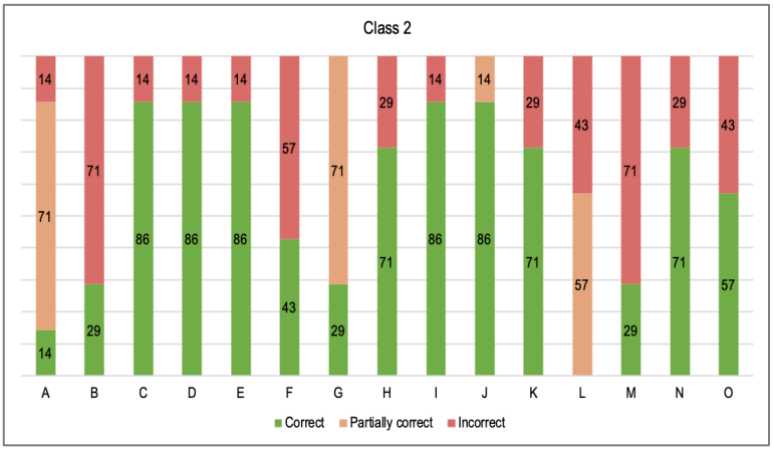
Section	I	J	K	L	M	N	O
% of overall success	80	88	72	28	60	72	68

Table 9. Summary of the % of overall success

If we look at the graphs shown below, we can observe that in general terms the percentages corresponding to correct answers are quite similar, with some exceptions. For example, we see a huge difference between the percentage of success of the two classes in sections F and M, both clearly more negative in Class 2. Another point to note is that Class 2 has a higher percentage of students who answered section G incompletely, obtaining only half of the score. Finally, it should be mentioned that no student in Class 2 responded section L completely.



Graph 1. Analysis of the answers in Class 1



Graph 2. Analysis of the answers in Class 2

The conclusions drawn from the students' answers are the followings:

- Section A: The vast majority of students indicated that it was an ion, but they did not indicate the charge, just as they had worked in class.
- Section B: Most of students who answered this section incorrectly, said that the compound was chronic acid, which means that they knew how to know the oxidation state of the metal, because in both cases chromium acts with the same oxidation number (+6), but they could not distinguish between an acid and a diacid.
- Section F: Students who answered this section incorrectly did not indicate the two possible options nor the aggregation states. The significant difference between the two groups may be due to the fact that in one of them the teacher emphasized on how that question should be answered in an exam, and in Class 2 there was no such insistence.
- Section G and L: The reason why the students did not get the full score was because they forgot that when a metal can act with more than one oxidation state, they must indicate two nomenclatures, just as they had worked in class.
- Section M: Students who responded incorrectly to this section misrepresented the name of the compound.

Question 5

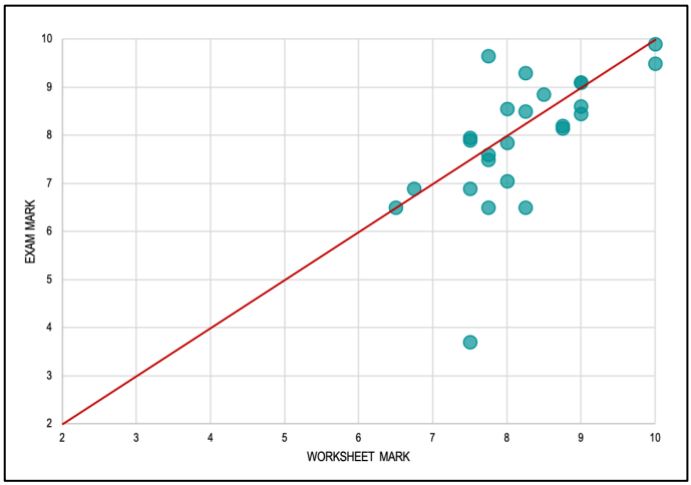
This question obtained the worst score in Class 1 and the second one in Class 2. The mistakes committed were:

- Do not put lone pairs in oxygen atoms.
- Do not put negative charge on oxygen in the Lewis structure of the oxyanion.
- 1 student did not answer properly the question.

This fact can be attributed that although this concept was explained and worked in the WS3, neither the questions nor the explanations made in class were enough for the students to assimilate the concepts in an appropriate way.

7.3. RELATIONSHIP BETWEEN THE WORKSHEETS AND THE EXAM

It is not unreasonable to think that the students who obtain better marks in the worksheets, will obtain better marks in the exam but observing the following graph, it is clear we cannot affirm this hypothesis.



Graph 3. Relation between the exam and the worksheets

Each point represents a student in the graphic. The X axis represents the worksheet mark and the Y axis the exam mark. The point located on the red line, indicates that the student has the same score at the worksheet and at the exam. In addition, 40% of students improved their marks at the exam.

In contrast, it is necessary to pay attention to the point that is far away from the trend line, which corresponds to the newcomer student. This fact will be analysed together with the observations made during the teaching hours in order to draw conclusions about this particular case.

7.4. STUDENTS' OPINION

Apart from the exam students had to answer a survey about the worksheets, the exam and the methodology (*see Appendix 4*). To provide students confidence and to be able to show their opinion and proposals on possible improvements to the teaching materials with total freedom, the surveys were anonymous.

7.4.1. About the worksheets

Students thought that the level of the worksheets was adequate. According to the survey results, students enjoyed the topic of WS1 with a result of 4.88 out of 5. In the same way, students affirm that WS1 helped them to get to know better the chemical compounds that surround them with a result of 4,04 out of 5. In contrast, there was a neutral opinion (3,72) about that WS1 helped them to see the subject from another perspective.

Although most of students thought that the time for doing the worksheets was enough, some would had preferred to spend more time in WS2 and WS3 and with a result of 3,84 out of 5, students affirmed that there were enough formulation and nomenclature questions to practise.

Students were asked about which questions of WS1 they liked more and which less. The questions that students enjoyed most were Question 8 (36%) and Question 6 (24%). On the other hand, the questions that students least liked are those more theoretical, such as Question 5 (24%). In conclusion, students preferred those questions which made them link concepts of chemistry with their day to day life.

7.4.2. About the exam

First of all, it should be mentioned that according to the results of the surveys, the students did not study too much. Some of them even commented that the only thing they did was to review what had been worked in class as a reminder.

Students believed that the exam was adjusted to the level and content seen during the experience with a result of 4,46 out of 5. In addition, 52% of the students thought that they

managed nervousness better when they faced the exam and 60% believed that they had learned more with the FC methodology.

7.4.3. About the methodology

Students affirmed that they felt comfortable asking in class, assessing it with 4,68 out of 5. On the other hand, students felt quite neutral when they were asked about working in group and if they thought that it had helped them with a result of 3,76 out of 5. Moreover, there were two students who mentioned in the section dedicated to comments and suggestions that they had not liked working in group because they felt that some of their groupmates had taken advantage of their work. Finally, according to the results of the surveys, 52% of the students preferred the FC methodology over the traditional method.

7.5. TEACHERS' OPINION

Teachers were interviewed since they had been present during the all the experience in their respective classes. The questions asked were the following:

- How did you see the class development these days?
- Have you ever worked with any active learning method?
- How do you think that education should evolve?

The answers of both teachers are reported in *Appendix 4*, after the results of students' surveys.

The opinion was very different between the teachers. Class 1 teacher affirmed that active learning cannot be used in all situations, as was seen in the specific case of her class because some students asked to return to the traditional method. She prefers integrating different teaching methodologies without abusing active learning, since she believes that the traditional method can be equally dynamic.

On the other hand, the teacher of Class 2 was satisfied with the students' behaviour and their results, and what is more, she saw that the work environment had been collaborative and that students had been the protagonists of their learning. She believes that education should evolve in the direction of active learning methods.

8. IMPROVEMENT PROPOSAL OF THE WORKSHEETS

By compiling and analysing all the information obtained during the class hours, the exam and the surveys, some parts of the WS will be reformulated in order to improve those parts where the students have shown more difficulties.

- **Modify Question 2 of WS1:** Due to the problems observed during class hour.
- **Specify more what is requested in Question 3**: The vast majority of students extended their response too much and did not distinguish the key concepts.
- **Insert more questions in WS1**: Based on curiosities that students have shown.
- **Indicate clearly in Questions 7 and 14 that the students must indicate the chemical reaction**: The vast majority of students did not indicate the chemical reaction.
- **Remove Question 23**: This question could not be resolved in either of the two classes nor commented with the students, so we do not know the difficulties that can be encountered since it is based on a topic seen in previous years.
- **Indicate clearly in formulation exercises that students must write all the possible nomenclatures if its needed**.
- **Add more questions similar to Question 3 of the exam:** In this way, the students would better understand the differences between different types of inorganic compounds and they would know how apply the formulation and nomenclature rules correctly.
- **Include a question to differentiate the acid oxides from the basic ones:** 52% of students failed the section 5 of Question 2 of the exam, meaning that this concept was not assimilated with the proposed question.
- **Include a question to differentiate the diacids**: Because students did not differentiate them from simple acids.

In the *Appendix 5* there is the improvement proposal of the worksheets, prepared with all the annotations mentioned above.

9. CONCLUSIONS

As expected, the development of the WS has been difficult and it has needed a lot of hours of dedication, but according to the results, this time has been used properly:

- A large majority of students achieved a good degree of knowledge, which means that the design of the different WS and the concepts included were adequate.
- Thanks to the daily follow-up and the evaluable material, the parts of the syllabus that represented a greater difficulty for students were detected and consequently, have been modified in the original WS.
- It was not possible to evaluate the active learning using only the WS, since the student can copy the answers. Team working was useful to discuss the worksheet questions, but every member had to understand the answers to get a good mark in the exam.
- In the specific case of the newly arrived student, we can conclude that teamwork was useful, as well as the supervision of teachers, since the score obtained in the WS was good. In agreement with the opinion of the professors, the problem of this student only responded to a difficulty in the understanding of the language.
- It was demonstrated that the number of students did not affect the method, although in a class with few students, doubts could be solved quickly.
- The opinion of the students about the FC was positive in general terms. They valued working in groups and took an active role in class. On the other hand, some students showed themselves to be against the methodology at some point in the experience; in active learning there is no place for passive attitudes.

10. REFERENCES AND NOTES

1. Brame, C. (**2013**). Flipping the classroom. Vanderbilt University Center for Teaching. Retrieved [20/12/2018] from http://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/
2. Prieto Martín, Alfredo. (**2017**) *Flipped Learning: Aplicar el Modelo de Aprendizaje Inverso*. 1st Ed. Madrid: Editorial Narcea.
3. Santiago, Raúl; Díez, Alicia; Andía, Luis Alberto. (**2017**) *Flipped Classroom: 33 experiencias que ponen patas arriba el aprendizaje*. 1st Ed. Barcelona: Editorial UOC.
4. Herencia, Arancha. (**2018**) *Teaching material for 1st year High School chemistry class*.
5. Enevoldsen, Keith. (**2015-2016**) *Periodic Table of the Elements, in Pictures and Words*. Seattle, elements.wlonk.com. Retrieved from: http://elements.wlonk.com/ElementsTable.htm
6. Atkins, Peter; Jones, Loretta. (**2012**) *Principios de química: Los caminos del descubrimiento*. 5th Ed. Editorial Panamericana.
7. Scodelaro, Federico. (**January 5, 2015**) *Los 9 peores desastres de la industria química*. Retrieved from: http://www.ingenieriaquimica.org/articulos/peores-desastres-industria-quimica
8. Denia, Santiago. (**June 22, 2015**) *Los peligros de combinar la lejía*. Retrieved from: https://www.republica.com/ciencia-para-todos/2015/06/22/los-peligros-de-combinar-la-lejia/
9. Admin. (**August 25, 2016**) Retrieved from: http://notinerd.com/galeria-16-curiosidades-de-la-quimica-que-vives-dia-a-dia/
10. Bertral, Xavier. (**July 9, 2018**) *Els gasos d'efecte hivernacle a Espanya registren la pujada més gran en 15 anys.* Diari Ara (Societat). Retrieved from https://www.ara.cat/societat/gasos-efecte-hivernacle-Espanya-creixen-major-augment-ultims-15-anys_0_2048195348.html
11. Atkins, Peter; Overton, Tina; Rourke, Jonathan; Weller, Mark; Armstrong, Fraser. (**2008**) *Química Inorgánica*. 4th Ed. McGraw-Hill/Interamericana Editores.
12. Sales, Joaquim; Vilarrasa, Jaume. (**2003**) *Introducció a la Nomenclatura Química Inorgànica i Orgànica*. 5th Ed. Editorial Reverté.

11. ACRONYMS

FA: Fulls d'Activitat

FC: Flipped Classroom

IUPAC: International Union of Pure and Applied Chemistry

WS: Worksheet

APPENDICES

APPENDIX 1: WORKSHEETS (USB)

APPENDIX 2: EXAM (USB)

APPENDIX 3: CLASS SCHEDULE

Hour	Monday	Tuesday	Wednesday	Thursday	Friday
8:00 - 9:00	-	-	-	-	Class 2
9:00 – 10:00	-	Class 1	Class 1	-	-
10:00 - 11:00	Class 2	-	-	Class 1	-
11:25 – 12:25	-	-	-	-	-
12:25 - 13:25	-	-	-	Class 2	Class 1
13:25 - 14:15	-	Class 2	-	-	-

APPENDIX 4: SURVEYS AND RESULTS (USB)

APPENDIX 5: IMPROVEMENT PROPOSAL OF THE WORKSHEETS (USB)