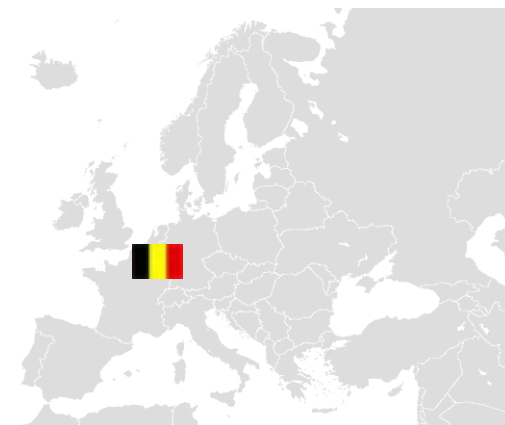# Successful Experiences in Chemistry Teaching in Belgium

Successful Experiences in Chemistry Teaching in Belgium

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Abstract

Teaching resources have been collected and reviewed since the beginning of the "Chemistry is All Around Network" project, as provided for in the project. Yet, Inforef and its working group went further as they used this opportunity to create new resources and train teachers to use them. Different working groups of teachers were formed. Since late 2013, Inforef has organised the testing of those resources in the different schools involved in the project. The idea was to create complete lesson sequences in which ICT resources would be integrated in a relevant way. The audience includes secondary school students of various levels and future science teachers.

1. Introduction

The official website of education in French-speaking Belgium is enseignement.be [1]. It contains among many things a list of resources and publications on education available for all, as well as news on many education-related events, initiatives and projects, videos, curricula, legal texts, lists of skills, a forum...

Another related source of information is the magazine "Prof" [2]. This monthly magazine, published by the Ministry of education, is sent in paper format to all teachers, and can be downloaded for free on enseignement.be. It contains articles by experts on all facets of education, from legislations to specific initiatives.

Several universities have their own scientific publications with articles by experts in all scientific fields. These include "Presses Universitaires de Louvain" [3] by the Catholic University of Louvain, "Atout Sciences" [4] by the University of Namur and "Education & Formation" [5] by the University of Mons. All publications by the University of Liège are available on the open access platform Orbi [6] at http://orbi.ulg.ac.be/?locale=fr.

Regarding ICT resources, the website of the project "École Numérique" (description in chapter 3.1) contains several links to websites approved by the Ministry of education with digital educational resources [7]. Still on "École Numérique", several teachers provide testimonials [8] about their use of educational resources.

2. Key competences and their development in chemistry education

Competences to achieve were set in 1997 by the decree "Missions" [9] of the French-speaking Community of Belgium. They are divided into three categories: "socle de competences" (core skills) [10] in primary school, terminal skills in secondary school, training and qualification profiles for professionals.

Core skills are divided between skills (or know-how) and knowledge. In science [11] the general categories of **skills** are the following: "approaching a complex reality"; "investigating a research lead"; "structuring", "communicating", "validating and summarising results". The general categories of **knowledge** are: "living beings"; "energy"; "matter"; "air", "water and earth"; "men and the environment"; "history of life and science". In both cases, the general categories are divided in several skills or type of knowledge. They tend to concern sciences rather than specific scientific disciplines. Chemistry is not a separate subject in primary schools, but many of those skills will apply there when students eventually have chemistry lessons.

Terminal skills in science [12], in secondary schools, are divided in two general categories: basic sciences and general sciences. Basic sciences are addressed to all students and provide knowledge and skills that

are useful in everyday life, while general sciences are addressed to students who will pursue scientific education.

Skills in basic sciences include general skills and attitudes (intellectual honesty, balance between open-mindedness and scepticism, curiosity and team work) and disciplinary knowledge and skills. The latters have different sets of skills in biology, physics and chemistry: living in the universe (ch: constitution of matter), living on earth (ch: natural cycles of elements, classification of elements, chemical functions, matter cohesion), living in society (ch: reactivity, transformation and use of substances, conversion of chemical energy into electric energy), living in family (ch: common chemical products, security and health, acids, bases and salts, oxidisers and reducers), living with one's body (notions of biochemistry, chemistry and hygiene).

Skills in general sciences are divided between **common skills** to biology, chemistry and physics, and **disciplinary knowledge and skills**. The first category is itself divided between "attitude respecting scientific ethics" (the same four as the general attitude and skills for basic sciences) and "commanding scientific skills" (fundamental concepts, models and principles; conducting a research and using models; using experimental procedures; building a logical reasoning; using communication procedures; solving concrete applications; using the appropriate mathematic and computer tools; using scientific knowledge to enrich interdisciplinary representations; making links between approaches and notions seen in sciences and other courses). All those skills are more detailed in the official text [12]. In chemistry, there are twelve categories of knowledge and skills: 1) constituents of matter; 2) matter at the atomic and molecular scale; 3) periodic classification; 4) the ionic model; 5) matter cohesion; 6) the ideal gas law; 7) solutions; 8) the chemical reactions; 9) elements of thermodynamics and chemical kinetics; 10) main chemical reactions and properties of common substances; 11) notions of organic chemistry; 12) using some common substances. For each set of skills are provided examples of questioning, specific skills and items of knowledge that need to be acquired.

3. Examples of successful experiences

3.1 Digital school

The main focus of the Belgian working group was ICT, and particularly how to use ICT appropriately in class so that it can really motivate students and help them understand the topic (integrating experiments, interactions between students...).

Based on an official survey [13] of the Walloon Region and a European survey of schools [14], it emerged that, in comparison with most European countries, Walloon schools are behind in terms of ICT equipment. This has an influence on teacher's use, but it is not the only factor. The survey pinpoints several measures that should be implemented to improve the situation: 1) developing and improving the network infrastructure, which includes an internet connection for each classroom; 2) raising the number of connected computers. Schools already have many desktop computers so they should be equipped with mobile material (laptop, tablets...); 3) training and assisting teachers to an educational use of ICT. It is indispensable to raise their confidence so that they use ICT in class; 4) creating favourable conditions to command ICT in school. Training "resource people" to provide assistance (not replace!) teachers in the use of ICT and giving those people a status; 5) fostering the creation of digital resources and expertise sharing, for example through call to projects and supports to initiatives; 6) setting up a narrower cooperation between the people active in digital development. Of those measures, the fifth one is particularly relevant to the project activities.

The French-speaking Community of Belgium aims to implement concrete actions to help schools develop information and communication technologies in education. Thus, currently it is possible to present three plans that have been developed.

First, the "Cyberécole" plan from 1999, aimed to provide 20,000 computers to primary and secondary

schools in the Walloon Region.

Then, in 2005, the "Cyberclasse" [15] plan was proposed, aiming this time to provide 40,000 computers to school over several years. Gradually, interactive whiteboards appear, first slowly, but with a will to equip classes constantly better.

Meanwhile, in 2003, the concept of "Passeport TIC" [16] was launched. This "passport" was created from the observation that ICT are increasingly present in homes and schools but that students (and often teachers) do not know how to use them accurately and cannot use them fully. Thus, lessons are proposed to train primary and lower secondary school students to an intelligent and enlightened use of those new tools. Armed with success, this "passport" still exists and, every year, classes can subscribe so that students receive it at the end of the training.

Finally, in 2011, the project "École Numérique" [17] was launched. Based on submitted innovating educational projects, schools receive grants to prepare themselves for the future. Indeed, schools can submit a project to integrate ICT in education proposing ideas on the positive educational impact for the schools.

This initiative – that literally means "Digital School" – comes from several ministers, including the minister of compulsory education. The call for projects includes two axes:

1. an axis "compulsory and continuing education", targeting "projects based on an innovative use of ICT in the educational approach";

2. an axis "educational categories in colleges", targeting future teachers' initial training to implement ICT in their educational approach and to create educational contents and resources.

The selected innovative educational projects will make it possible to:

• test new educational uses supported by ICT in the context of education through skills, as it is carried out in the French-speaking Community of Belgium ("Fédération Wallonie-Bruxelles");

• assess the relevance of using, in the context of education, a large array of technological equipment and digital resources;

• identify factors that guarantee the dissemination of educational uses and technologies on which they are based, and the means to solve possible difficulties, at the level of the French-speaking Community.

The projects submitted by schools are evaluated according to several criteria (originality, innovative aspect, benefits for students' learning, exportability of the project, details of the project, correspondence between the means and the aims). Support and training by experts are provided. The laureates in 2013-2014:

The Walloon minister of new technologies, in charge of upper education in the French-speaking Community and the minister of compulsory education approve the selection of seventy-two schools selected by a jury of experts in the framework of the second call for projects "École numérique". All the projects concern the creation of digital educational sequences on tablet, interactive whiteboard and in network. Two schools involved in the project "Chemistry is All Around" (HELMo and Collège Sainte-Véronique) were selected to carry out sequences in chemistry: "Using the IWB and modelling to complement the experimental approach". This sequence integrates experiments, ICT – with the Interactive Whiteboard – and the systemic approach, as advised by Jean-Luc Piecynsky, one of the experts involved in the "Chemistry is All Around Network" project.

3.2 Experience assessment

When they submit a project to École Numérique, schools also have to complete a descriptive sheet. It contains basic data on the activity (what discipline, audience, length, material that will be used), a description of its different phases and the skills targeted by the activity. These skills are divided between discipline-

specific skills, ICT skills and transversal skills. Teachers or whoever submitted the project are invited to evaluate the activity, although this is apparently not compulsory.

Specifically regarding HELMo, the activity that was tested targeted two families of tasks: to describe, explain a phenomenon or how an object works, to predict the evolution of a phenomenon (FT1) and to carry out an experimental approach (FT2). Those families of tasks each include several skills.

FT1: analysing the phenomenon; identifying the resources; using the resources; producing an explanation or making prevision(s); justifying the explanation or the prevision(s); communicating the explanation or the prevision(s).

FT2: identifying the object of the research; designing and/or conducting an experimental procedure; detecting the main parameters that can influence a phenomenon, and make predictions; designing an experiment; conducting an experiment; analysing the results and drawing conclusions; presenting the experiment in writing or orally.

Those families of tasks are assessed through a task called "science journalist".

4. The Impact of the Project on Successful Experiences

4.1 Workshop

The third national workshop took place on the 26th of February 2014 at HELMo-Sainte-Croix, in Liège. It gathered fifteen participants, including teachers, teacher trainers, future teachers and experts. Regarding successful experiences, the following topics were addressed:

4.1.1 MOOC – Fostering learning in the digital era

Laurent Gruber presented the concept of MOOC (Massive Open Online Courses) to the participants. The digital era changes our relation to knowledge; the teacher is no longer the sole source of information as students can find it on the Internet. MOOC are online platforms that provide courses to a very large audience. There are two general categories of MOOC. xMOOC maintain a passive transmissive approach to knowledge (texts, videos...) while cMOOC connect learners who can teach each other. An increasing number of universities provide courses through MOOC.

Laurent Gruber then presented flipped classrooms, in which students prepare their lessons before seeing them in group in the classroom. This method makes it possible to foster interactions and practice in the classroom, moving away the transmissive part of the lesson.

4.1.2 Examples of new learning sequences

- Discovery of the chemical reaction in flipped classroom through the platform Claroline Connect (for third year students)
- "MOODLE: how can ICT support the investigative approach?" Evaluation of a teaching resource through the platform MOODLE. First year science students at HELMo tested the resource "Discovering the chemical reaction" on the Interactive Whiteboard. This sequence is addressed to third year secondary school students. According to the students (future teachers), there were two main benefits: increasing their knowledge of the subject and learning how to properly use the IWB in a lesson.
- "Evaluation of ICT tools – an experience in England". Jerome Kariger, a third year science student who writes his dissertation [18] on ICT in learning, travelled to Portsmouth in United Kingdom. During an observation internship, he tested a resource with English secondary school students. The resource uses animations presented on the Interactive Whiteboard. He then submitted questionnaires to teachers and students to evaluate the resource. This trip also provided the opportunity to observe the methods and technologies used in English science classes and to compare with the Belgian situation and practices.

Among other, he noted that while English schools are better equipped in computer equipment, English teachers make little use of the interactivity of the IWB, highlighting the need for training to use it. The whole experience is the object of his dissertation, defended in June 2014 and will be presented during the final conference [19] of the "Chemistry is All Around Network" project in October in Genoa. For the purpose of the dissertation, new learning scenarios were also tested in Belgian classes (more about it in section 4.2.4).

- "Working group TIChimiE – Co-building learning scenarios using ICT". The working group TIChimiE gathers teachers and future teachers from different schools in Liège and its province. It is led by Divna Brajkovic, teacher trainer and expert in the project, who presented their results during the workshop. The working group was created thanks to two projects: the European project "Chemistry is All Around Network" and "École Numérique", a Belgian initiative to fund projects that involve ICT in education (see point 3.1). The objective of this group is to create learning scenarios in a triple cooperation: 2nd year science students – internship supervisors – HELMo science teachers. These scenarios foster the investigative approach and integrate ICT. ICT can support the investigative approach at different moments of the process in order to make the transition from the macroscopic to the microscopic level and to symbolic writing easier (see Divna Brajkovic's paper [20]).
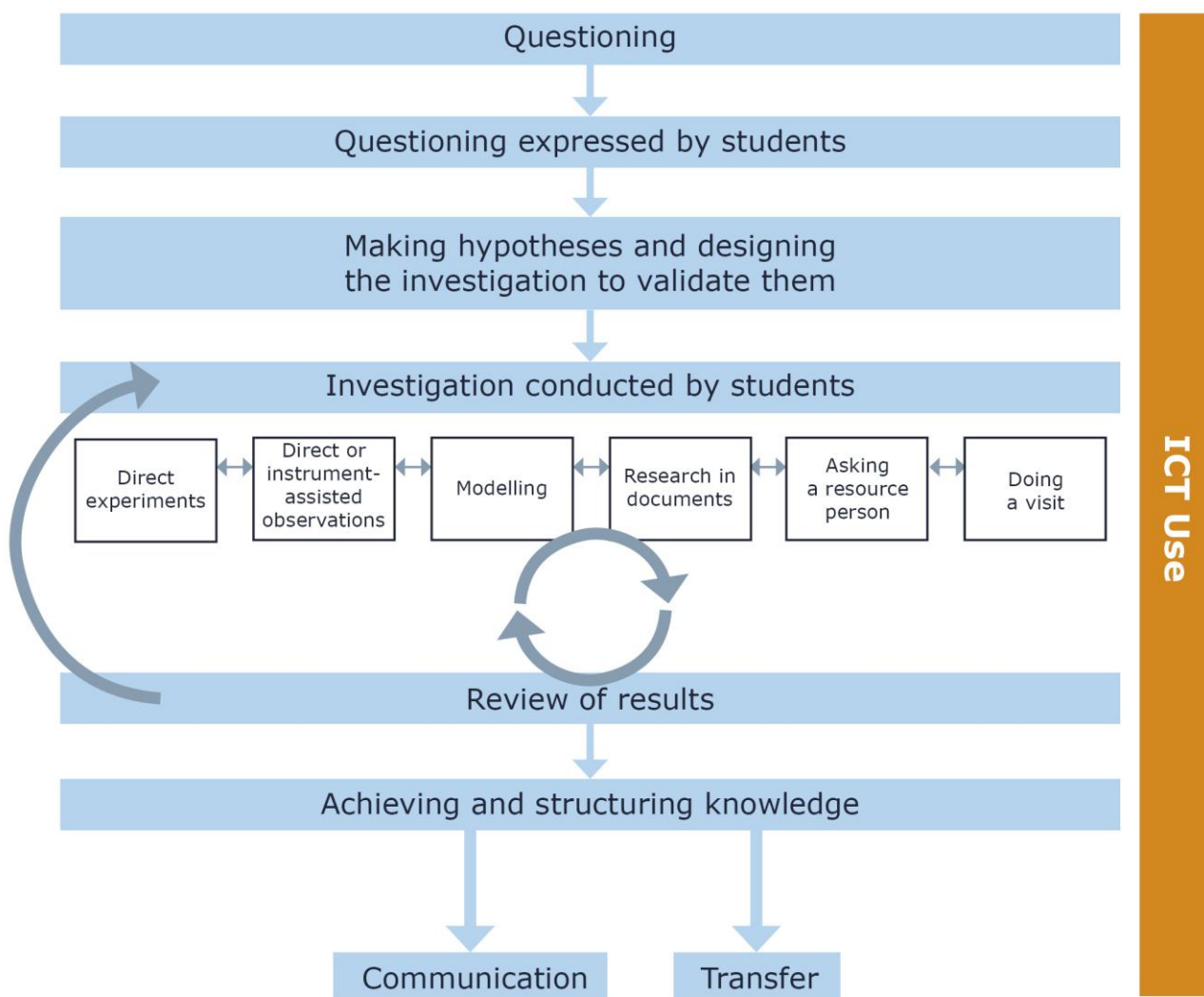
Fig. 1. Diagram showing the integration of ICT in the investigative approach

Four sub-groups work on four topics: "atom models", "photosynthesis", "introduction to chemistry" and "statics – components of forces". The groups work among other on the interactive whiteboard and tablets (received in the framework of the project "École Numérique") and with the technical help of Inforef (which provides training and support).

- "There's carbon, and then there's carbon": a riddle to solve on tablet, presented by Nathalie Matthys. Ms Matthys also showed the website Didac-TIC [21], which contains tools to be used in science classes.

- Implementation of a grid to review the interactivity in the use of the interactive whiteboard, by Tanguy Pironet.

4.2 Testing of ICT

4.2.1 Test with secondary school students

We received feedback from the testing of two resources: "PhET" and "BBC School Science". Those resources were tested at Collège Sainte-Véronique in Liège with 73 students of third, fourth and fifth secondary years (14-17 years old). Those were English immersion classes, which means the students were able to use and evaluate the resources in English.

PhET

This websites contains nearly forty simulations in chemistry (and more in other sciences) freely available online. Each animation ends with a quiz to assess knowledge. Three animations were tested with the students. The topics were: "Balancing chemical equations", "Build an atom" and "Isotopes and Atomic Mass". Thanks to the animations students could better understand chemical concepts through visualisation of the microscopic level and using different approaches. The animations were used to reinforce subjects seen in theoretical lessons. Each student used it on an individual computer but discussions were allowed.

Teacher's feedback

"Students consider it gave them a clear view of chemical concepts and therefore help them better understand these. Most of them felt they would be able to explain the topic to someone else after using the animations. Students were stimulated by the animations. The students took the quiz as a challenge and tried to answer faster than their classmates."

"This website is a great source of teaching material. This approach is innovative as each activity includes an interactive animation, with a recap and a quiz at the end. It can clearly help to understand better as it gives another approach to learning with different types of explanations."

Students' feedback

The resources received positive reviews from the students. Most of them enjoyed using it because of the interactivity. They particularly enjoyed the final quiz. They thought this resource fostered interactions and help them understand. Not all of them considered it more effective than books, because it contains less information, but they at least think it fostered practice. Most students think after using this resource they could explain the subject to another student, including those who felt the resource did not teach them much. Several students noted that, unlike in a lesson or with books, they are not disturbed by their mobile phones while using a computer. This highlights the motivating aspect of ICT resources.

Some quotes

"It's funny to learn because we are playing but we still learn."

"It's like a real course but we are the teacher because we do the job."

"Now, I am implacable on the subject about the atoms because trained to answer all the questions of the game very fast."

"We are easily talking and helping each other, and we can illustrate what we are saying with the website."

BBC School Science

The website proposes six activities; three were tested in class on the following topics: Particle model, Atoms and Elements, Compounds and Mixtures. This resource was tested by the same teacher as PhET, in a third year English immersion class of sixteen students. Unlike with PhET, it was impossible to use the resource individually because of oral explanations in the animations. The resource was therefore projected on an interactive whiteboard and one student was appointed to conduct the lesson in front of the classroom.

Teacher's feedback

"The activities proposed on this website are useful to reinforce what is seen during 'theoretical' lessons. As it gives a different approach, using individual computers, it may raise the interest of some students. I'm not sure that it can help students understand faster but it can clearly help to understand better as it gives another approach with different types of explanations. I think that this approach is innovative as each activity includes an interactive animation, with a recap and a quiz at the end."

Students' feedback

The students enjoyed the interaction but it was limited as only one student had the possibility to run the activity in front of the class. The video recap and final exercises helped them understand better. Most of them felt they could explain the subject to their classmates after using the resource.

4.2.2 Test with future teachers (Liège)

The resource "Discovering the Chemical Reaction" was tested at *Haute École Libre Mosane* (HELMo) in Liège, with twenty-two first year students (future science teachers). It is a learning sequence that favours the experimental and systemic approach of the chemical reaction. Therefore, the activities (laboratory, observations of phenomena, modelling) are organised so as to facilitate a progressive gradation of abstraction levels (from the macroscopic to the microscopic levels). The interactive whiteboard is used as an open and interactive written support all along the sequence. The varied ICT resources integrated on this support makes the modelling of the phenomena, and thus transition to abstraction, easier. Since the resource is addressed to a secondary school audience, those students did not learn much, the focus was on how to use the resource with younger students.

Students could provide their feedback through a questionnaire on the learning platform Moodle. When asked what they learn, most students answered how to use the interactive whiteboard, or further applications of the IWB. While the sequence is addressed to younger students, several students who tested it said it helped them refresh some notions related to the chemical reactions. Students considered the sequence was well organised and stimulating, and could help understand the topic. Those learnings were built especially during the oral presentations in group supported by the IWB. According to them, learning is made easier by experimentation and the use of ICT. Mentioned obstacles to learning concern modelling during hypotheses. Besides, during knowledge consolidation exercises, some students had difficulties to analyse everyday life examples.

Teacher's conclusion

According to those first experimentations, based on a limited number of students, the following temporary conclusions can be drawn:

a) Regarding the creation of learning scenarios integrating ICT:

To foster chemistry learning, learning scenarios should specifically integrate ICT (videos, animations, IWB…) to support the investigative approach for a gradation of abstraction levels. Those learning scenarios would help develop scientific, technical and transversal skills.

In the experimented learning scenario, ICT resources, integrated in the IWB, are mainly used:

- In the beginning during the phases of questioning and common gathering of students' hypotheses,
- At the end for structuration and knowledge consolidation.

However, depending on the topics, ICT can be used at other moments of the process. Without replacing real experimentation, ICT can support the investigative approach at different moments of the process. Indeed, the main asset of ICT to support the investigative approach is the improved analyses of complex dynamic phenomena at the macroscopic level (with videos) and their modelling at the atomic and molecular levels (flash animations or others) to make the transition from the macroscopic to the microscopic level easier.

ICT integrated to the IWB have other assets to support the investigative approach.

b) Regarding the assets of the IWB:

The assets of the IWB are presented in relation to the investigative approach. The four main categories are built on a student-centred educational approach.

The diagram below shows the most specific asset of the IWB, in the centre, interactivity, to which other assets, to be moderated, can be added: information stocking and use; information visualisation; production and creation process; automatic processing of complex information.
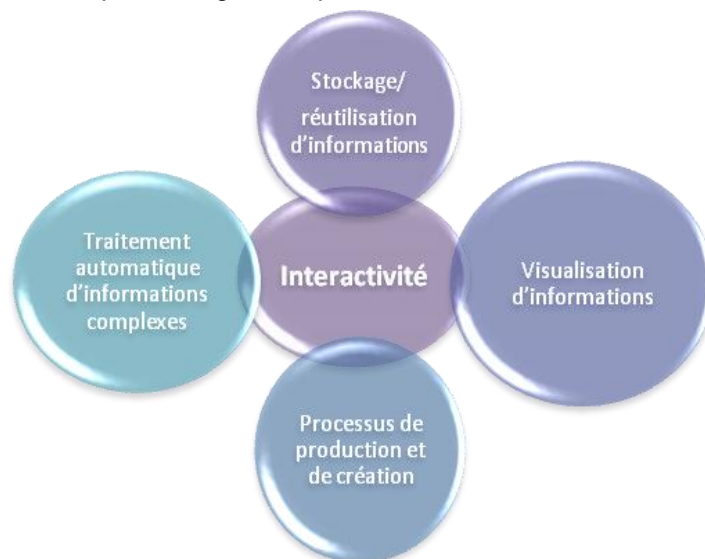

Fig. 2. Assets of the IWB

A detailed description of the testing is available on the project portal [22].

4.2.3 Test with future teachers (Louvain)

Four resources were tested, three of them from the project portal: "Chromatography of Colorants Used in Medicines", "Ionic compound dissolution" and "PCCL". They were used at *École Normale Catholique du Brabant Wallon* (ENBW-Vinci) in Louvain-la-Neuve, in a second year class with future science teachers.

Chromatography of colorants used in medicine

The learning objectives of this experience were the following: preparing a chromatography, practicing the scientific method and showing a chromatography. The exercise was carried out by small groups on a computer than shown in the classroom with an interactive whiteboard.

<u>Teachers' feedback</u>

The resource is a good way to test the exercises after a laboratory session.

<u>Students' feedback</u>

Students had mixed feeling about this resource as it contains many data, some of them too advanced, but they all liked the presence of a periodic table of elements.

Ionic compound dissolution

The objective of this exercise was to view what happens at the microscopic level during a dissolution and therefore better understand the phenomenon. It was used after a laboratory session.

<u>Teachers' feedback</u>

The animation is relevant and scientifically accurate, but needs to be used correctly by the teacher or students will just watch an animation without doing anything.

<u>Students' feedback</u>

The animation is clear and helps understand the phenomenon, but the teacher needs to present it to foster interactions between students, otherwise it is too passive.

PPCL (Physics and Chemistry by a Clear learning)

This resource makes it possible to visualise molecules thanks to 3D modelling. It was used to compare a Lewis structure and the geometry of molecules.

<u>Teachers' feedback</u>

It provides a good visualisation of the geometry of molecules. It respects the colour convention and relative size of the different atoms.

<u>Students' feedback</u>

Students can use the programme to draw structures and manipulate 3D atoms. It helps understand the concept, but does not foster interactions between students.

4.2.4 New learning scenarios (Liège)

Fort the purpose of his dissertation [18], Jérôme Kariger created three learning sequences on the following subject: metals and nonmetals; ions, anions and cations; molecular formula. They were tested in a third year class (14-15 year old students) in a secondary school near Liège. One of the purposes of the sequences is to use the IWB with all its functionalities, especially its interactivity. Two questionnaires were used to assess the sequence: one to assess the whole sequence trying to identify the moment that contributed most to their learning. The students thus completed three such questionnaires (one per sequence), and one to assess a specific animation and whether it helps understand the targeted concepts. This questionnaire is adapted from the WP2.C questionnaire. The students completed four such questionnaires (one per animation). The evaluation showed that a large majority of students are motivated by the use of the IWB.
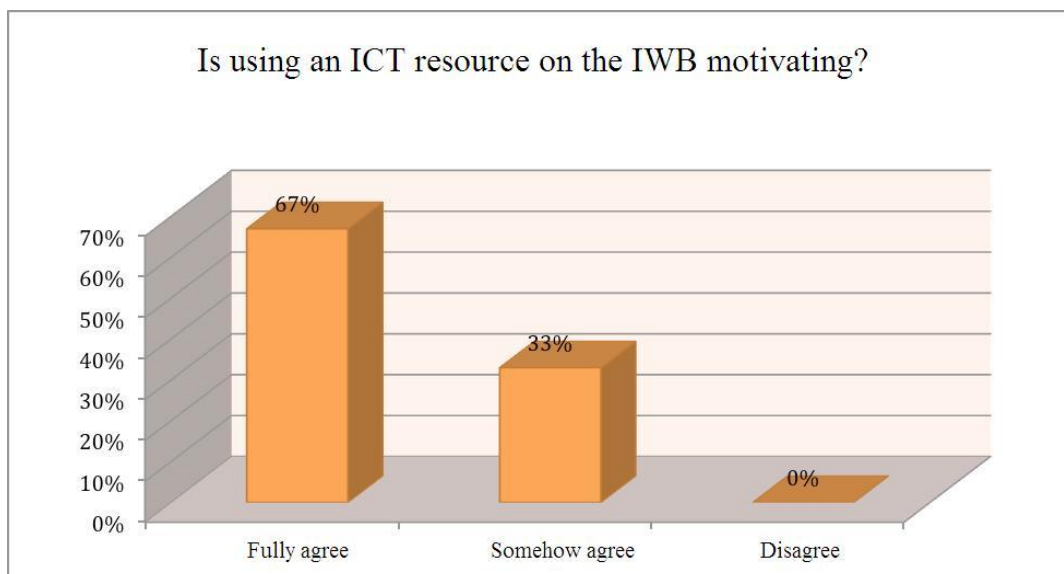
Fig.3. The IWB and students' motivation

5. Conclusions

While Wallonia is still below the European average in terms of ICT equipment in schools, recent surveys showed there were some improvements. This is good news as the different experiences carried out the last couple of years in the framework of this project have shown that, when they are used correctly, ICT tools help students understand chemical concepts that are not always easy to grasp (seeing what happens at the microscopic level). Moreover, they are a major motivation tool for young people who have been all their life surrounded by computers and mobile devices. However, ICT cannot replace the teacher or experiments, nor should they be used as a mere accessory. Our teachers' most significant experiences consisted in whole lesson sequences that associated students' questioning, experiments, concrete modelling with objects and virtual modelling. Students were brought to ask questions, carry out scientific methods, use their imagination while animations helped them understand the notion providing a dynamic visualisation of the phenomenon studied. Through the involvement of future teachers in the testing, we hope to extend and develop those innovative practices.

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