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# CHIMACTIV: an open-source website for student-centered learning in analytical chemistry

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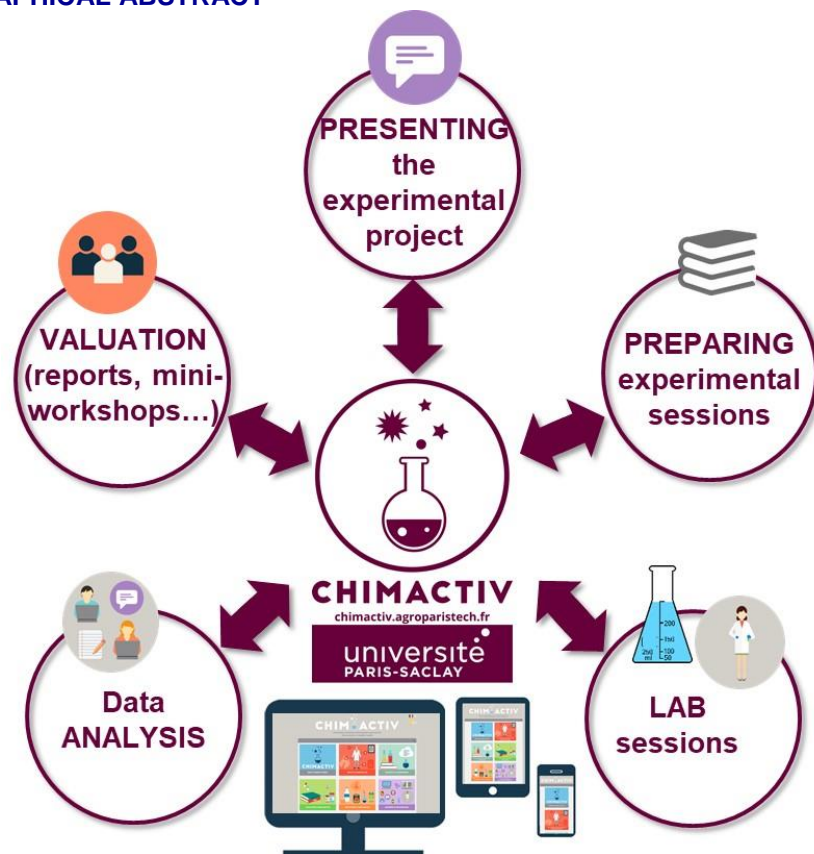
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## ABSTRACT

The CHIMACTIV website (<http://chimactiv.agroparistech.fr/>) offers open educational resources related to analytical chemistry. It tackles a teaching problematic: how could we encourage students to be more involved in learning during teaching courses (especially during lab work) and provide deeper teacher-learner interactions during the sessions? With 30 digital bilingual (English/French) sheets classified in 5 topics (security in a chemistry lab, basics of manipulations, food analysis, drug analysis, and getting familiar with experimental methodologies), CHIMACTIV offers a great variety of media (scientific content, short videos, interactive schemes, pictures, games, quizzes and exercises) which are responsive whatever the digital medium (computer, tablet, smartphone). Depending on their educational objectives and their students' curricula, teachers can guide students towards the appropriate resources to consult before, during or after class and/or lab sessions, in order to strengthen backgrounds, build new scientific background or analyze data. These digital resources are also very useful for students aiming to self-train, for trainees in research labs, as well as for professionals working in a sector related to chemical analysis.

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## GRAPHICAL ABSTRACT



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## KEYWORDS

General public, Analytical Chemistry, Food Science, Drug / Pharmaceuticals, Laboratory Instruction, Distance Learning / Self Instruction, Internet / Web-Based Learning

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## INTRODUCTION

Laboratory instruction is very important in analytical chemistry in order to acquire practical skills.<sup>1</sup> It is also the best way to train students to experimental approaches, as well as to metrology concepts since they have the opportunity to acquire their own data and thus to become aware of the bias and imprecision linked to the experiments. Yet, the time devoted to such sessions in some graduated chemistry programs has been decreasing in recent years, mainly due to associated costs or lack of preparation time as already reported.<sup>2</sup>

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Since learning outcomes remain the same in graduated curricula to fulfill professional skills, chemistry teachers need to find options to make experimental sessions more efficient, i.e. allowing students to benefit more from practical sessions and discussions with teachers in such situation. In the meantime, within graduate programs, the learners' audience is getting more and more heterogeneous (partly due to students coming from different topics) so that students enter these sessions with diverse background. In particular, they arrive in the laboratory without any safety notion, or any knowledge of the practical experiments they have to perform. Also, as already observed,<sup>3,4</sup> pre-laboratory work is a key issue to optimize experimental sessions. It allows students to anticipate what they will do in the lab and how, thereby increasing their self-confidence as they feel better prepared. Consequently, they are more involved in these sessions, and benefit from a subsequently improved and deeper learning. In such a context, we decided to provide students with appropriate assets so that they have the opportunity to train themselves before sessions. Since students are now digital natives, we created the open-source website CHIMACTIV (<http://chimactiv.agroparistech.fr/>)<sup>5</sup> offering digital educational resources we designed and produced (students' preferences regarding interactive tools have been recently reported<sup>6</sup>). All these resources are gathered in 30 digital sheets, all available in bilingual versions (French / English).

## OVERVIEW OF THE FIELD COVERED BY THE WEBSITE

### Scientific field covered

CHIMACTIV is covering the field of chemical analysis, with special emphasis on complex matrices such as foods or drugs. Bearing in mind that the laboratory is a complex system for learning,<sup>3</sup> we produced resources with different degrees of complexity as illustrated in **figure 1**.

The basics cover main aspects related to safety in the lab, as well as descriptions of basic equipment and tasks (e.g. performing a dilution). Consulting such resources before lab sessions enable students to become more familiar with lab environment and simple tasks, allowing them to perform more complex work during the courses.<sup>5</sup> Of higher degree of complexity, concrete applications are presented with detailed experimental procedures, extensively illustrated by short videos; they focus on food and drug analysis, two major topics of interest in our programs. Finally, students can also find reflexive content linked to methodological aspects that are of great importance in master degrees.

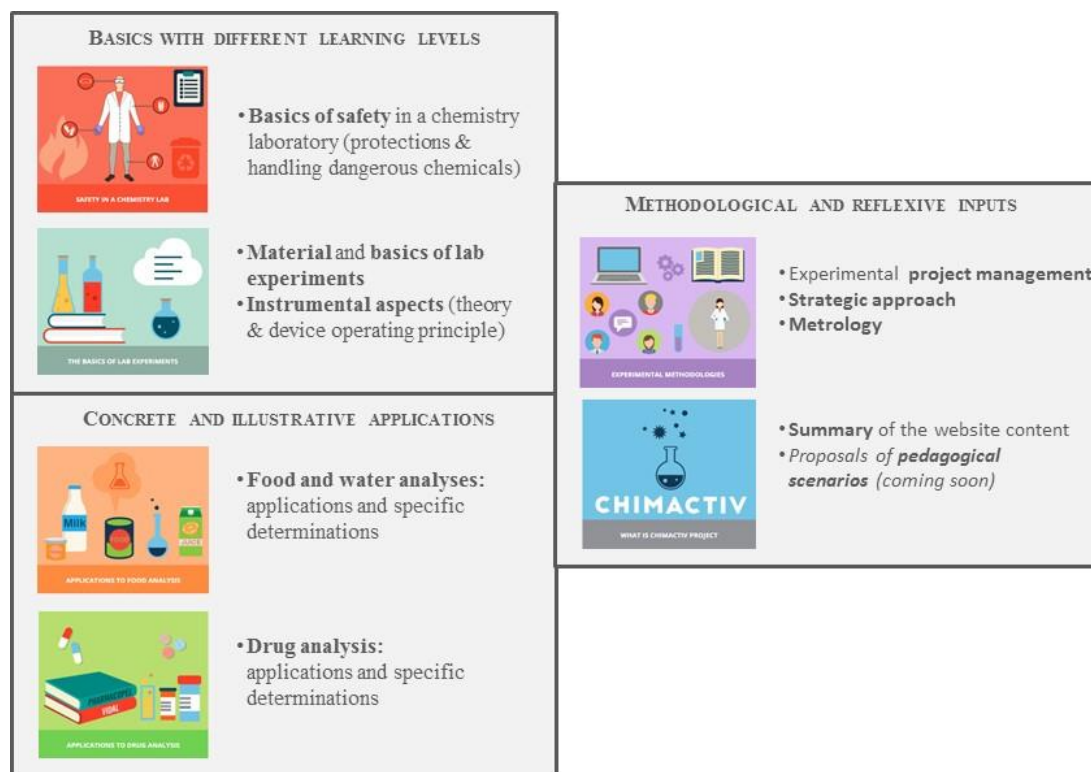


Figure 1. Illustration of the scientific field covered by the CHIMACTIV website.

### Types of educational resources

75 As previously recommended,<sup>3</sup> the resources cover experimental, theoretical and post-laboratory analysis aspects of laboratory work. Another major valuable aspect of CHIMACTIV lies in the great diversity for the types of resources it offers as illustrated in **figure 2**.

Besides details of scientific theories and principles underlying some phenomena, experimentations or equipment, the website enables visitors to experience active-learning thanks to numerous  
80 interactive schemes (mostly drag and drop). Several quizzes and exercises are also very useful for students to assess their understanding and knowledge retention. Then, short videos are also of great interest to present some theoretical concepts, to make some demonstrations of particular procedures to be performed by students during the sessions, to focus on some operational tasks of experiments or to detailed data analysis. For all videos, text transcripts with timeline are available as recommended,<sup>6</sup>  
85 enabling students with auditory deficiency to train.

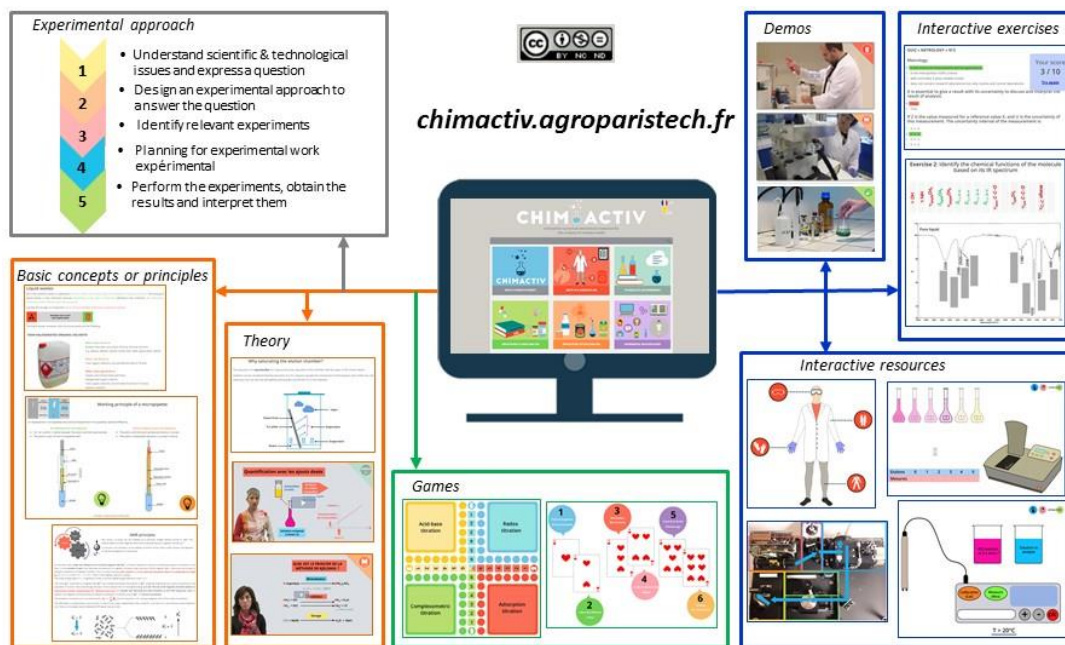


Figure 2. Illustration of the great diversity of the educational resources available on the CHIMACTIV website.

The experimental approach is also explained and illustrated, to get the students familiar with the key steps of the whole approach before they assist to the experimental sessions, and to continue to guide them during the sessions. Finally, to make the web site exploration attractive, several games are also proposed or presented.

### Target curricula

The website initially opened in December 2016 targeting mostly graduate students (master's degree programs in science). Later on, many discussions with chemistry teachers from undergraduate programs or even high schools clearly revealed their great interest in using such resources for their teaching. So, we have implemented our website in April 2019 with several new educational resources that cover a wider content of basics in chemical analysis, thereby ensuring enlargement of our teachers and learners audience.

## THE WEBSITE CONTENT

### General presentation

CHIMACTIV is organized in five main sections, directly accessible from the front page of the website and gathering different digital sheets: (i) security in a chemistry lab/2 sheets, (ii) basics of manipulations/15 sheets, (iii) food analysis/5 sheets, (iv) drug analysis/4 sheets, and (v) getting

105 familiar with experimental methodologies/4 sheets. Another section dedicated to the general website presentation is also proposed, describing the genesis and content of the website; this section will soon (around Spring 2020) be implemented with proposals of pedagogical scenarii to facilitate the website integration in existing courses for teachers.

110 Several items and tools are proposed on each page as illustrated in **figure 3**, to ensure fast and easy overview of available resources on the website. A color code for each section is also adopted to facilitate tracking. Graphics and browsing within the website were initially tested by a pilot group of thirty students, in order to design attractive resources for them.

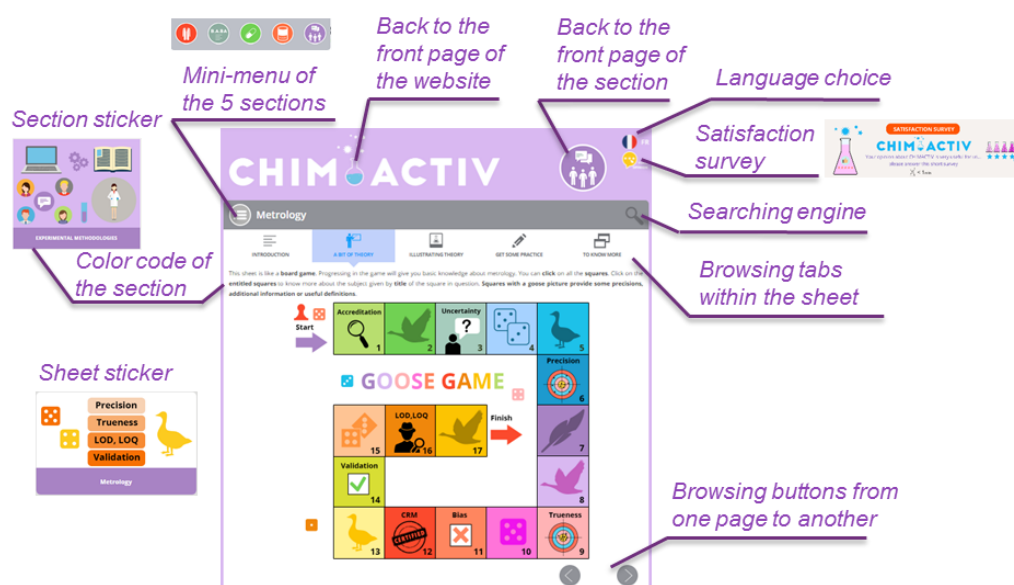


Figure 3. Details of items and tools enabling intuitive and easy navigation within a CHIMACTIV sheet.

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Several generic tabs at the head of each page enable convenient and rapid browsing among the different contents and resources within each sheet. Supportive information<sup>3</sup> related to concepts and underlying theory are clearly distinguished from procedural information<sup>3</sup> describing the apparatus and/or the different steps of the experiments to be conducted in the lab (e.g. “Introduction”, “A bit of theory” tabs *versus* “Experimental procedure”, “Illustrating theory” tabs). Direct access to the front page of either the current section or the website is also proposed on each page, along with direct access to the previous or forehead page. A mini-menu also authorizes to easily jump from one section to another. Real-time direct access to the language (French or English) on each page is greatly

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appreciated, both by students and teachers. A searching engine is also available and may be helpful  
125 for the new visitors. Finally, a satisfaction survey is proposed, helping us to acquire users' perceptions  
and commentaries, in order to regularly implement and optimize the website.

#### The safety in a chemistry lab section

The section relative to security gathers two sheets which are very useful for students to consult  
before experimental sessions. Hence, the first sheet details the different options to protect oneself (e.g.  
130 wearing laboratory coat and protective glasses) and the others (e.g. organizing working space on a  
laboratory bench, ranging a lab room); several recommendations in case of incidents are also given, as  
well as detailed information relative to safety materials (e.g. types of fire extinguishers). Two short videos  
show concretely bad and correct behaviors to adopt in a chemistry laboratory.

The second sheet is related to the manipulation of hazardous chemical products: it details the  
135 hazard pictograms, the types of products classically found in a chemistry lab (organic solvents,  
reagents, toxic products, acids and bases) as well as the recommended storage conditions. It also  
presents the fate of solid and liquid wastes; for each type of waste, a decision tree is proposed to help  
students to choose the best management option.

#### The basic manipulations section

140 The section relative to the basics of manipulations is very extensive, with 15 sheets. Few of them  
focus on material or basic procedures (e.g. choosing lab equipment, preparing a dilution), with  
sometimes short videos to allow students to specifically visualize the performance of some operations.  
Others sheets are more concerned with instruments or techniques (e.g. fluorescence, HPLC); in some  
cases, after a more or less detailed presentation of the theory and the relevant scientific principles, the  
145 apparatus part is illustrated (photos, schemes) and documented. In some sheets (vibrational  
spectroscopy and nuclear magnetic resonance), data analysis procedure and spectra interpretation are  
also detailed.

It appears that this section is the most polyvalent in practice, with resources available by learners  
from different study levels. A proposal showing the possible study levels concerned by each of the 15  
150 sheets of this section is illustrated in **figure 4**. Of course, this is only indicative, the levels concerned



by each sheet being dependent on the type of formation (initial or executive / general or specialized in chemistry), on the knowledge of the students and also on the pedagogical intention of the teacher.

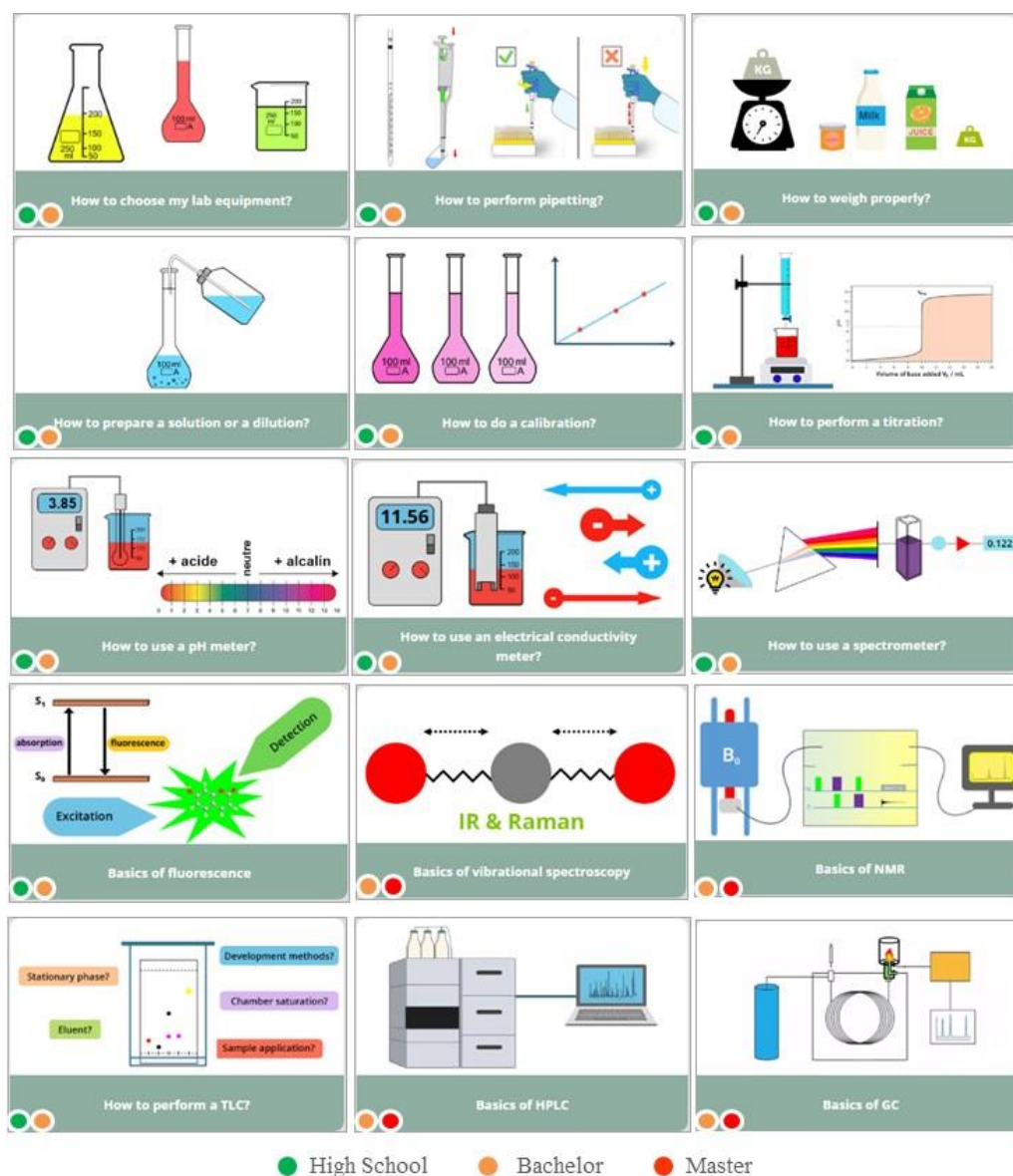


Figure 4. The 15 sheets of the basics section and possible degrees concerned.

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### The food analysis section

The section related to food analysis gathers five sheets. The detailed and widely illustrated applications range from relatively general determinations (dry residue or proteins' content by Kjeldahl method) up to more specific analyses (quantification of vitamin E, oxidation state of fats or antioxidant activity of a plant extract). This section also includes a very complete sheet dealing with the analysis of

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a spring water, where different methods and their experimental procedures are detailed for determining several characteristics (hardness, conductivity, alkalimetric title) or measuring some parameters (contents of cations, anions, dissolved oxygen or even permanganate index).

#### The drug analysis section

165 The other applicative section is related to drug analysis. It offers four sheets, each related to a specific determination that is deeply detailed with the operating conditions: controlling the ascorbic acid purity using redox assay, ion-pair extraction or potentiometric titration of lidocaine hydrochloride, and spectrophotometric determination of paracetamol or sulfamethoxazole in galenic forms. Short videos enable to visualize in large plan the dosage during its execution, such as the mixing operation  
170 or titration during the analysis of ascorbic acid for example.

#### The experimental methodologies section

The last section is about getting familiar with experimental methodologies. It proposes four sheets. Two of them are rather methodologic (managing a supervised experimental project, metrology) whereas the other two sheets are rather orientated towards applicative problematics (methodology of analyzing  
175 contaminants in complex matrices, or choosing and developing an extraction method).

### TEACHING WITH CHIMACTIV

#### Back from our experience

From around three years of using CHIMACTIV with our students from different graduated programs, we have designed several pedagogical scenarios. Of course, we engage the students to  
180 consult specific resources of the website before lab sessions. That way, they can get familiar with safety aspects as well as with key concepts and practical issues of the experiments they will perform in the lab. The responsive character of our resources authorizes the students to go back to the information required during the lab sessions, so that they can get the information “just-in-time”, which is very helpful for conducting their experiments. We also use the website for flipping classroom.  
185 Whatever the scenario, we have experienced that CHIMACTIV must be integrated to the overall teaching experience as recommended,<sup>3</sup> otherwise the students will lack motivation to consult the resources over time.

#### Benefits for students

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190 As already underlined,<sup>3</sup> enabling students to engage in appropriate pre-activities before the lab sessions is benefit for learning. We clearly observed that students having used CHIMACTIV before the sessions were more prepared, and thus more engaged in the lab. <sup>5</sup> Thereby discussions between the students and the professors are deeper than before as previously noticed by other authors. <sup>8</sup> Also, getting the information “just-in-time” should lead to a better retention of the information from a  
195 cognitive point of view. Hence, most of the students investigated declared having the feeling of the website being useful for achieving their learning objectives.<sup>9</sup>

## CONCLUSION

Our open-source website CHIMACTIV shows unique features that deserve interest and attention of both teachers and students concerned with chemical analysis. The diversity of the types of educational  
200 resources available along with their responsive character allow their use in different contexts. Flip teaching is one opportunity, both for classroom and laboratory. Traditional teaching is also concerned, with several resources being useful after class, to interpret data, write a laboratory report or prepare an exam.

## AUTHOR INFORMATION

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