UNIVERSITÀ DEGLI STUDI DI CAMERINO

School of Advanced Studies

DOCTORAL COURSE IN

CHEMICAL SCIENCES

XXXII cycle

NEW APPROACHES TO THE TEACHING AND LEARNING OF CHEMISTRY AT DIFFERENT EDUCATIONAL LEVELS

PhD Student

Chiara Schettini

Supervisors

Prof. Rossana Galassi

Prof. Silvia Zamponi

"Cercai di spiegargli che la nobiltà dell'Uomo, acquisita in cento secoli di prove e di errori, era consistita nel farsi signore della materia, e che io mi ero iscritto a Chimica perché a questa nobiltà mi volevo mantenere fedele.
Che vincere la materia è comprenderla, e comprendere la materia è necessario per comprendere l'universo e noi stessi: e che quindi il Sistema Periodico di Mendeleev, era una poesia, più alta e più solenne di tutte le poesie digerite al liceo.
A pensarci bene, aveva perfino le rime!"

[Primo Levi, Il sistema periodico, Giulio Einaudi Editore, 1975]

Acknowledgements

This study is the capstone experience of the very special years I have spent in my doctoral program at the University of Camerino. First, I am extremely grateful for my supervisor, Prof. Rossana Galassi, who provided me with expertise and guidance and constant support over these three years. I have appreciated all her contributions of knowledge, time and new ideas to make productive and enriching my PhD experience. I am also grateful for my tutor, Prof. Silvia Zamponi, which first believed in my research project and constantly supported me.

My sincere thanks also go to PhD Dr. Daniela Amendola of the E-learning Office of UNICAM, together with Dr. Giacomo Nalli, who provided me constant support over these three years in implementing, analyzing and discussing all the digital tools and activities included in my research.

A special thanks to PhD Dr. Michela Quadrini and to Dr. Ido Borsini, School of Advanced Studies of the University of Camerino, for their important support with the statistical elaboration and analysis of data.

This period has been a unique opportunity for my professional growth, to deepen educational issues and to meet and collate with realities and experiences in other countries. A special thanks to Prof. Silvija Markic of the University of Ludwigsburg whose guide during my traineeship was essential to enrich my knowledge of chemistry education, and to my PhD mates, Dr. Julian Küsel and Dr. Lilith Rüschenpöhler, for the possibility of sharing our ideas and point of views.

Thanks to the high school teachers, Nadia Bianchi, Donatella Bussoletti, Clara de Martino Rosaroll, Loredana Locci, Tiziana Pirani and Gabriella Russo, who trusted me and generously participated to the application of the 5ELFA model with their students, and to my doctoral colleague, Immacolata Ercolino, who always encouraged me in pursuing my purposes.

Finally, a special thanks to the most important people of my life, my family, Gerri, Germana, Gianmaria, Daniele e Giuliana, for sustaining my effort with love and patience and for being so smart in discussing my doubts. I hope all of you, and especially my loving and supportive husband Gerri, will realize I would not have been able to accomplish this endeavor without you.

Thank you all.

Abstract

The main purpose of this study is to evaluate the impact of the introduction of new methods on the teaching and learning of chemistry in different educational contexts. The key points of this research lie first in the design and then in the assessment stage of the didactic proposals following their implementation in terms of their impact on students' and teachers' perceptions of their approach to learning and teaching, respectively.

The research explores different learning contexts of chemistry education, starting from the didactics of chemistry addressed to high school students, then concerning the training of high school science teachers, till the development of a suitable method of study and problem solving skills in first year students of a general and inorganic chemistry academic course. Some of the studies were realized in the framework of Piano Lauree Scientifiche whose activities have been contributing for several years to bring the academic world closer to school's needs, with the common aim to motivate students to scientific careers.

In this perspective, the complex task of identifying and measuring the efficacy of these strategies and its impact was described in detail.

The choice to undertake this direction was suggested by different factors.

The first factor is that, as shown by national and international studies, most students lack basic knowledge regarding general chemical concepts and principles, both at high school level and even in the early university years. The inadequate skills in acquiring the required content knowledge are a deterrent for students wishing to join a university chemistry course or they could hinder their academic success. However, research studies show a wide range of pedagogical strategies whose results have variously contributed to an increased understanding of the learning process in chemistry and, consequently, to more effective methods of instruction. For these targets, high school students and freshmen, some suitable strategies were identified and adopted in this study and its impact analyzed with quantitative and qualitative methods.

The second factor is teachers' increasing need for implementing new instructional strategies that can be motivating and lead students to acquire not only disciplinary knowledge, but even transversal skills, as a suitable method of study or the ability to design an experiment. This implies more training needs to be provided with the aim to encourage and support teachers to develop new teaching conceptions and

practices. A line of research of the present study addressed these teachers' demands, using a variety of tools and training strategies and analyzing teachers' opinions and general satisfaction.

The third factor is the recognition of the current impact of ICT on both teaching and learning Chemistry at all levels of education. Computer simulations, online resources and freeware programs can help students in better understanding chemical concepts and even develop problem solving skills. On the other hand, instruction in blended modality, integrating online and face-to-face activities, is nowadays widespread, as in the Flipped Classroom methodology, and adopted even for teachers' training. Furthermore, most of the teachers lack the technical and pedagogical skills to effectively incorporate the use of digital tools to enhance learning and therefore need a help to move from simply technology users to developers of learning units including ICT tools. In three of the four lines of this study, digital tools and blended learning approaches were adopted and their efficacy on users' learning outcomes and general satisfaction analyzed and reported with qualitative and quantitative methods.

The entire PhD project provided information that can contribute to a body of knowledge for the improvement of instruction in chemistry classroom and provided quantitative data to validate the benefits of new approaches on chemistry learning outcomes and motivation to study. My point of view developed in this training, being a high school teacher and researcher during my PhD study, provides me the capacity to capture several issues and the big picture.

This thesis includes a general introduction, reporting the barriers to learning Chemistry in the considered educational contexts, the drivers for change and the needs of innovation for teaching and learning Chemistry and four chapters, each one describing a line of research, as synthetically described below.

A Learning by doing laboratory based on Johnstone's model: a motivating approach to Chemistry for High School students

Since 2012 the UNICAM Chemistry Department, in the framework of PLS, has been organizing a day long general chemistry laboratory for 4th year high school students. Five laboratory experiments, directly performed by students, concerned mainly the knowledge of the characteristics of different chemical reactions and a "learning by doing" approach, were proposed. This hands-on approach to learning directly exposed students to the experimental context, minimizing the acquisition of theoretical information, before and during the laboratory, and emphasizing students' interaction with their environment in order to adapt and learn.

In previous years, survey questionnaires were addressed to students and teachers, detecting students' high liking score and a general appreciation of the teachers.

To evaluate the impact of this laboratory even on students' knowledge acquisition and skills acquired during the experiments performed, I analyzed the results of the same multi-answers questionnaire, administered before and after the laboratory, by applying dedicated Excel functions. On the whole, the analysis of the data showed a significant increase (+20%) in the number of correct answers to the various questions of the test and therefore it appeared to confirm, in educational terms, the validity of the procedure.

A further analysis on the individual questions was carried out to investigate which chemistry topics knowledge were reinforced after the laboratory and in which areas there were lower results.

Results of this pilot study gave some suggestions for further implementation and the rather poor connection between the three levels of Johnstone´s triangle both in the experiments' presentation materials and in tests was identified as a criticism. Following the indications of Prof. Silvija Markic, Supervisor of the traineeship carried out at the Institute for Science and Technology - Chemistry Education of the Ludwigsburg University of Education (Germany), the way in which both the activities and the evaluation test should be redesigned, presenting more closer the link between the three levels, was then discussed and planned.

The further aims of the research will be to redesign the activities, utilising the foreseen tools, to provide adequate scaffolding materials and to reformulate the test, according with the identified issues.

A blended learning approach for in-service teachers training based on online Moodle platform

Concurrently with the activities for students, since 2006 UNICAM has been holding residential training courses addressed to in-service high school science teachers, as part of the framework of PLS project. Meeting the demands for the implementation of digital media in education, the CLIL requirements, and for an overall improvement of the laboratory feasibility, "The online chemical experiments:

Instructions for use" in blended mode has been run since 2016, offering teachers both face-to-face classes and online activities, hosted on a dedicated e-learning Moodle platform.

The course was planned with a bottom-up approach, refreshing some disciplinary issues and adopting the tetrahedral model of Mahaffy for the presentation of Chemistry topics. Then the implementation of multimedia tools followed, thus providing original materials (video of experiments, interactive exercises and problem solving, self-assessment tests) with the purposes of stimulating teachers to effectively incorporate the use of laboratory practice and digital tools to enhance students' learning.

Aims of my research in this field were: (i) to investigate through a survey questionnaire teachers' opinion about the different tools and teaching methodologies proposed and (ii) to promote their active use in the classroom, helping teachers to become developers of learning units aimed to motivate students to the study of chemistry, introducing real-life contexts.

Regarding the first objective, a survey questionnaire was administered in the first edition of the course whose results showed the teachers' positive ratings on the blended training and on the quality and usefulness of digital materials.

In order to promote the best practices acquired, during the first edition of the course (2016-17 S.Y.) two teachers were involved in an action research on the application of the 5ELFA (Flipped Classroom Approach Based on the 5E Learning Cycle Model) to the study of the reactivity of metals, addressed to a group of 38 students, aged 15-17 years.

The analysis and discussion of the action research results provided the basis for a following pilot study that was carried out in the 2018-2019 S.Y, which represents another point of my research and it is reported below.

In the second edition, the didactic structure of the teachers' course was slightly modified to make teachers participate more actively: they were asked to design and implement a Chemistry unit by their own to be experimented with their students, using the digital tools, the furnished materials and the new methodologies studied in the course. A rigorous evaluation of teachers' works was set up with a specific rubric. Nonetheless, also in this edition, general satisfaction and appreciation were recorded by the survey questionnaire

Further implementation of this research will concern the promotion of collaborative activities among group of teachers in the Moodle learning context and the development of instruments to support teachers' design of their own units.

An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology

The analysis and discussion of the previous teachers' action research results provided the basis for a new research activity, consisting of a pilot study that was carried out in the 2018-2019 S.Y., involving 150 students of three Italian high schools, and 6 teachers, previously trained through an online training course.

First aim of the research was the evaluation of the efficacy of the learning unit affording the reactivity of the metals on:

- students' acquisition of chemistry knowledge,
- ability to design an experiment.

The topic was chosen because it is included in all the chemistry curricula, it allows connections with real-life examples, increasing students' interest to chemistry study, and allows the implementation of laboratory activities, suitable for the high school context and familiar to teachers too.

The design of the learning unit was based on the 5ELFA model, that is a didactic approach integrating the inquiry method's characteristics with the Flipped Classroom methodology that allows the experimentation of a virtual laboratory and frees up time in the classroom for investigating activities.

Moreover, the integration of the two methodologies allows to select the best features of each of them, with the aim of designing activities leading to better results regarding learning outcomes and needed time for their application. As a matter of fact, this latter aspect is often reported by teachers as a critical point for a full application of innovative methodologies as Inquiry. The articulated didactic sequence was adopted to stimulate students in the acquisition of skills which make them active in the design of the experiments and in the interpretation of data, enhancing their problem solving ability as well.

The research was carried on with a quasi-experimental research design, the "One-Group Pretest-Posttest Design, a kind of experimental research in which a single group of research participants or subjects is pretested, given some treatment or independent variable manipulation, then post tested.

The comparison between the results of the pre-test and post-test administered to the students, realised by a statistical analysis, showed a positive increase in both the

acquired knowledge and the design skills of an experiment.
The monitoring of the research was then carried out with survey questionnaires administered to teachers and students who expressed a widely positive opinion on the usefulness and adequacy of the activities implemented with the new methodology, highlighting the critical points and strengths.
Further implementation of this research concerns the extension of the pilot study to a larger sample of students and the adoption of "Pretest-Posttest Control Group Design" with two groups of subjects used, both groups being measured or observed twice, but only one receiving the experimental treatment while the other does not.

A blended learning approach to general chemistry modules inspired to Johnstone's triangle for first year academic students

To conclude the multi-target path, following an imaginary thread of education in chemistry, the research was then addressed to first year students of general and inorganic chemistry course of Biosciences and Biotechnology and Geological, Natural and Environmental Sciences degree courses of UNICAM.
This kind of academic course represents freshmen's first impact with the demands for a deepest chemistry knowledge acquisition and for an appropriate method of study, involving problem solving skills. On the other hand, a rough analysis of students' performances at the mid-term test and at the final exam of the last ten years (2006-2016) highlighted a superficial knowledge of the chemistry topics covered and, above all, difficulties in critical thinking and problem solving skills, even more evident in the resolution of stoichiometric problems.
Aiming at supporting students' learning process in these areas, an online tutorial chemistry course was designed and made available on UNICAM Moodle platform. The topics, grouped into seven modules, were mostly about Stoichiometry with the main goal of revision in order to fill possible knowledge gaps and to foster adequate problem solving strategies. Each module was structured, using interactive tools of the e-learning environment, following Johnstone's triangle indications, allowing students to shift along the three levels.
The research concerned the evaluation of the impact of the course on students' performance (i.e. mid-term exam's scores, successful students' percentage per each year), collected and analyzes through qualitative and quantitative methods, comparing three academic years. As a matter of fact, in A.Y. 2016-2017, the

students did not have at their disposal the e-learning online course, in 2017-18 the Moodle course was first implemented and finally in A.Y. 2018/2019 fully adopted. Apart a general students' satisfaction perceived by the answers to a survey questionnaire, the analysis of the data shows **an increase of 11 %** of students passing the final exam within three exam sessions and an improvement and a positive correlation between the time spent on the platform and the mid-term scores achieved and also a large propensity for self-evaluation during the course time.

The indisputable analytical results of this last research activity clearly underline the usefulness of a customizable opportunity of tutoring and put the basis for new approaches in the teaching of chemistry in a first year academic context. In fact, it is becoming always more demanding the need to cover the often inadequate knowledge and skills of the yearly pools of freshmen, mainly concerning not only problem solving and self-evaluation skills improvement, but also the early adoption of a rigorous method of study. Thus, an extension of the application of the blended course herein proposed might be the future development of this research.

Table of Contents

Appendices

List of Tables

List of Figures

Abbreviations

5ELFA	Flipped Classroom Approach Based on the 5E Learning Cycle
ANOVA	Analysis of variance
A.Y.	Academic Year
CLIL	Content and language integrated learning
DCK	Disciplinary Content Knowledge
EACEA	Education, Audiovisual and Culture Executive Agency
ESERA	European Science Education Research Association
EU	European Union
FC	Flipped Classroom
IBSE	Inquiry Based Science Education
ICT	Information and communication technology
ISS	Insegnare Scienze Sperimentali (Teaching Experimental Sciences)
LL	Linguistic Lyceum
MIUR	Italian Ministry of Education, University and Research
OCDE	Organisation de cooperation et de development économiques
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
PLS	Piano Nazionale Lauree Scientifiche (National Scientific Degrees Plan)
SL	Scientific Lyceum
SLOSA	Scientific Lyceum Option Applied Sciences (Opzione Scienze Applicate)
STEM	Science, Technology, Engineering and Mathematics
S.Y.	School Year
TALIS	Teaching and Learning International Survey
UNICAM	University of Camerino

Chapter 1: Introduction

In this introduction, some of the barriers to learning Chemistry in the educational contexts of High school and first year academic courses are briefly analyzed, then the drivers for change, both socio-economic and institutional, that make necessary a new teaching approach to STEM (Science, Technology, Engineering and Mathematics) disciplines are considered.

Afterwards, the needs of innovation for teaching and learning Chemistry, already identified as priority in the literature and more suitable to our targets, are synthetically reported.

1.1 Barriers to learning Chemistry

Chemistry is a complex discipline and some difficulties linked to its effective learning are precisely due to the complexity of its structure.

Indeed, matter can be observed and studied at macroscopic level, but also described at the sub-microscopic level. Furthermore, chemists represent both macroscopic and sub-microscopic levels through chemical symbols, chemical formulas and chemical equations. As indicated by Johnstone in his studies, now being a milestone of educational research in Chemistry, it is precisely the threefold manner of representing matter, as indicated in figure 1.1, that makes learning Chemistry difficult. A further cognitive obstacle is related to the frequent use of symbols, formulas and mathematical equations, formally representing the relationship between the macro and the sub-micro levels (Johnstone, 1991).

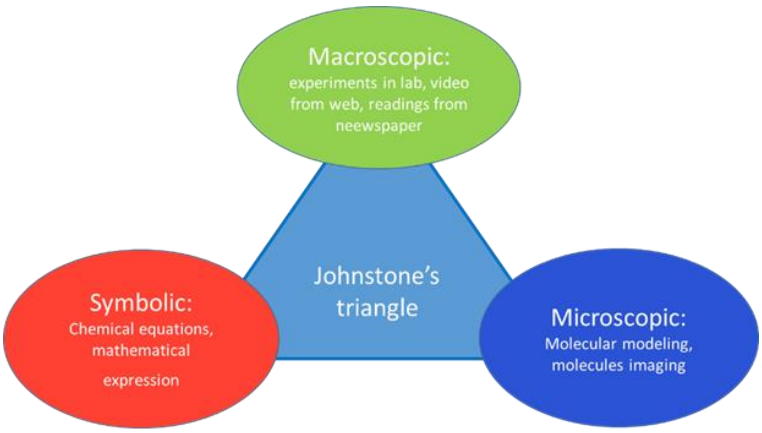


Figure 1.1: The Johnstone's triangle

However, the first barrier to understanding chemistry is not the existence of the three levels of representation, but the fact that chemistry teaching occurs predominantly at the symbolic level, the most abstract, without teachers' awareness of the need to address them in different times, according to the age of students or to their prior knowledge (Ghibaudi,2016).Furthermore, students should be able to associate models or analogies to the particles, in order to represent and fully understand the sub-microscopic level and to connect it to the symbolic level. On this point, it is still an unresolved issue in education the age level at which molecular models become comprehensible and which type of instruction is the most effective for understanding them (Gabel, 1999).

The Johnstone's triangle helps also teachers to understand students' misconceptions occurring at all three levels. Education research on the misconceptions present in students of all levels and related to almost all Chemistry topics, has played an important role in the last 20 years, as evidenced by numerous reviews, highlighting how misconceptions are related both to the complex nature of the discipline and to the way it is taught (Krajcik ,1991;Wandersee ,Mintzes and Novak,1994;Stavy , 1991; Kind, 2004).

Most teachers are unaware of the presence of such misconceptions and/or don't use strategies to counteract them in instruction (Krajcik,1991; Wandersee, Mintzes and Novak, 1994; Stavy , 1991; Taber , 2002). As a matter of fact, besides the cognitive obstacles due to the nature of the discipline itself, many learning difficulties are caused by the persistence of teacher-centred methods that do not consider the new models elaborated in the research in psychology, in example about how students learn, like the Information Processing Model, (Johnstone, 1997).

Moreover, both in books and lessons, chemistry is still taught with a strong emphasis on the symbolic level and at an abstract and decontextualized degree, far from students' reality.

Even laboratory activities are often proposed in a traditional manner, "recipe- book" style, which do not develop inquiry and problem solving skills in students, asking them to interpret at a sub-microscopic level what they observed macroscopically, without providing adequate scaffolding (Johnstone, 1991).

Moreover, this type of laboratory, though helpful in developing students' manual skills, do little to stimulate cognitive activity or to challenge their curiosity and it is unlikely to lead students to fully understand the role of experimentation in science

(Eilks and Byers,2010).

1.2 Drivers for change

In the last decade, many pressures have been given to change science education in general, and namely chemistry.
Drivers for change includes the use of information and communication technology (ICT) in teaching chemistry at all levels of education that has expanded rapidly over the past decade, resulting in the development of an educational research on the methods and evaluation of the new technologies approaches, in particular blended learning and tools such as online lecture support, quizzes and virtual learning environments (Brouwer and Mc Donnell , 2009).
The European Union's training policies, expressed in the Lisbon Strategy first and in Europe 2020 then, represent important institutional drivers for change with the general objective of promoting the development of a Europe-wide knowledge-based economy and, related to our context, with the specific objective, of increasing the number of graduates in mathematics, science and technology (increase by at least 15% and at the same time reduction of the imbalance between the sexes; Alulli , 2010).
In the field of school education, the Rocard Report " Science education TODAY: a renewed education for the future of Europe", published on 17 June 2007 by the European Commission, underlined the need for the transition from a deductive method to an inductive one in the teaching of Sciences and therefore the implementation of teaching strategies based on the investigation, such as IBSE (Inquiry Based Science Education), to increase the interest and motivation to the study of scientific disciplines. An essential prerequisite for this goal is the training of educators on these methods and the development of teachers' professional networks.
In the field of higher education, the 1999 Bologna Process has set as its objective the promotion of the European system of higher education on a global scale to increase its international competitiveness and then requiring transparency within and comparability between degree courses throughout the EU to facilitate graduate mobility. The proposed credits system, known as ECTS (European credit transfer

and accumulation system), promotes a shift from teaching to learning in university education. In this way, the Bologna Process emphasizes students' learning outcomes and modern pedagogical methodologies, including active learning (Pinto, 2010).

1.2.1 The Italian context

In the teaching of chemistry in the Italian secondary schools, an approach based on superficial factual knowledge is still prevalent and centered on the theoretical study of models or on the numerical solution of problems, with little space for laboratory practice and for the use of innovative methodologies such as problem solving and inquiry (Domenici, 2018).

Numerous and subject of debate (Olmi 2014, Borsese 2016), the reasons behind a teaching method of chemistry, and of science in general, based on a traditional and almost exclusively transmissive type:

- very few hours per week (from two in classic and linguistic Lyceums and in the first two years of technical and professional Institutes to three in scientific Lyceum) are dedicated to science programs, not enough for a science education by active learning approaches, with the only exception of the scientific Lyceum "applied sciences option " classes (up to 5 hours per week);
- laboratory activities are not mandatory and often the chemistry lab is generally absent or less used;
- inadequate teachers training, both in-service and pre-service, with an initial training based mainly on the acquisition of disciplinary contents, without enough attention to the didactic aspects (Duranti and Olmi, 2015) is generally provided. In addition, although educational research is crucial to develop a proficient teacher training (Eurydice report, 2016), pedagogical research in the field of experimental science occurs only in a few Italian universities.

The most recent ministry guidelines (DPR 87, 88, 89/2010; Law number 107/2015 *"Buona Scuola"*), explicitly referred to international researches and European documents, ask teachers to move from teacher-centered to student-centered instruction.

In particular, the *National Indications* of Gelmini Reform (Law n. 169 of 30 October 2008), suggest the use of innovative teaching methods in the teaching of Science, also with the use of new technologies, , with the aim of filling the gap between our students and their peers in other industrialized countries.

As a matter of fact, the results of the most recent PISA survey (a triennial international survey developed on initiative of OECD and aimed to compare education systems worldwide through evaluation of skills and knowledge in 15-year-old students), carried out in 2018 and involving over half a million students in 80 countries, showed that the Italian students' science literacy scores were lower than the OECD average (468 points, compared to an average of 489 points), ranking 39th compared to all the participant countries[1].

In recent years, some institutional initiatives have been launched to improve the teaching and learning of science in first and second grade secondary schools, such as the three-year National Project "Insegnare Scienze Sperimentali" (Teaching Experimental Sciences"-ISS)[2], launched in 2006, and "Piano Nazionale Lauree Scientifiche" ("National Plan of Scientific Degrees" -PLS) [3], which since 2004 aims to increase the number of students enrolled in scientific degree courses. Despite these institutional efforts, supported by methodological indications for a more effective teaching and learning of chemistry proposed by Italian researchers who were well aware of the critical issues of our school system (Roletto, 2005, Fiorentini et al., 2007), there is a long road to actually innovate the Italian school and overcome what it can be defined as a real emergency in science education in Italy.

1.3 Needs for innovation in the teaching and learning of Chemistry

1.3.1 Progressing from a teacher-centred instruction towards student-centred learning

First of all, it is increasingly necessary to move from an education based on the simple transfer of information, teacher-centred, to a constructivist, student-centred learning. In fact, information can be transferred, but meaning and understanding can only be constructed in the mind of each individual learner (Wittrock, 1989), in agreement with the principles of constructivist learning theory (Coll and Taylor,

[1] https://www.invalsiopen.it/risultati-ocse-pisa-2018
[2] https://archivio.pubblica.istruzione.it/docenti/allegati/piano_iss_06.pdf
[3] https://www.pianolaureescientifiche.it/

2001; Bailey and Garratt, 2002). The learning process is certainly more complex than merely listening, memorizing and reproducing and even the most motivated or dedicated student may lack the necessary cognitive or transversal skills or the needed previous knowledge to acquire new information (Bodner, 1986).

As a matter of fact, the way in which students learn chemistry can be outlined according to the already mentioned Information Processing model (figure 1.2):

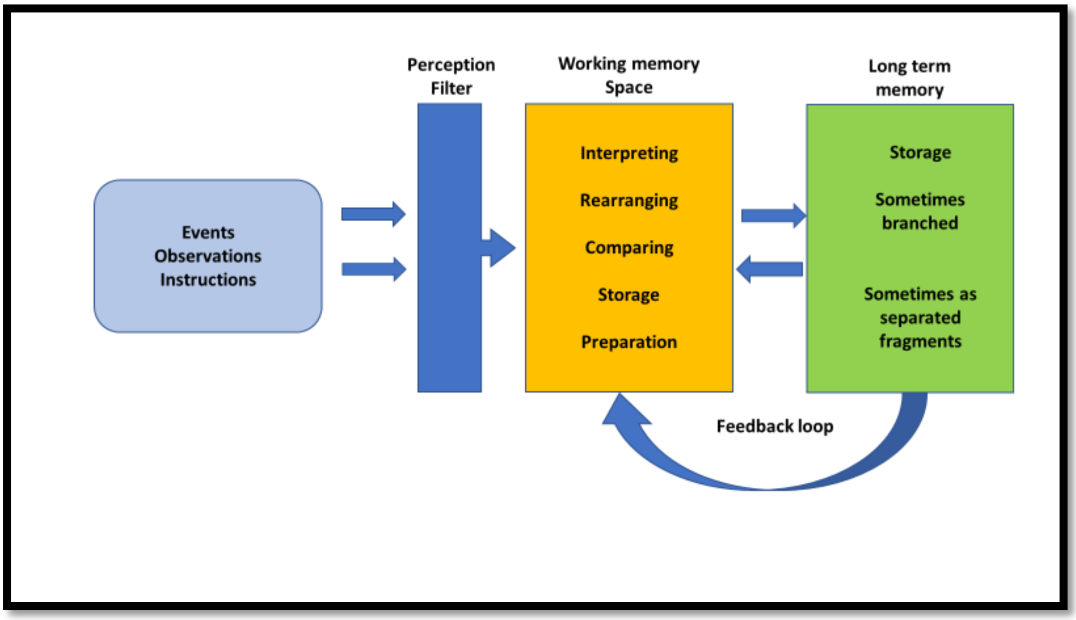


Figure 1.2: The Information Processing Model (after Johnstone, 1997)

New information from the senses enters the short-term memory, which has a limited capacity, and can be lost or transferred to the long-term memory, based on its complexity and on the space available in the short-term memory. Information that passes into the long-term memory interacts with information already present in a network that is expanding or remains as an isolated fragment.

As evidenced by Ausubel (1968), the pre-existing knowledge in student's mind represents the necessary basis for activating the learning of further knowledge and must therefore be well known to the teacher. Learning a new idea becomes significant for the student, that is functional to the explanation of his reality, only if it allows the integration of new information with those already held and the use of it in different contexts, developing problem-solving, meta–reflection, critical thinking, so transforming knowledge into real skills.

The misconceptions, the spontaneous ideas or the ones built wrongly in previous educational experiences that students possess about natural phenomena, are cognitive obstacles that the teacher must unearth and that are difficult to change through a transmissive model of teaching (Fensham et al., 1994).

In high school learning contexts, meaningful learning is realized if the new concepts, often abstract, are connected to experiences familiar to the students and therefore linked to the macroscopic world or to analogies with concepts they already possessed.

In a constructivist sequence, indeed, the students are initially motivated to learn by proposing them practical activities or real-life examples, bringing out any students' misconceptions on the subject (*orientation phase*). Subsequently, students explicit their ideas about the phenomenon studied, comparing them and discussing them even in small groups with their classmates (*explication of ideas*). Then a series of further clarifying experiences is proposed (*restructuring of ideas*) and students are given the opportunity to apply new knowledge in familiar or new situations (*application phase*). At the end of the sequence, the students are encouraged by the teacher to take note of the transformations undergone by the ideas initially possessed (*critical analysis of changing ideas*). In this restructuring of teaching / learning process, the role of the teacher changes substantially, from a concepts' dispenser to a promoter and facilitator of a set of experiences that allow meaningful learning (Bargellini,1998).

As learning is an active process, learning environments are needed that allow for and provoke activity (Bodner,1986). Moreover, it is important to stimulate discussion between students, according with social constructivism theory that states that the construction of knowledge takes place inside the socio-cultural context in which the individual acts, considering learning as a process of construction of meanings negotiated with the others (Driver and Oldham, 1986).

Recent educational research in chemistry has therefore identified different approaches that can promote active learning, based on problem solving, such as Inquiry (Anderson, 2007), Problem based learning (Kelly and Finlayson, 2007) and Learning by doing (Shank, Berman and Macpherson, 1999).

The information processing model and the social constructivism theory together can produce a significant learning of chemical concepts, both at school and university level, and thus both must be considered in the design of the educational activities in which learning is a collaborative achievement where students help each other.

1.3.2 Using authentic learning contexts: from Johnstone's triangle to Mahaffy's tetrahedron

In addition to the ones already outlined, a further driver for changing chemistry teaching is given by external forces, such as global concerns on energy, climate and water and by the need to raise scientific literacy and the limited or incorrect public understanding of the role of chemistry in everyday life.

Mahaffy's tetrahedron is an effective visual metaphor that includes these instances by expanding Johnstone's triangle (Mahaffy, 2004). As already illustrated, the introduction of the three levels of the Johnstone triangle has become a fairly common practice in school curricula and university degree courses, at least in the Anglo-Saxon countries, helping instructors and curriculum developers to pay attention to all three levels of understanding, rather than working almost exclusively at the symbolic level (Mahaffy , 2006).

In the tetrahedron, Mahaffy adds a fourth dimension which he calls the human element, expressing the need to allocate chemistry and its representations in the authentic social and economic contexts where students live and in which chemistry influences citizens and communities (Figure 1.3).

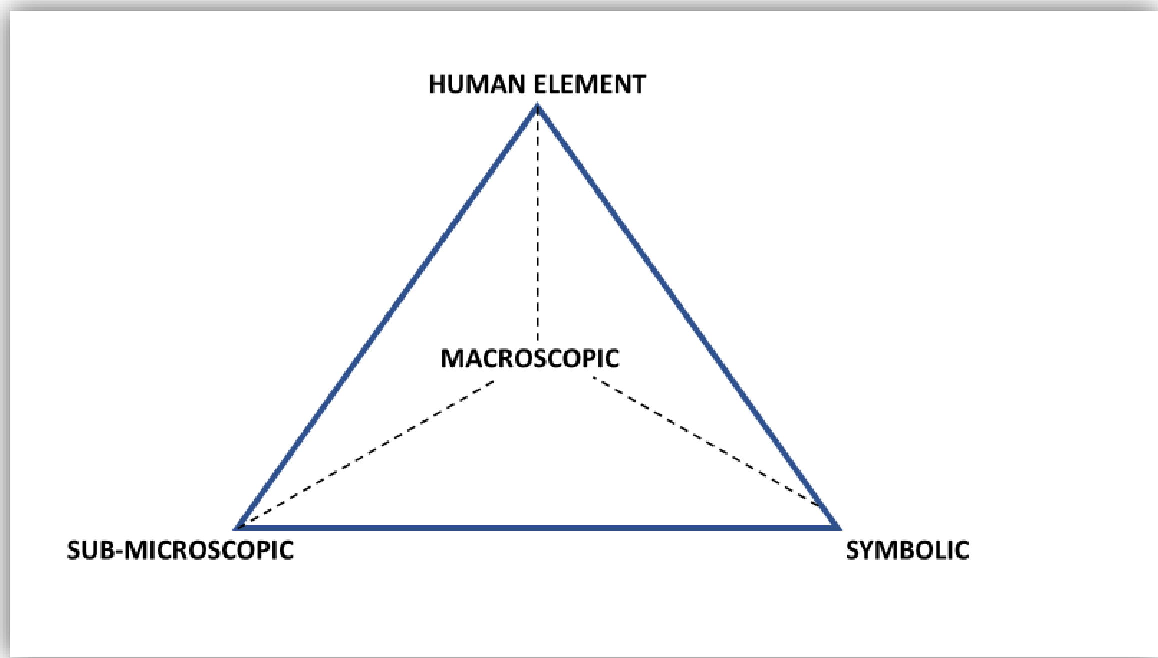


Figure 1.3: The Mahaffy’s tetrahedral metaphor

The Mahaffy’s tetrahedron purpose is to ground the three dimensions of chemistry curriculum in real world problems, including industrial processes and

environmental applications, with the aim of motivating students with the adoption of familiar and interesting contexts as already suggested by the theory of situated cognition (Greeno,1998; Sjostrom and Talanquer, 2014).
This involves practically the adoption of active learning, case studies and investigative projects for linking "school chemistry" to everyday life.

1.3.3 Innovating laboratory work

The need for a constructivist and student-centred approach is also reflected in the setting of laboratory activities that must differ from the traditional ones, recipe-cook style, as already underlined, not only in high school but also in University courses.
A few strategies are available to introduce more discovery and inquiry type assignments into laboratory programs in order to promote better student learning.
An inquiry-type laboratory, properly designed and performed, can give students the opportunity to practice the metacognitive skills, nowadays required in the attempt of broaden the learning skills developed through science topics study (Kipnis and Hofstein,2007).
It is not necessary to change the experiments themselves, but only the way they are presented and used by the students, to improve, for instance, the ability of experimental design (Szalay and Toth, 2016). Appropriate laboratory activities can be effective in promoting problem solving and creative skills (Ramsey and Howe, 1969) and in fostering the development of skills in cooperation and communication (Hofstein and Lunetta,1982).Moreover, according with Mahaffy’s model, laboratory work can act as a driver for learning in authentic contexts, as Health and Safety and Green Chemistry (Ranke et al., 2008).These approaches have been shown to be successful in both secondary (Witteck and Eilks,2006) and higher level (McDonnell et al.,2007) of chemistry education.

1.3.4 Using new technologies in chemistry education

The use of ICT in teaching Chemistry at all levels of education has expanded rapidly over the past decade.
Today the growth of information increasingly requires the use of new technologies, both to acquire the basic knowledge and to proceed towards a deeper understanding.

Virtual reality may produce more efficient learning, for example students can understand the particulate nature of matter better by using computer simulations instead of diagrams such as pictures and transparencies (Williamson and Abraham, 1995).

Online resources and freeware programs have been used to support the learning of chemistry students in laboratory practice, often using virtual contexts that allows students to replicate what happens in a research laboratory, improving students' problem-solving skills (Cox et al., 2008; Tsai, 2007).

Bibliography

- Allulli , G. (2010). From the Lisbon strategy to Europe 2020. European Training Policies, Rome.

- Anderson RD, (2007), Inquiry as an organizing theme for science curriculum, in SK Abell and NG Lederman (eds.), Handbook on research on science education, Mahwah: Lawrence Erlbaum, pp. 807-830.

- Ausubel DP, (1968), Educational psychology: a cognitive view, New York: Holt, Rinehart and Winston.

- Bailey PD and Garratt J., (2002), Chemical education: theory and practice, Univ. Chem. Educ., 6, 39-57.

- Bargellini, A., & Scaioni U.(1998). Environmental society chemistry. Signorelli.

- Bodner GM, (1986), Constructivism: a theory of knowledge, J. Chem. Educ ., 63, 873-878

- Borsese, A. (2016). Brevi riflessioni sulle difficoltà di apprendimento. Orientamenti pedagogici: rivista internazionale di scienze dell'educazione, 63(365), 553-559.

- Brouwer, N., & McDonnell, C. (2009). Online support and online assessment for teaching and learning chemistry. Innovative teaching methods and learning Chemistry in Higher Education, 123-152.

- Coll RK and Taylor TGN, (2001), Using constructivism to inform tertiary chemistry pedagogy, Chem. Educ. Res. Pract ., 2, 215-226.

- Domenici, V. (2018). Teaching and Learning Chemistry. Mondadori University).

- Driver, R.; Oldham, V. Stud. Sci. Educ. 1986, 13, 105–122.

- Duranti, C., & Olmi, F. (1995). L'ESPERIENZA DEL TIROCINIO DIDATTICO E DEL LABORATORIO DI DIDATTICA NELLA FORMAZIONE PRIMARIA DEI DOCENTI: UN BILANCIO, LE

PROSPETTIVE. LA CHIMICA NELLE SSIS.

- Eilks , I., & Byers, B. (2010). The need for innovative methods of teaching and learning chemistry in higher education - reflections from a project of the European Chemistry Thematic Network. Chemistry Education Research and Practice, 11 (4), 233-240.

- EURYDICE: The Structure Of The European Education Systems 2016/17 http://eurydice.indire.it/pubblicazioni/the-structure-of-the-european- education-systems-201617

- Fensham, PJ, Gunstone, RF, White, RT, & White, RT (Eds.). (1994). The content of science: A constructivist approach to its teaching and learning. Psychology Press.

- Fiorentini, C. , Aquilini E., Colombi D., Testoni A., (2007) Leggere il mondo oltre le apparenze. Per una didattica dei concetti fondamentali della chimica. Armando Editore.

- Gabel, D. (1999). Improving teaching and learning through chemistry education research: A look to the future. Journal of Chemical education, 76 (4), 548.

- Ghibaudi, E., Roletto, E., & Regis, A. (2016). DIDATTICA DELLA CHIMICA E TRASPOSIZIONE DIDATTICA Parte seconda-Un'approccio didattico alla costruzione del concetto di trasformazione chimica. Perspectives in Science, 10, 28-45.

- Greeno JG, (1998), The situativity of knowing, learning, and research, Amer. Psych., 53, 5-26.

- Hofstein , A., & Lunetta , VN (1982). The role of the laboratory in science teaching: Neglected aspects of research. Review of educational research, 52 (2), 201-217.

- Johnstone AH, (1991), Why is science difficult to learn? Things are seldom what they seem, J. Comp. Assist. Learn., 7, 75-83.

- Johnstone, AH (1997). Chemistry teaching-science or alchemy? 1996 Brasted lecture. Journal of chemical education, 74 (3), 262.

- Kelly, OC, & Finlayson, OE (2007). Providing solutions through problem-based learning for the undergraduate 1st year chemistry laboratory. Chemistry Education Research and Practice, 8 (3), 347-361.

- Kind, V. (2004). Beyond appearances: Students' misconceptions about basic chemical ideas.

- Krajcik , JS The Psychology of Learning Science; Lawrence Erlbaum: Hillsdale, NJ, 1991; pp 117–147.

- Mahaffy, P. (2004). The future shape of chemistry education. Chemistry

Education Research and Practice, 5 (3), 229-245.

- Mahaffy, P. (2006). Moving chemistry education into 3D: A tetrahedral metaphor for understanding chemistry. Union Carbide Award for Chemical Education. Journal of Chemical Education, 83 (1), 49.

- McDonnell C., O'Connor C. and Seery M. K., (2007), Developing practical chemistry skills by means of student-driven problem based learning mini-projects, Chem. Educ. Res. Pract., 8, 130-139.

- Olmi, F. (2014). La valutazione delle competenze nell'apprendimento della Chimica. La Chimica nella Scuola, 2, 9-24.

- Pinto, G. (2010). The Bologna process and its impact on university-level chemical education in Europe. Journal of Chemical Education, 87 (11), 1176-1182.

- Ramsey, G. A., & Howe, R. W. (1969). An Analysis of Research on Instructional Procedures in Secondary School Science, Part I--Outcomes of Instruction. Science Teacher, 36(3), 62-70.

- Ranke J., Bahadir M., Eissen M. and Koenig B., (2008), Developing and disseminating NOP: an online, open-access, organic chemistry teaching resource to integrate sustainability concepts in the laboratory, J. Chem. Educ., 85, 1000-1005.

- Rocard , M., Csermely , P., Jorde , D., Lenzen , D., Walberg- Henriksson , H., & Hemmo , V. (2007). Science education now. A renewed pedagogy for the future of Europe. Brussels: European Comission.

- Roletto, E. (2005). La scuola dell'apprendimento. Trento: Erikson.

- Shank, RC, Berman, TR, & Macpherson, KA (1999). Learning by doing. In CM Reigeluth (Ed.), Instructional design theories and models: A new paradigm of instructional theory (Vol. II, pp. 161-81). Mahwah, NJ: Lawrence Erlbaum Associates.

- Sjostrom, J., & Talanquer, V. (2014). Humanizing chemistry education: from simple contextualization to multifaceted problematization. Journal of Chemical Education, 91(8), 1125-1131.

- Stavy , R. (1991). Using analogy to overcome misconceptions about conservation of matter. Journal of research in science teaching, 28 (4), 305-313.

- Szalay, L., & Toth, Z. (2016). An inquiry-based approach of traditional 'step-by-step'experiments. Chemistry Education Research and Practice, 17(4), 923-961.

- Taber KS, (2002), Chemical Misconceptions - Prevention, Diagnosis and Cure: Theoretical Background, vol. 1, London: Royal Society of Chemistry

- Wandersee , JH, Mintzes , JJ, & Novak, JD (1994). Research on alternative conceptions in science. Handbook of research on science teaching and learning, 177, 210.

- Williamson, V. M.; Abraham, M. R. J. Res. Sci. Teach. 1995, 32, 521–534.
- Witteck T. and Eilks I., (2006), Max Sour Ltd. – Open experimentation and problem solving in a cooperative learning company, Sch. Sci. Rev., 88 (323), 95-102.
- Wittrock MC, (1989), Generative processes of comprehension, Educ. Psych., 24, 325-344.

Chapter 2: A Learning by doing laboratory based on Johnstone's model: a motivating approach to Chemistry for High School students

Some paragraphs of this chapter were extracted from the manuscript written by C. Schettini, S. Zamponi, F. Marchetti, C, Di Nicola, R. Galassi and S. Markic with the title" A Learning by doing laboratory based on Johnstone's model: a motivating approach to Chemistry for High School students", published in the book "Building bridges across disciplines for transformative education and a sustainable future", a collection of invited papers inspired by the 24th Symposium on Chemistry and Science Education, held at the University of Bremen in June 2018.

This study started in 2016 from the educational activities for high school students already implemented by the Department of Chemistry of the University of Camerino within the framework of PLS, with the research objective of analyzing and evaluating the impact of the learning by doing methodology adopted in the laboratory on the knowledge acquisition of students.

Following the indications of Prof. Silvija Markic, Supervisor of the traineeship carried out at the Institute for Science and Technology - Chemistry Education of the Ludwigsburg University of Education (Germany), a redesign of the activities, presenting closer the link between Johnstone's levels, was then considered.

Abstract

In Italian secondary schools, chemistry teaching is still quite disjointed from both practice and connection with real-life contexts. This is true even for specific high schools (Scientific Licei), which are strictly devoted to the study of Natural Sciences, and hence of chemistry. The lack of chemistry teaching methods based on laboratory practice can be a serious deficiency in the learning process leading to students having poor motivations to study chemistry. As a consequence, according to PLS, in 2015/16 academic year, the UNICAM promoted chemistry degree course and evaluated the impact of a 6-8 hours long General Chemistry laboratory, addressed to 436 students (15-18 years old) of 11 Scientific Licei of the Marche region in Italy. 5 laboratory experiments, directly performed by students, concerned mainly the knowledge of the characteristics of different chemical reactions and a "learning by doing" approach was proposed, also allowing students to work at the three levels of Johnstone's triangle. The analysis of the results of the multi-answers questionnaire administered showed an increase of about 20% correct answers after the laboratory session. However, the connection between the levels of Johnstone´s triangle was rather poor. This should be taken into consideration even more in the further step of the development.

2.1 Theoretical background

According to the traditional model of chemistry education, in chemistry lessons students are first taught definitions, basic concepts and principles of chemistry. This is followed by teaching experiments and data that support the principles and laws and finally students are exposed to how to apply the knowledge in experiments, calculation problems and in real-life examples of application. According to the Information Processing model, separation between theorical concepts' learning and its application could result in pieces of information which are hardly remembered and even much less used (Evan et al., 2004; Holbrook, 2005). These limitations in the way of learning chemistry can further be explained by comparison with the learning cycle (Spencer, 1999).

As a matter of fact, studies in the field of cognition have shown that the model that best resembles the way one learns a new concept is the learning cycle: (i) Exploration, (ii) Concept Invention and (iii) Application (Karplus and Thier, 1967). Thus, the best way for a student to build understanding of a concept begins with the exploration and data collection phase, followed by the concept building phase and finally the application of the new knowledge. The original three-steps model of the Learning cycle, proposed by Karplus, was then expanded in a five-stage inquiry cycle including engaging, exploring, explaining, elaborating and evaluating in the structure of inquiry experiences (Trowbridge and Bybee, 2000).

The lack of such chemistry teaching method based on or supported by practical experiences can be a serious deficiency in the learning process, leading to students` poor motivation for chemistry and scarce attitude to acquire a correct understanding of matter composition and related transformations. On the other hand, the main difficulties students have in learning chemistry could be explained by assuming that learning of a chemistry concept involves understanding it at all three levels: macroscopic, symbolic and sub-microscopic (Gabel, 2000; Sirhan,2007). Students are unaware that there are three levels of chemistry presentation to be learned and as much less aware of interrelationship of those three levels. In addition, according to the information processing model, difficulty in learning, especially in the laboratory, is related to the cognitive overload of the working memory space caused by discussion of the macroscopic level involving unfamiliar processes and chemicals, learning about unseen sub-microscopic processes and use of numerous symbols and chemical equations (Johnstone, 2006).To overcome these difficulties and increase students ‘learning, the three levels approach to teaching and learning chemistry was proposed by Johnstone (1991) who suggested that making chemistry easier to learn and understand may reduce the likelihood of students losing interest toward the subject.

In our days in Italian secondary schools, chemistry teaching is still disjointed from both practice and connections with real-life. This is true also for “Licei Scientifici”, which are upper secondary schools preparing mostly for academic scientific careers. As laboratory practice is recommended, but not mandatory, often in most of these schools a physics laboratory is present, but a chemistry one is generally absent or less used, mainly because teachers do not possess specific skills, as they are generally graduated in scientific disciplines other than chemistry.

2.2 Presentation of the project

Since 2006, UNICAM Chemistry degree course has been involved in PLS, a project from the Italian Government designed to increase the number of chemistry careers and the enrolment to the academic course of chemistry, industrial chemistry and materials science. To pursue this objective, UNICAM has promoted and evaluated the impact of a 6-8 hours long chemistry laboratory course to 11 Scientific Licei of the Marche region and relative chemistry teachers, to be attended by students of 3rd to 5th year high school (15-18 years old). The schools involved responded to a UNICAM call for the project.

The topics of the day long practical laboratory experiments were chosen in discussion with teachers and concerned mainly the knowledge of the characteristics of different chemical reactions, with recalls of basilar chemistry law and concepts (Di Nicola et al., 2014). The five experiments were chosen for their characteristics that better allow students to work at the three levels of Johnstone’s triangle. In previous years, questionnaires were addressed to students and teachers, evaluating exclusively students` satisfaction with the offer. As a general evaluation, we got a full success and a high liking score, denoting the strong attitude to practice and enjoy chemistry labs of these students and a general appreciation of the teachers.

From this background, members of UNICAM Department of Chemistry planned in

2016 to start a preliminary study focusing on the impact of these laboratory courses on students´ knowledge improvements (Schettini et al., 2007). The obtained data were used for an analytical discussion promoting the “learning by doing” approach (Shank, Berman and Macpherson, 1999).

2.3 Research method of the pilot study

The study was conducted in February 2017 with 436 students, aged 16-18 years old, coming from 11 different high schools and attending different courses of study (classical, linguistic, traditional scientific and scientific with applied sciences option) and grades (328 fourth year students and 108 fifth year students).

In each session, about 40 students with their teachers were hosted in UNICAM laboratory and students were located in front of a laboratory bench where the glassware, the reactants and the laboratory sheets were available (Figure 2.1).

Figure 2.1: Students at work in the UNICAM laboratory

The students (gathered in groups of three/ four) completed all five experiments described in Table 2.1.

Experiment 1: Reaction of calcium and water	A sample of solid Calcium was let to react with water, the evolving gas was collected in a graduated cylinder.
Experiment 2: Double exchange reactions	Double exchange reactions were made with solutions of alkaline and earth alkaline chloride and nitrate, or lead (II) nitrate and sodium sulfate, potassium iodide. An unknown solution was identified by comparison with the results of the preliminary study. Warming/cooling crystallization of golden leaves from PbI_2 was also performed.
Experiment 3: Reduction of copper (II) chloride by aluminium	The spontaneous redox process of reduction of copper (II) chloride by aluminium foil pieces was observed.
Experiment 4: Effect of temperature on the dimerization of NO_2	Gaseous NO_2 in sealed quartz tube was cooled in liquid nitrogen bath, in an ice bath and warmed in boiling water (Brooks, 1995)
Experiment 5: Effect of concentration and temperature on chemical equilibrium in solution	A blue coloured solution of $[CoCl_4]^{2-}$ was treated with water and furtherly with HCl again to get a visive evaluation of the impact of reactants/products concentration on the chemical equilibrium position.

Table 2.1: Experiments proposed in the 6-8 hours long Laboratory

Following learning by doing methodology, students didn't previously receive a specific knowledge about the topics of the experiments by their teachers, and, before the execution of the laboratory experiments, UNICAM researchers provided only some essential information, underlining the basic concept involved. Sub-microscopic level and symbolic levels were shown on a multimedia board. A laboratory sheet describing the procedure to be followed was given and showed the particles representation, the chemical formulas, and equations related to the experiment.

2.3.1 Data collection

In order to assess the impact of the laboratory experience on students' knowledge, the same test was administered twice, prior to (pre-test) and after (post-test) the implementation of the activities. The test consisted of 10 questions, related to the topics of the five experiments performed by the students (Appendix 1), chosen among those that are usually afforded in all the different courses of study involved.

In particular, five multiple-choice questions were related to the reaction of calcium with water generating hydrogen and the relative ideal gas law (Q1-Q5); two questions, one of which with multiple-choice and the other with two options (soluble or insoluble involving three different salts), concerned the reactions of precipitation and recognition of metal ions (Q7,Q8); a two-option question (oxidation or reduction referred to aluminum and copper) concerned the redox reaction between aluminum and copper chloride (Q6); a multiple- choice question regarded the balance between nitrogen dioxide and dinitrogen tetroxide and a multiple-choice question was on the equilibrium between $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$ (Q9, Q10). All multiple-choice questions had three options.

In the test, most of the questions assessed the knowledge students reinforced or directly acquired during the execution and observation of the experimental procedure. Only a limited number of questions concerned theoretical knowledge, predictably already attained by students during the school course.

All the questions linked to the symbolic-representative level of the experiments, requiring the recognition of formulas of elements and compounds or to relate the reactions to the corresponding chemical equations and vice versa.

2.3.2 Data analysis

The results have been included in an Excel spreadsheet and then analyzed by applying the logic function (*if*) to compare the pre-test with the post-test responses, in relation to the total average of all the responses and, analytically, to each single response.

Regarding all the test responses, the following indicators have been applied: 1) ***R+ total***: indicating the average percentage of corrects answers in the post-test that were incorrect in the pre-test 2) ***R- total***: concerning incorrect answers in the post-test which had been correct in the pre-test 3) ***RS+ total***: concerning correct answers in both the pre-test and the post-test, 4) ***RS- total***: concerning incorrect responses before and after the experimental activity.

Furthermore, the four indicators were applied to the analysis of the individual responses.

2.4 Results and discussion

Regarding all the test responses, the following values, expressed as percentage, have been obtained (Table 2.2 and Figure 2.1):

R+ total	***R- total***	***RS+ total***	***RS- total***
26.42%	5.46%	49.22%	18.90%

Table 2.2: R+ total, R- total, RS+ total, RS- total for all the responses

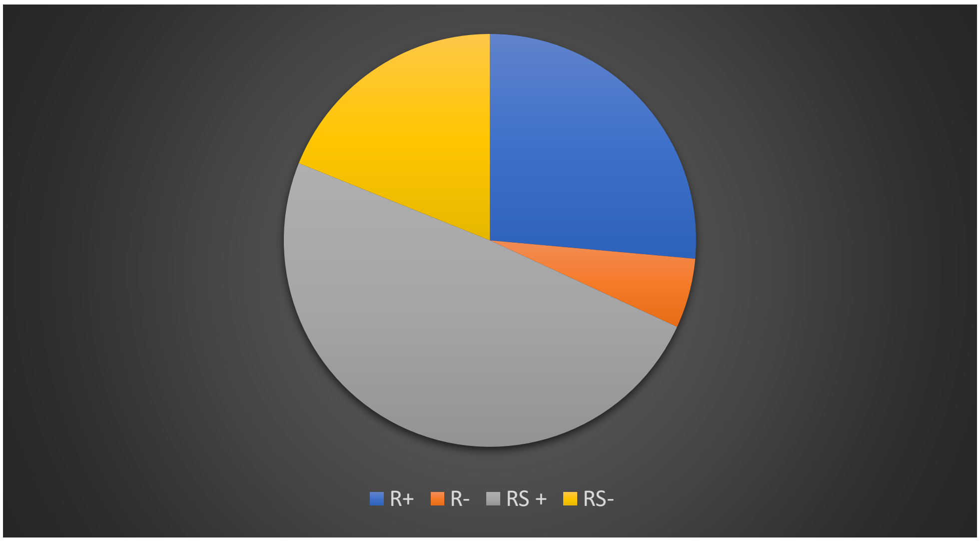


Figure 2.2: R+ total, R- total, RS+ total, RS- total for all the responses

The R+ value shows the essentially positive impact of the experimental work on increasing students' knowledge of the different aspects of chemical reactions; likewise, the RS+ value implies the stabilization of already acquired knowledge. Furthermore, the low value of R- provides evidence that the implementation of the experiments had a limited impact as a factor contributing to incorrect knowledge. Finally, the RS- value can be considered as acceptable and, to some degree, to be expected, given the heterogeneity of the sample and the limited time available for the clarification of previous misconceptions and the acquisition of new, correct knowledge.

Regarding the individual responses, the following data were obtained for all the indicators (Table 2.3):

Question	R+	R-	RS+	RS-
Question 1	0,09	0,05	0,80	0,06
Question 2	0,41	0,03	0,36	0,20
Question 3	0,32	0,02	0,62	0,04
Question 4	0,54	0,03	0,12	0,31
Question 5	0,19	0,08	0,57	0,16
Question 6	0,27	0,05	0,55	0,13
Question 7	0,18	0,10	0,20	0,52
Question 8	0,39	0,06	0,33	0,22
Question 9	0,10	0,06	0,80	0,04
Question 10	0,17	0,05	0,58	0,20

Table 2.3: R+ total, R- total, RS+ total, RS- total related to the responses for each question

From the analysis of individual responses, it appears that the best results, in terms of R+, referred to questions 1 - 5, relatively to the experience of calcium in water which is the longest and more articulated experiment, and to question 8 on the precipitation of lead(II) iodide and the relative striking crystallization to “golden leaves”. Positive results, in terms of RS+, are surprisingly related to questions 9 and 10 on the two experiments with a great visual impact, related to the difficult concepts of chemical equilibrium. The worst result, in terms of RS-, is instead related to question number 7, on the experiment concerning the precipitation of various salts, for which the time dedicated in the laboratory was not probably enough to fill the gaps in their previous knowledge.

Regarding the comparison between the number of correct answers for each question, the following data are reported in Figure 2.3, showing, on the whole, a significant increase in the number of correct answers to the various questions of the test.

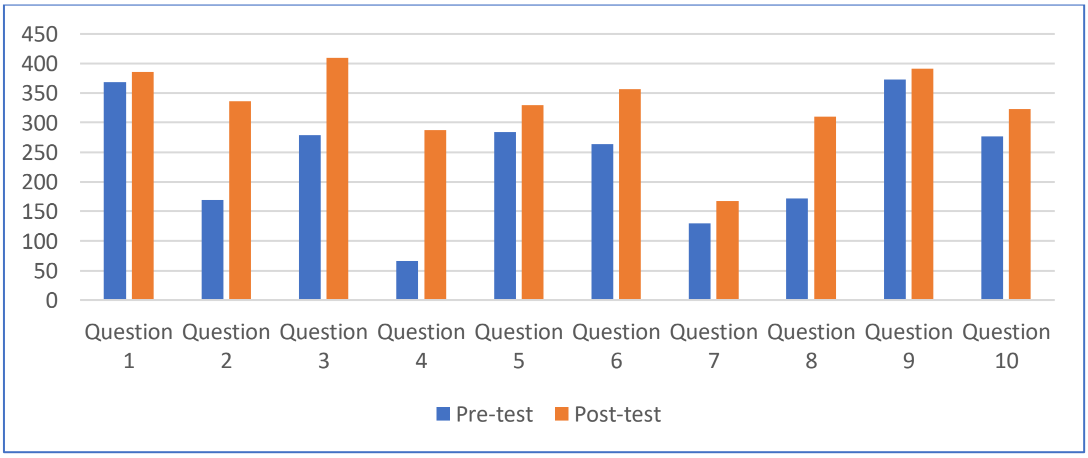


Figure 2.3: Number of correct answers in pre-test and post-test

2.5 Conclusions

On the whole, the analysis of the data appears to confirm, in educational terms, the validity of the procedure that directly exposes the students to an experimental context, minimizing the acquisition of theoretical information load right prior to the experiment, while emphasizing learning by doing. The designed laboratory activities motivate the students and encourage them to test their prior knowledge, at the same time creating an ideal learning environment for the acquisition and integration of new knowledge.

From the analysis of individual questions, it emerges that for some of them the best performances are closely related to the compliance and implementation of the experimental protocol (evidence of calcium hydroxide precipitation and hydrogen gas evolution, of lead iodide precipitation, evident color change in the equilibrium reaction of dimerization of NO_2 and the pink/blue forms equilibrium between $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, calculating the volume of hydrogen released in the reaction between calcium and water), and, obviously, to the students' prior knowledge, even though, this latter was extremely heterogeneous in the tested sample of students.

An explanation to the findings connected to question 7, on the solubility in water of different salts, resulting in a high value of RS-, can be attributed to insufficient knowledge or previous misconceptions about the concept of solubility. In the absence of strong experimental evidence or procedural error, this gap in knowledge was not filled.

Therefore, these results confirm the validity of the study conducted in terms of motivation and orientation to the study of chemistry for high school students, while suggesting areas of possible implementation, both in the planning of the University activities and as part of the school chemistry curriculum.

2.6 Further implementation

Results of the pilot study give some suggestion for both further implementation and evaluation. Despite the good results from the pilot study, the connection between the three levels of Johnstone`s triangle should be presented more closer as well as the focus of evaluation should be stronger on this issue.

Till now, some further ideas are developed and the stronger connection between the levels will be presented, on the example of *Gaseous* NO_2 *in sealed quartz tube was cooled in liquid nitrogen bath, in an ice bath and warmed in boiling water, showing the equilibrium with* N_2O_4 (see figure 2.4). This presentation is to be explained to and discussed with the students.

For better understanding of the connection between the levels and for better translation, different tools of language sensitive chemistry teaching and learning as described by Markic, Childs, and Broggy (2013) will be used. Those are tools such as (i) changing the representation form, (ii) clear separation between the levels, (iii) linguistic helping tools for the translation between the levels, (iv) stronger differentiation and (v) both ways translation between the levels.

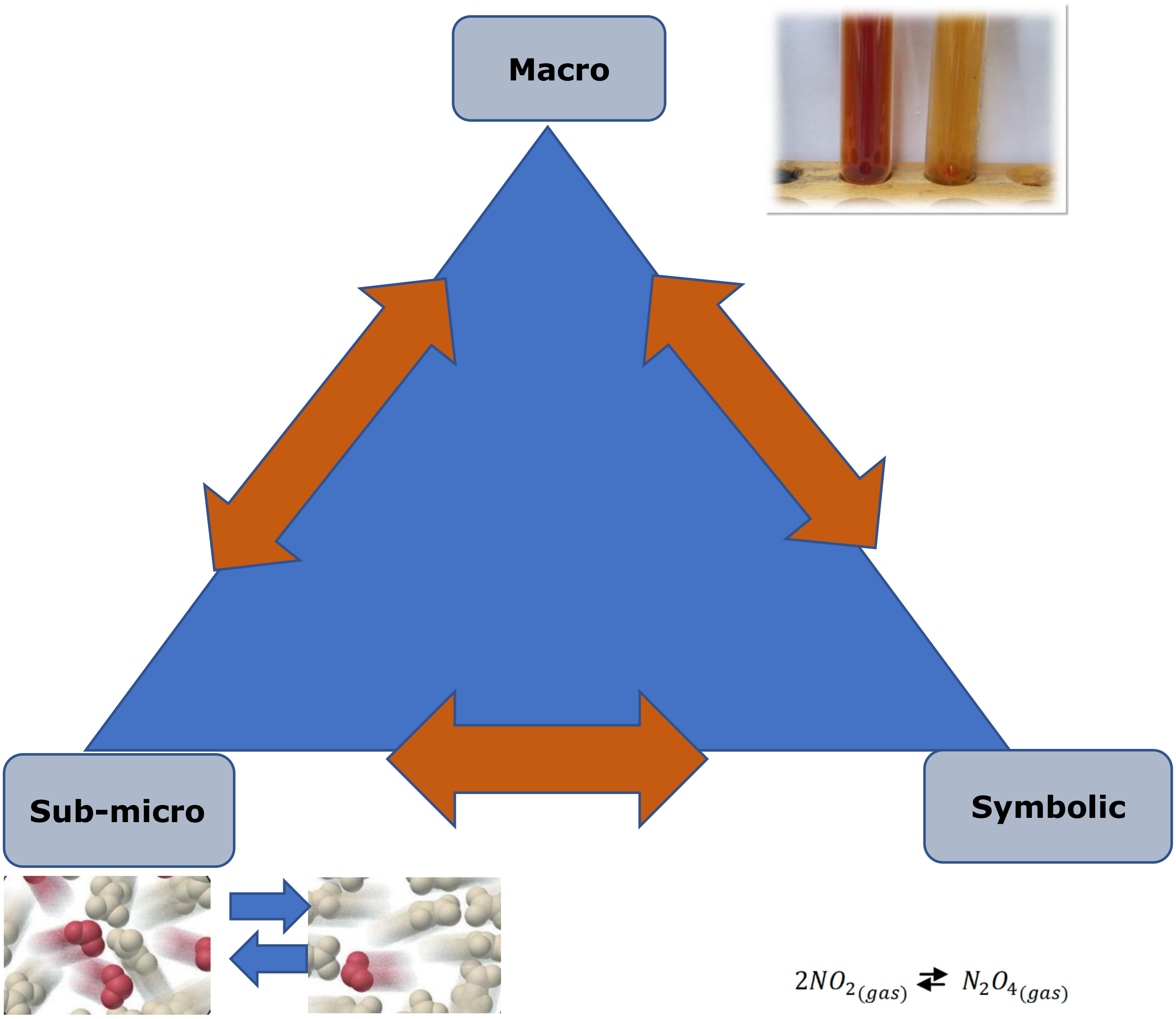


Figure 2.4: Presentation of Experiment 4, considering the three levels of Johnstone's triangle

Bibliography

- Di Nicola, C., Galassi, R., Marchetti, F., Timokhin. I., Pettinari, R., & Pettinari, C. (2014). Viaggio tra gli Elementi e le Reazioni della Chimica. In G. Anzellotti et al. (Ed.), L'insegnamento della Matematica e delle Scienze nella Società della Conoscenza [The teaching of Mathematics and Sciences in the Knowledge Society] (pp 149-155). Milano: Mondadori Ed.

- Evan, K. L., Karabinos, M., Leinhardt, G., & Yaron, G. (2004). Chemistry in the field and the classroom: A cognitive disconnect. Journal of Chemical Education, 83(4), 655-661.

- Gabel, D. (2000). Theory-based teaching strategies for conceptual understanding of chemistry. Education Quimica, 11(2), 236-243.

- Holbrook, J. (2005). Making chemistry teaching relevant. Chemical Education International, 6(1), 1-12.

- Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. Journal of Computer Assisted Learning, 7, 75-83.

- Johnstone, A. H. (2006). Chemical education research in Glasgow in perspective. Chemistry Education Research and Practice, 2006, 7 (2), 49-63.

- Karplus, R., & Thier, H. D. (1967). A new look at elementary school science: Science curriculum improvement study. Rand McNally.

- Markic, S., Broggy, J., & Childs, P. (2013). How to deal with linguistic issues in the chemistry classroom. In I. Eilks & A. Hofstein (eds.), Teaching Chemistry - A studybook (pp. 127-152). Rotterdam: Sense.

- Schettini, C., Marchetti, F., Di Nicola, C., Zamponi, S., & Galassi, R. (2017). Evaluation of the impact of a day long general chemistry laboratory on 4th year high school students. In Pixel (ed.), Conference Proceeding, 6thInternational Conference New Perspectives in Science Education, (pp133-136),Padova: Libreria Universitaria.it Edizioni.

- Shank, R. C.;Berman, T. R., Macpherson K. A. (1999). Instructional-design Theories and Models: A New Paradigm of Instructional Theory, Volume 2, Lawrence Erlabaum Associated Publishers, Edited by Charles M. Releguth, Chap 8, Pag 161.

- Sirhan, G. (2007). Learning difficulties in chemistry: An overview. Journal of Turkish Science, 4(2), 2-20.

- Spencer, J. N. (1999). New directions in teaching chemistry: A philosophical and pedagogical basis. Journal of Chemistry Education, 76(4), 566-569.

- Trowbridge, L. W., Bybee, R. W., & Powell, J. C. (2000). Models for effective science teaching. Teaching secondary school science (pp. 232-251). Upper Saddle River (NJ): Merill.

Chapter 3: A blended learning approach for in-service teachers training based on online Moodle platform

This chapter provides the results of the survey, conducted with the teachers who attended in 2016/18 S.Y., the training course in blended mode, "The online chemical experiments: Instructions for use". Meeting the demands for the implementation of digital media in education, since 2016 the Department of Chemistry of UNICAM, as part of the framework of PLS project, designed this course in blended mode, offering teachers both face-to-face classes and online activities, hosted on a dedicated e-learning Moodle platform. My research concerned teachers' satisfaction of the provided contents and tools, evaluated through the analysis of the final questionnaire administered at the end of the course. The contents of this chapter are an elaboration of the presentations of the research at the 7th Euro Variety Conference in Belgrade (2017, included in the proceedings) and at the ESERA Conference 2019 in Bologna, as part of the symposium "Digitally supported teaching and learning formats-Development and evaluation" (article ready for proceedings' submission)

Abstract

As part of the Italian ministerial project "National Scientific Project" (PLS), on chemistry's learning empowering, the University of Camerino has been holding residential training courses addressed to in-service high school science teachers. Meeting the demands for the implementation of digital media in education, a course in blended mode has been run since 2016, offering teachers both face-to-face classes and online activities, hosted on a dedicated e-learning Moodle platform.

The course was planned with a bottom-up approach, which included discussions with a group of teachers in order to reach a common agreement on which key chemistry concepts should be addressed. The first aspect involved refreshing some disciplinary issues as science teachers are often not graduated in chemistry but in other subjects. The second task was the adoption of the extended Johnstone's model (Mahaffy,2014) for the presentation of chemistry topics, considering that the three levels are normally showed in the curriculum, but its tetrahedral extension to real life cases is often neglected. Then the implementation of multimedia tools followed, thus providing original materials in Italian and in English to respond to the demand for CLIL methodology (Marsh, 2008). The analysis of the final questionnaire administered at the end of the course showed the teachers' positive ratings on the blended training method and on the quality and usefulness of digital materials.

3.1 Introduction

Since 2007, the Italian Ministry of Education (MIUR) has promoted and funded many initiatives with the main objective of changing learning environments and promoting digital innovation in schools. Despite the investments, in the S.Y. 2014/15, regarding the students' skills, Italy was 25th in Europe for the number of Internet users (59%) and 23rd for basic digital skills (47%).

This gap was also visible in the case of specialist ICT skills (Italy 17th) and the number of graduates in STEM disciplines, for which Italy was 22nd, with 13 citizens per 1,000 (Mangione, Mosa & Pettenati, 2016).The data from the OECD TALIS 2013 survey saw Italy in first place for the ICT training needs of its teachers: at least 36% said they were not sufficiently prepared for digital teaching, compared to an average of 17% (OCDE, O., 2014). The 2015 Eurydice Report also underlined how digital skills were certainly among the training needs most felt by Italian teachers, both in terms of teaching enhanced by technologies, both as regards the use of technologies for their profession (European Commission/EACEA/Eurydice, 2015). In 2015 MIUR launched the new National Digital School Plan (Schietroma, 2016) with numerous actions aimed at strengthening technological infrastructures and a massive investment on in-service teacher training, On the other side, in Italy the development of e-learning system in Universities has taken place in the absence of significant regulatory action but through independent initiatives for elevating the quality of traditional didactics with the support and integration of online communication (Capogna, 2012).

In addition to the promotion of digital innovation, since 2004 MIUR has been funding PLS (Marasini, 2010), a project designed to increase the number of chemistry careers and the enrolment to the academic course of chemistry, industrial chemistry and materials science. The strongest point of the project is the collaboration between schools and universities for the development of STEM skills in high school students and for the training of teachers on the design of digitally supported teaching and learning contents.

3.2 The “online chemical experiments: Instructions for use” course- I edition

In 2016, a chemistry training course was set up in blended mode to comply with the requests of institutions and teachers, with multiple aims regarding the teaching and the learning of chemistry.

3.2.1 Design of the course

Over the last ten years, blended learning has been growing in demand and popularity in higher education and has become a large-scale teaching phenomenon. It becomes increasingly evident that blended learning can overcome various limitations related to online learning and face-to-face instruction. A meta-analysis of more than 1100 empirical studies published between 1996 and 2008 concluded that blended learning proves to be more effective than either online learning or face-to-face instruction (Means,Toyama,, Murphy, Bakia,& Jones, 2009). Among the different blended learning approaches described in the literature, the high-impact method was chosen, building our course from scratch (Alammary,Sheard & Carbone,2014).

The benefits of building a course from scratch are widely discussed (Littlejohn & Pegler, 2007; Wozney,Venkatesh,& Abrami,2006), including the possibility of rethinking and redesigning the course considering the learners’ needs and the learning outcomes to achieve. Designing an effective blended learning course requires indeed to identify all parts of the course that could be better presented in an online format, and then an examination of available educational technologies is needed to select those that best meet the users’ needs.

Regarding the modality of e-learning, the course designers chose to adopt the *model of assisted training* (Banzato &Midoro, 2015), that provides both individual study based on materials prepared specifically for self-learning and interaction with online tutors, experts and colleagues.

Once established the model of the course, a bottom-up strategy was adopted to fulfil the training needs of the teachers, most of them haven’t a Chemistry degree, but graduated in Biology, Geology or Natural Sciences. A working group was then set up to respond to the demands of a group of natural science teachers who previously followed the residential training courses.

Teachers' main requests were:

(i) mastering technological tools both for the immediate use in the blended course and for their introduction in teaching practice,

(ii) refreshing topics to be treated with an experimental approach,

(iii) acquiring new teaching methods that integrate new technologies, such as the Flipped Classroom method (Tucker, 2012).

3.2.2 Design of the chemistry units

The extended Johnstone's model, also called the tetrahedral model, proposed by Mahaffy (2014), was adopted for the organization of the chemistry units. The three thinking levels in learning chemistry are widely used into the design of secondary and post-secondary curriculum. The rehybridization of the triangle metaphor into a tetrahedron (Sjöström,2013) introduces the human contexts in chemistry as fourth vertex, thus providing a clear framework for grounding the three dimensions of chemistry curriculum in "real world" problems and solutions, including industrial processes and environmental applications. Highlighting the human element provides strong rationale for emphasizing case studies, active learning, and investigative projects for linking "school chemistry" to everyday life.

This model's issues were therefore adopted in the design of the course units, with the precise aim to make chemistry topics nearer to students' interests.

3.2.3 Structure of the course

In November 2016 the first edition of the "Online Chemistry Experiments: Instructions for Use" course was hosted on the UNICAM Moodle platform, followed by 28 science teachers belonging to 12 high schools of Marche Region. The total duration of the course was 25 hours, including 5 hours of face-to-face training, organized in 2 residential seminars, and 10 hours of online activities, assisted by two tutors. The first residential meeting illustrated the chemistry issues of the course, while in the second meeting teachers tested themselves the digital tools for building innovative paths.

On the Moodle platform, the course was structured in 12 units, addressing different general chemistry concepts model (Table 3.1) and designed according to the

Mahaffy's tetrahedral model.

Unit	*Topic*
1	Reaction of calcium and water to form gaseous Hydrogen
2	Double exchange reactions and an approach to qualitative chemical analysis
3	Effect of temperature on NO_2 dimerization
4	Test of CO and CO_2 during the aspiration process of a lit cigarette
5	Ammonia reaction with cupric sulfate
6	Effect of concentration and temperature on chemical equilibria in solution
7	Reactivity of alkaline metals
8	Reactivity of earth alkaline metals
9	Visualization of water polarity
10	Electrolytic properties of solutions highlighted by a toy car
11	Thermal conversion of an allotropic form to another one
12	Photo-assisted reduction of thionine

Table 3.1: The topics of the 12 units of Inorganic Chemistry hosted on the Moodle

Teachers were also supported with a webinar, held by the online tutors, addressing new approaches in chemistry education, such as IBSE methodology, problem solving in the chemistry laboratory, the implementation of authentic tasks and the assessment of laboratory activities. Moreover, the "Scientix"[4] project was presented, a European project that collects and promotes best practices in science teaching and learning in Europe and organizes trainings and workshops for STEM teachers.

A technical and a disciplinary forum were also hosted on the learning platform, allowing discussion and exchange of ideas among the participants and with the tutors. At the end of the course a final monitoring questionnaire was administered online.

All the materials were in Italian and in English to respond to the demands for the introduction of CLIL methodology in the Italian school curricula (Leone, 2015).

[4] http://www.scientix.eu/

Furthermore, during the course, two teachers undertook an action research project on the teaching of some chemical concepts, involving two 11th grade classes of pupils (16-17 years old) and using the pedagogical model of the Flipped Classroom and the IBSE approach, with emphasis on the 5E Learning Cycle. The results of this study were reported in Chapter 4.

3.2.4 Structure of the units

The core of each unit is a video showing a laboratory activity related to the topic (Figure 3.1). The adoption of video tutorials leads to optimized teaching and learning processes in the fundamental chemistry education in universities (He,Swenson & Lents, 2012). The main advantage of videos is the connection of both visual and auditory elements. Mayer's Cognitive Theory of Multimedia Learning additionally states that the simultaneous presentation of verbal and visual material, as realized in videos, is the most effective solution for beginners and visual-style learners (Mayer, 2009).

According to the fourth vertex of the tetrahedral model, in-depth materials in digital form were provided in every unit, as examples of real-life connections and cross-sectorial applications of the chemical concepts (Figure 3.2).A technical sheet of the experiment, theoretical references with description of the symbolic and sub-microscopic level of the phenomenon, problem solving exercises and a self-assessment test were associated to each video (Figure 3.3).

Figure 3.1: Screenshots of the video of Unit 1 (Reaction of calcium and water to form gaseous hydrogen)

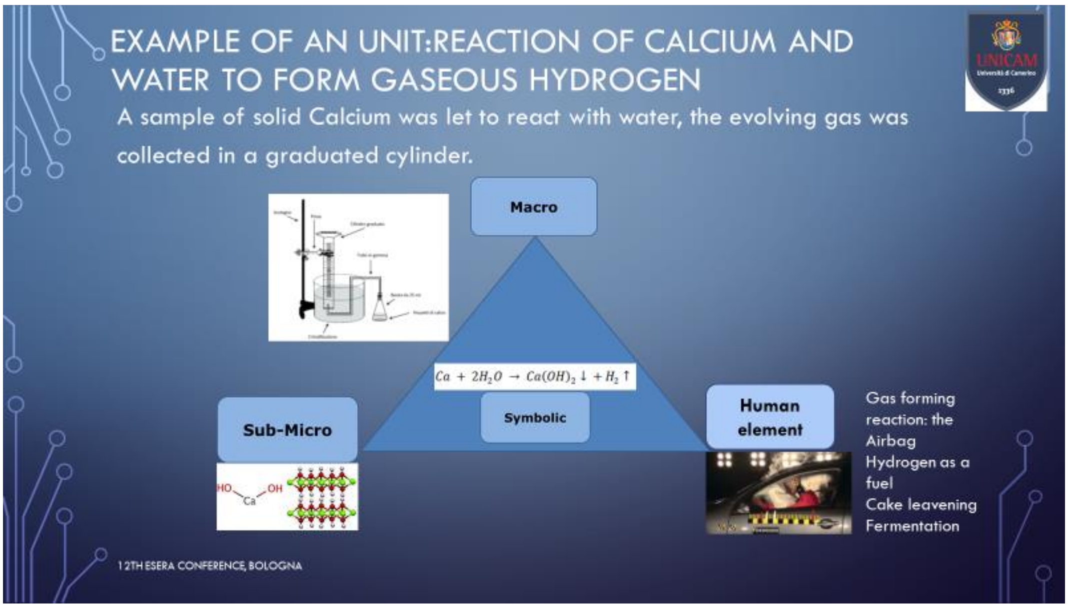


Figure 3.2: Structure of Unit 1, according to Mahaffy's model

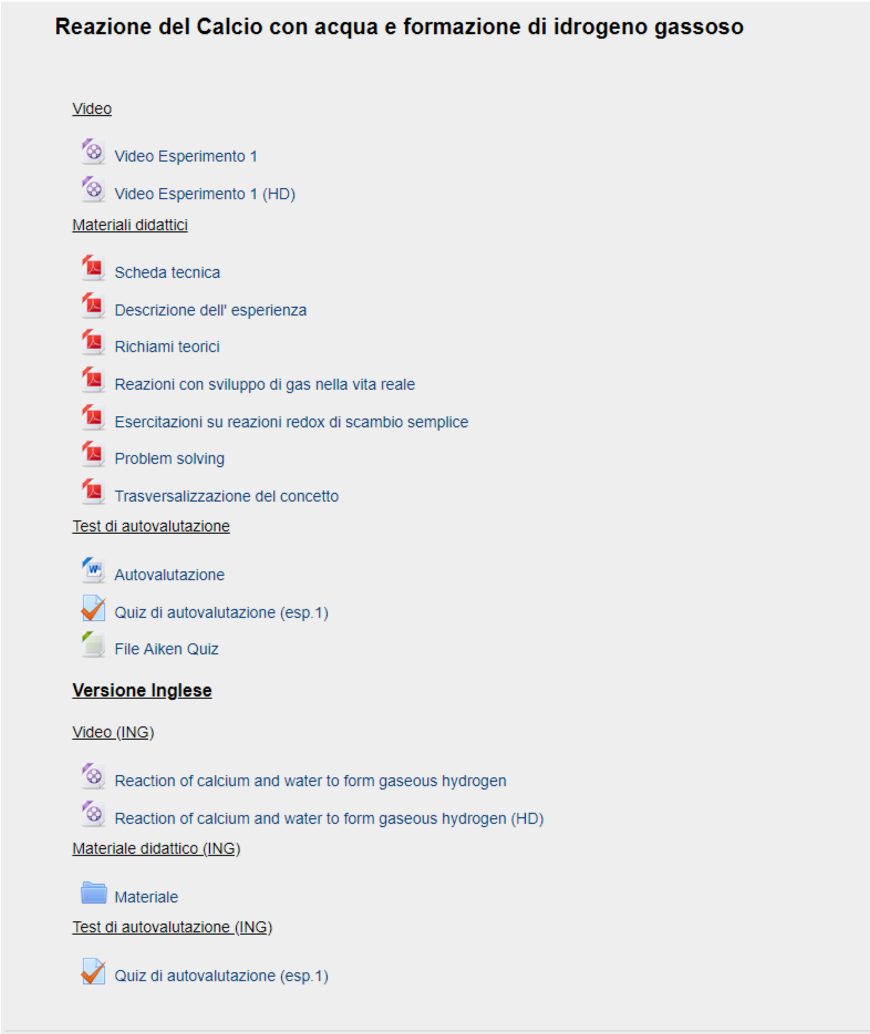


Figure 3.3: Screenshots of Unit 1 contents

3.2.5 Teachers' survey

At the end of the course, a final questionnaire of 61 questions was administered to assess the degree of teachers' satisfaction about the training (Appendix 2). The questionnaire was divided into four sections (general aspects of the course, usefulness of the videos and related materials for the training, use of the videos and related materials with students, webinar on new approaches in chemistry education) and directly administered online on the Moodle platform. All the 28 teachers, attending the course, completed the questionnaire.

The responses were automatically elaborated by the Moodle software and provided in the form of percentage of the different answers (for closed questions where more than one answer was possible) or delivering the statements answered to open questions.

Regarding teachers' general opinion on the course, 25% judged it "excellent", 42,86% "very good" and 32,14% "good" and 75% of the teachers would recommend its frequency, even charged.

When teachers were asked to rate (with a score from 0 to 10) the skills acquired by the different activities, the best results were achieved by "using and studying the videos of the experiments", followed by "refreshing basic chemistry knowledge" and "studying examples from real life situations" (Figure 3.4).

Furthermore, when asked on which aspects of their professional development the course provided the best upgrade, teachers chose the "introduction of examples in lessons" (23,08%) and "contextualization in real-life situations" (15,38%), highlighting science teachers needs for connecting chemistry topics to everyday life to increase students' motivation, according to Mahaffy's model. 19.23% of the teachers chose the" knowledge of online training opportunities" option, as the course focuses also on web resources for teachers' training (Figure 3.5).

On the overall, teachers considered more useful for their training the educational material accompanying the videos, followed by simply watching the videos and then by the webinar's attendance, probably for its short duration (Table 3.2).

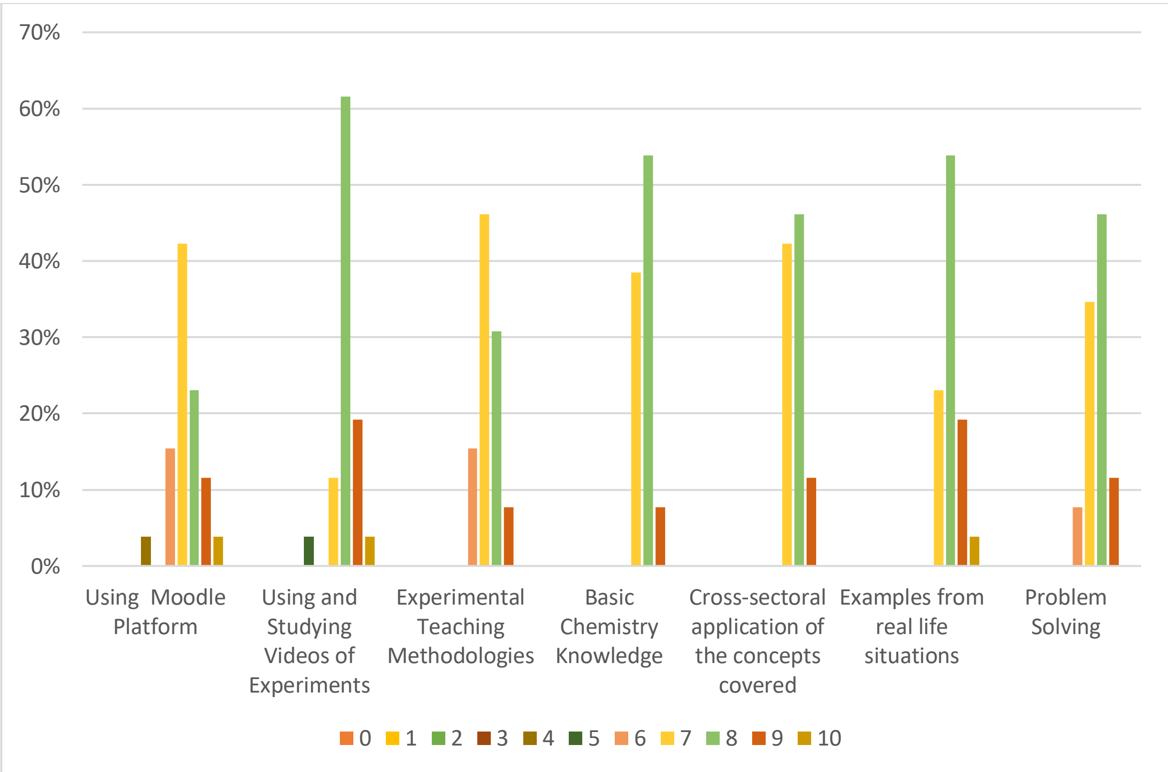


Figure 3.4: Ratings of the different activities' impact on teachers' skills

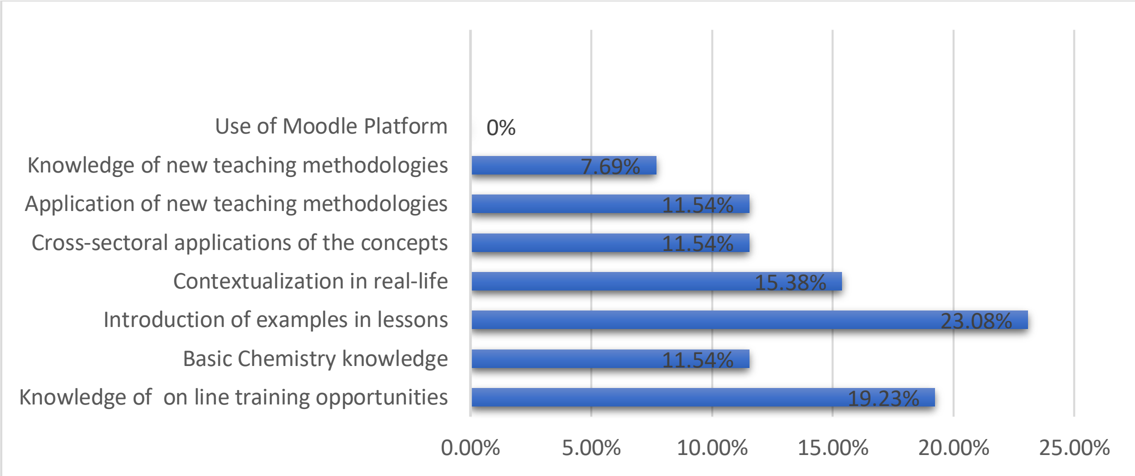


Figure 3.5: Percentage of answers to the question about skills upgrade

How useful was for your professional development?	YES	MORE YES THAN NO	MORE NO THAN YES	NO
Watching the videos	73.08 %	19.23 %	3.85 %	3.85%
The education material accompanying the videos	96.15 %	3.85 %	0.00 %	0.00 %
The webinar	61.54 %	30.77 %	0.00 %	7.69%

Table 3.2: Percentage of answers to the question about different activities' usefulness

Regarding the use of videos in the classroom, 15.38% of teachers employed them a lot and 42.31 % only a little. Most of them considered the videos *"well described in the different steps, taking a short time and with a visual impact able to arouse students' curiosity and attention"*. Some teachers used the videos in the absence of laboratory and others, after the practice, for reviewing and reflecting on the different steps. Some teachers reported that they didn't use the videos extensively, because the topics were not included in their current course of study and asked for more experiments to record, even about organic chemistry. Some teachers showed videos in their classroom as a starting point before introducing an analytical law or as validation, after studying an analytical law, even in flipped classroom modality. Furthermore, 42.31% teachers included video-related questions in their tests.

Regarding the other resources 'use with students, teachers reported, above all, the use of examples related to real-life, followed by the cross-sectorial application to concepts. The lack of use of video in English was motivated in some cases by the limited time available or by students' insufficient language skills (Figure 3.6).

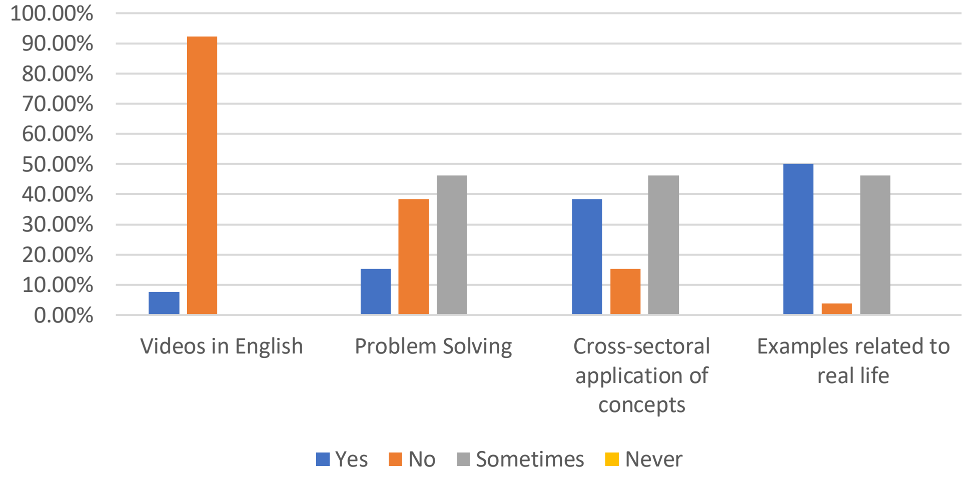


Figure 3.6: Percentage of answers to the question about use of resources with students

Regarding the interest of the topics afforded in the webinar, teachers preferred the assessment of students' skills by the means of authentic tasks and the suggestions for the evaluation of laboratory activities (more than one answer available),as showed in Figure 3.7.

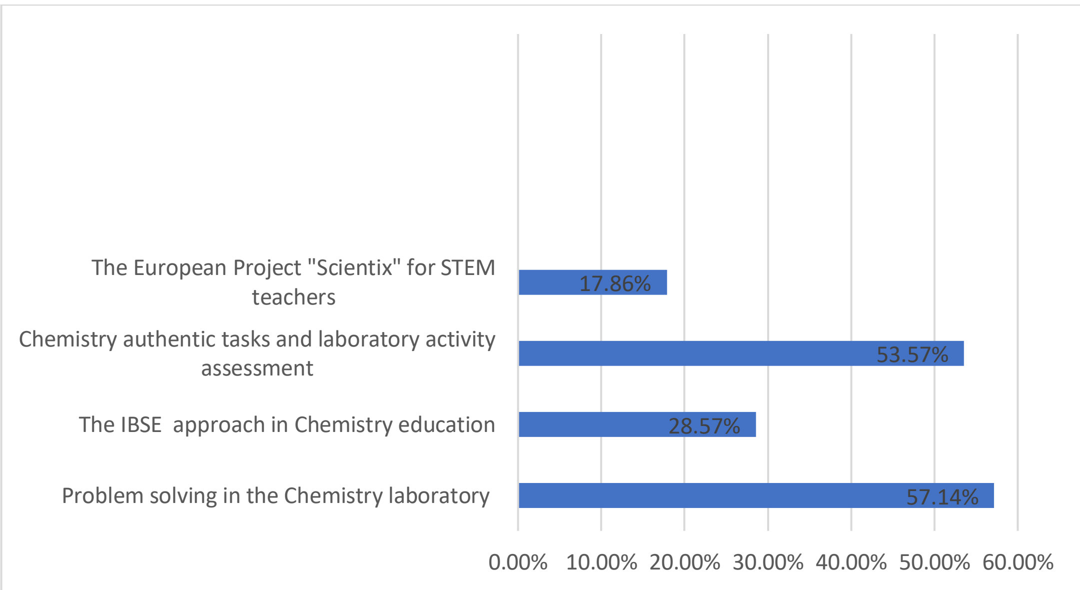


Figure 3.7: Percentage of answers to the question about webinar's topics interest

3.3 The "online chemical experiments: Instructions for use" course-II edition

In 2017, a second edition of the course was delivered with 13 teachers and it was implemented, following teachers' opinion and suggestions derived from the reported survey. Two webinars were included, instead of one, and the teachers received training in the Flipped Classroom methodology, as required.

Furthermore, all teachers were asked to design a learning unit, including the digital materials of the platform, especially videos, and adopting one of the innovative teaching methods experimented during the course.

Then, they were asked to approach the fourth vertex of the tetrahedron model in their units, connecting the chemical concepts to students' experience and real-life contexts. The learning units were evaluated with a rubric (Appendix 3), considering the following aspects: (i) adequacy to the students' characteristics and to school context, (ii) structure of the educational path, (iii) use of the Moodle platform materials and originality of the proposal , (iv) propriety of the real-life connections and (v) quality of evaluation tests.

3.4 Conclusions and further implementation

The course has been useful as a stimulus for the teachers' active reflection on the benefits derived from adopting an experimental approach to the teaching of chemistry, for the acquisition of experimental procedures and for the possibility of replacing a "real" chemistry lab, in the absence of reagents or suitable equipment.

Conversely, lack of familiarity with the Moodle platform, inadequate Internet connection and, in some cases, the impossibility of repeating the experiment in a laboratory were perceived as critical issues.

According teachers' request, a greater number of videos will be designed and provided, introducing also organic chemistry topics and they will be made accessible to pupils as well. For the next editions it is expected to increase the number of webinars, introducing more examples of new approaches to chemistry teaching and learning

Furthermore, collaborative activities among group of teachers to be developed in the Moodle learning context will be promoted.

The collaboration with the Institutions members, partners in the same ESERA[5] symposium "Digitally supported teaching and learning formats-Development and evaluation" (Dr. Sandra Puddu of the Austrian Educational Competence Centre Chemistry of the University of Vienna, Dr. Franziska Zimmermann and Prof. Insa Melle of the Department of Chemistry of the Technical University of Dortmund, Dr. Julian Kuesel and Prof. Silvija Markic of the Institute for Science and Technology - Chemistry Education of the Ludwigsburg University of Education), will allow the sharing of new ideas and methodologies for effective teacher training and the development of further educational research issues.

Bibliography

- Alammary, A., Sheard, J., & Carbone, A. (2014). Blended learning in higher education: Three different design approaches. Australasian Journal of Educational Technology, 30(4).
- Banzato, M., & Midoro, V. (2005). Models of e-learning. Italian Journal of Educational Technology, 13(3), 60.
- Capogna, S. (2012). University and E-learning Classes in Italy. E-Learning and Digital Media, 9(2), 143-156.
- European Commission/EACEA/Eurydice. (2015). Adult Education and Training in Europe: Widening Access to Learning Opportunities (Eurydice Report).
- Gallet, C. (1998). Problem-Solving Teaching in the Chemistry Laboratory: Leaving the Cooks... Journal of Chemical education, 75(1), 72.
- He, Y., Swenson, S., & Lents, N. (2012). Online video tutorials increase learning of difficult concepts in an undergraduate analytical chemistry course. Journal of Chemical Education, 89(9), 1128-1132.
- Johnstone, A. H. (2000). Teaching of chemistry-logical or psychological?. Chemistry Education Research and Practice, 1(1), 9-15.
- Leone, A. R. (2015). Outlooks in Italy: CLIL as language education policy. Working Papers in Educational Linguistics (WPEL), 30(1), 3.
- Littlejohn, A., & Pegler, C. (2007). Preparing for blended e-learning. Abingdon, Oxon: Taylor & Francis.

[5] https://www.esera2019.org/

- Mahaffy, P. (2004). The future shape of chemistry education. Chemistry Education Research and Practice, 5(3), 229-245.
- Mangione, G. R., Mosa, E., & Pettenati, M. C. (2016). Dalla Gelmini alla Giannini. Il Piano Nazionale Scuola Digitale, i PON disciplinari e il ruolo dell'INDIRE nella formazione continua degli insegnanti. [From Gelmini to Giannini.The National Plan for a Digital School, the disciplinary PONs (National Objective Projects of European Social Fund) and the role of the INDIRE in teachers' continuing education] FORMAZIONE & INSEGNAMENTO. Rivista internazionale di Scienze dell'educazione e della formazione, 13(3), 139-166.
- Marsh, D. (2008). Language awareness and CLIL. Encyclopedia of language and education, 1986-1999.
- Mayer, R. E. (2009). Multimedia learning (2nd ed.). New York, NY, US: Cambridge University.
- Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. Washington, DC:U.S. Department of Education.
- OCDE, O. (2014). TALIS 2013 Results: An International Perspective on Teaching and Learning. OECD Publishing.
- Schietroma, R. (2011). Il Piano Nazionale Scuola Digitale. [The National Plan for a Digital School].Annali della Pubblica Istruzione, 2, 15-29.
- Sjöström, J. (2013). Towards Bildung-oriented chemistry education. Science & Education, 22(7), 1873-1890.
- Tucker, B. (2012). The flipped classroom. Education next, 12(1), 82-83.
- Wozney, L., Venkatesh, V., & Abrami, P. (2006). Implementing computer technologies: Teachers' perceptions and practices. Journal of Technology and teacher education, 14(1), 173-207.

Chapter 4: An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology

This chapter was extracted from the manuscript written written by C. Schettini, R. Galassi and M. Quadrini, submitted and under review.
It describes method and results of a pilot study carried out in the 2018-2019 S.Y., involving 137 students (age 16-17 years old) and 6 teachers of three Italian high schools. The aim of the research was the evaluation of the efficacy of a learning unit on the reactivity of the metals. The research was carried on with a quasi-experimental research design, the "One-Group Pretest-Posttest Design", employing the 5ELFA approach that integrates the Inquiry modality of the 5E learning cycle and the Flipped Classroom methodology.
The comparison between the results of the pre-test and post-test administered to the students showed a positive increase in both the acquired knowledge and the design skills of an experiment. The analysis of the monitoring questionnaires is reported as referring to the appreciation of teachers and students.

Abstract

Although the advantages of the inquiry-based learning in chemistry are widely reported in the literature, especially for the development of experimental design, such approaches don't have the space they deserve in high schools, even for teachers' reservations and lack of time. In these cases, simpler and more structured inquiry-based tasks, with increased teachers' guidance, can be an effective start, opening the way to more complex, open-ended inquiry activities.

In this study, an approach to investigate the reactivity of metals using the 5ELFA (Flipped Classroom Approach Based on the 5E Learning Cycle Model) is proposed, with the main objective of developing students' ability to design an experiment and to achieve knowledge on the topic. In this method, the Flipped Classroom is combined with the Inquiry-based 5E Learning cycle, with the dual aim to free up time for investigative activities in the classroom and to give students the opportunity to practice in a virtual laboratory, before designing and doing the experiment at school.

In 2018/2019 School Year a pilot study was carried on with a quasi-experimental research design on 137 Italian students of 11th grade with the aim to assess the efficacy of the 5ELFA approach to the development of students' skills to design an experiment and their disciplinary knowledge. Results suggest that students benefit from this approach, especially for design skills' improvement.

4.1 Introduction

Nowadays, the process of learning and teaching chemistry in high school aims not only to acquire basic knowledge, but also to develop transversal competences in students such as problem solving and experimental design skills in authentic contexts (European C., 2006). As a matter of fact, it’s a growing belief that learning should be contextualized and that the building of authentic knowledge can be acquired by solving meaningful and real-life connected problems (Brown, Collins and Duguid, 1989).

Laboratory activity has always been considered an essential part of chemistry curriculum, as it offers students the possibility to experiment directly phenomena (Hofstein,2004) and to build their own understanding of chemical concepts "learning by doing" (Johnstone, 1983).

However, for developing critical thinking and gaining a better idea of the nature of science and scientific investigation, it is necessary that laboratory activities are designed to emphasize the process of discovery and to develop inquiry-type skills. This conception is significantly in contrast with the idea of a laboratory used primarily to demonstrate and verify what has already been learned theoretically. (Tobin, 1990; Gunstone, 1991; Bybee, R., 2000; Rocard et al., 2007).

Some studies have shown that high school chemistry students involved in inquiry activities develop the ability to ask a greater number and more significant questions on the chemical phenomena investigated compared to group of students who have attended traditional laboratory activities (Hofstein et al., 2005) and at the same time are challenged to design investigations and reflecting on the conclusions of their experimental work (Krajcik, Mamlok and Hug, 2001).

Furthermore, for other authors students involved in well-designed inquiry activities can develop high level thinking skills and metacognitive skills and more positive beliefs about learning chemistry in general and approaching chemistry concepts in a laboratory context , in particular (Tomperi and Aksela,2014).

On the other side, the implementation of inquiry laboratory activities is considered by some teachers time-consuming , both for the investigative tasks and for the following reflection in the classroom community , made even more difficult by large class size and by the requirements of the high school chemistry curriculum that do not allow sufficient time for unguided inquiry and for topics not closely connected to the curriculum (Cheung, 2011).

Furthermore, for some authors (Kirschner et al. 2006; Sweller,1998) constructivist approaches such as IBSE that are unguided or partially guided are less effective for learning than traditional ones, if students do not already possess sufficient basic skills and teachers are not expert enough to handle the cognitive overload during investigations.

Regarding, in particular, inquiry-based laboratory activities, it has been reported in the literature that they do not always achieve the objectives set in terms of learning outcomes and thinking skills (Berg et al, 2003; Germann,1989) , especially if the activities are aimed at students who are not sufficiently trained and are guided by underprepared instructors (Hancock et al., 1992; Lewis, 2002).

For Criswell (2012), especially for students with lower skills, it is therefore necessary to provide scaffolding strategies that can offer guidance when they are faced with the challenging demands on both content acquisition and scientific reasoning required by the chemistry laboratory inquiry tasks. In the "framing” model proposed by Criswell, connected to the scaffolding categories of “channeling and focusing” identified by Pea (2004), teachers should reduce the students’ degree of freedom in a problem solving task, orienting them to the investigation organization and solution with background information, shared prior of the inquiry activity.

Szalay and Toth (2016) have then proposed to modify laboratory activities, traditionally done step-by-step, so that students should design only some stages of the experimental activity, gradually introducing them to more complete and open inquiry activities. In their model, teachers choose laboratory activities, closely related to the curriculum and already consolidated in practice, that could be adapted to convert them into inquiry-based tasks. Laboratory activities are always followed by a group review of the results achieved.

As indeed stated by Allen (1986), it is possible to convert an experiment conducted in the traditional way as "verification" of what has already been studied at a theoretical level in a "guided inquiry" experiment to foster problem solving skills, providing a minimum theoretical support to students. Allen reports that students’ opinions of the new format of guided inquiry laboratory are largely positive, ranking guided experiments high in terms of greater interest and development of critical skills and problem solving, despite the major difficulties encountered.

According to Brucks and Town model (2009), a students’ preliminary preparation to inquiry laboratory, led by their teachers, is necessary and it should also continue during and after practical activities. In a constructivist perspective, in fact, students must possess preliminary knowledge to connect the new ones, without these hindering the investigation process. Teachers should ensure that students also master the necessary laboratory procedures and techniques, before carrying out inquiry-based activities independently (Meester et al., 1995).

For the structure of the inquiry path behind our research study, we have then identified a type of inquiry that could guide students in their investigations and at the same time provide teachers with a plot for organizing classroom activities, in order to eliminate the sense of frustration often experienced by teachers regarding inquiry activities (Criswell, 2012).

A method that has proved effective in structuring inquiry-based chemistry laboratory activities is the 5E learning cycle, developed by Bybee (1989) and based on previous pedagogical models, such as Herbart’s instructional model, Dewey’s instructional model, Heiss, Obourn, and Hoffman Learning Cycle, and Atkin-Karplus Learning Cycle.

The learning experience, proposed as an instructional sequence for course design or lesson planning, is divided into 5 phases. In an initial phase of ENGAGE, students develop interest in the subject and refresh already possessed knowledge; they are free to express their own opinions and observations, collected by the teacher. This phase has the task of attracting attention and stimulating curiosity in the students, representing the most important step whose organization will influence the success of the entire path (Bybee et al., 2006, Di Fabio et al., 2012; Christopher, 2013). In the second stage of EXPLORE, students acquire knowledge on the topic also through experimental activities, even suggesting different ways to experience the phenomenon (Bybee et al., 2006). The EXPLAIN phase is more teacher-directed as the teacher introduces scientific and technical information, clarifying students’ misconceptions, possibly emerged in the previous steps. Formal definitions, principles and laws are provided, even in digital form with video, software or computer animation (Bybee t al, 2006; Duran and Duran, 2004). In the ELABORATE phase, students apply what they have learned in a new and different situation, generally of a hands-on and minds-on type, while reinforcing new skills. The goal of this step is to help develop critical thinking skills and deeper understandings of the theoretical concepts through a transfer of learning (Bybee and Landes, 1988; Bybee et al., 2006; Stamp and O’Brien, 2005). In the final stage of EVALUATE there is the teacher’s evaluation of what has been learned and the students’ self-assessment or peer assessment. Assessment in this kind of inquiry-based setting is usually different than in traditional science lessons, including formal and informal approaches, such as the realization of portfolios, concept maps, digital products, demonstrating students' learning. However, it is possible to include a summative experience such as a test, exam, or writing assignment. (Bybee et al., 2006).

Numerous researches have demonstrated the effectiveness of the 5E learning cycle on students' conceptual understanding of scientific concepts, scientific reasoning and motivation in all school and university levels (Wilder and Shuttleworth, 2005; Bybee et al., 2006; Ceylan, 2009; Liu, 2009) and in pre-service and in-service teachers' training programme (Yalçin and Bayrakçeken,2010; Artun and Coştu, 2013; Ercan, 2014; Flaherty, 2017).

Recently, a few studies have used the 5E learning cycle in Flipped Classroom modality, developing the so called 5ELFA (Flipped Classroom Approach Based on the 5E Learning Cycle) Model (Jensen, Kummer and Godoy, 2015; Svensson and Adawi, 2015; Lo, 2017).

During the past few years, the Flipped Classroom methodology (FC) have been used throughout the world and in various educational contexts, as a promising alternative to traditional lectures and a theoretical and applicative systematization has been produced (Lage, Platt and Treglia, 2000; Bergmann and Sams, 2012; Bishop and Verleger, 2013; Roehl, Reddy and Shannon, 2013; O' Flaherty and Philips, 2015).

The FC usually reverses the two lecture's traditional steps, the face-to-face lesson inside class and the individual study outside class. In the FC, during the out-of-class learning steps, students explore the online learning resources, (e.g. texts, audio-visual products, multimedia, video lessons, but also interactive tools that allow simulations, virtual reproductions, contacts with experts), directly prepared or chosen in the Web by their teachers (Cecchinato, 2014). Moving activities concerning lower levels of Bloom's taxonomy (Krathwohl, 2002) outside class frees up the in-class time for higher level cognitive activities and interactive group learning or small- group tutoring, radically shifting from an instructional and teacher-centred educational setting to a constructivist and social one (Bergmann and Sams, 2008).

In our research, we describe the implementation of an inquiry-based learning path on the reactivity of metals, carried out in six classes of 11th grade students of three Italian high schools, using the 5ELFA model as a theoretical framework to discuss the overall design of the teaching and learning activities implemented, because it assists teachers with the implementation of the FC (Gerstein, 2015) and aligns teaching with what we know should optimally occurs in the process of human learning (Tanner, 2010).

Our main objective is to prove the effectiveness of this approach on the ability of students to develop the skills of experimental design and, secondarily, on the understanding of the disciplinary content knowledge linked to the activity. Results according to students' gender and different course of study are also included.

Finally, the results of questionnaires administered to teachers and students on the usefulness and interest of the approach described are presented.

4.1.1 The preliminary action-research

In the 2016/17 academic year, the Department of Chemistry of UNICAM organized a chemistry training course in blended mode (the "Online Chemistry Experiments: Instructions for Use" course) for 28 Science teachers, belonging to 12 High Schools of the Marche Region, funded by PLS (as thoroughly described in Chapter 3).

During the training course, two teachers of Liceo "Galilei" of Ancona were involved in an action research study on the application of the 5ELFA Model to the study of the reactivity of metals (C. Schettini et al, 2017). The monitoring and evaluation of the action research were carried out with survey questionnaires administered to teachers and students and two final tests for the assessment of knowledge and skills, related both to the activity in the virtual classroom and to the design and implementation of the laboratory activity. Teachers and students expressed a widely positive opinion on the usefulness and adequacy of the activities implemented with the new methodology, highlighting its critical points and strengths (C. Schettini et al, 2017).

The analysis and discussion of the action research results provided the basis for the pilot study described below.

4.2 Research method

In 2018/19 S.Y. , a pilot study on the application of the 5ELFA to the study of the reactivity of metals was carried on with a quasi-experimental research design, the **"One-Group Pre-test-Post-test Design",** a kind of experimental research in which a single group of research subjects is pre-tested, given some treatment and then post tested

(Fraenkel, Wallen and Hyun, 2011), as showed in Fig. 4.1.

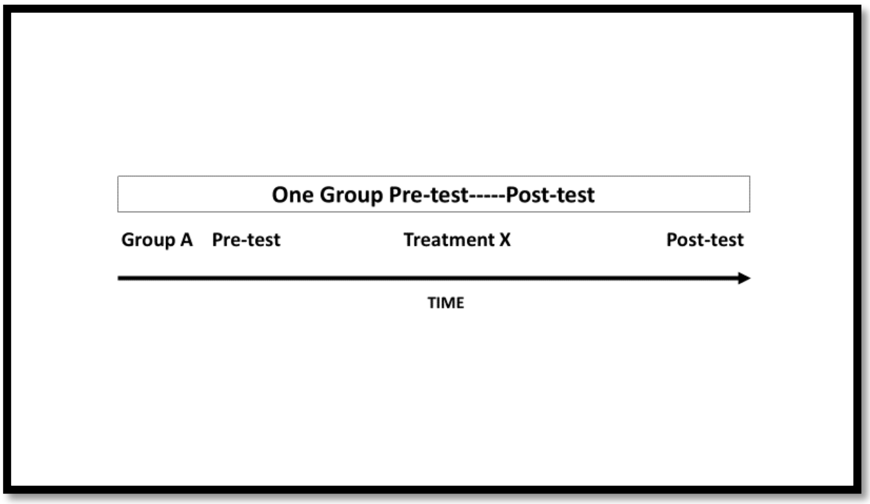


Fig. 4.1: Scheme of the "One-Group Pre-test-Post-test Design" method

Pre-tests and post-tests were used to assess the possible effects of the 5ELFA approach on the development of students' skills to design experiments and on chemistry knowledge related to the topic. Furthermore, teachers' and students' perception of the experimented approach were investigated through survey's questionnaires.

4.2.1 Sample

The research was organized in 3 Italian schools High Schools in Ancona, Jesi and Naples, involving 6 teachers and 137 students of 11th grade (those who completed the pre- and post-tests), 77 males and 60 females.

2 teachers had taken part to the previous action research and belonged to the same school; the others were included in this pilot study with their students as in the past they had worked in other projects with the researchers.

At the beginning of the research, teachers explained to the students that tests results would not be considered in their chemistry final assessment and that they were free to leave the study at any time. Researchers asked and obtained a parental permission for the activities.

All the students attended a 11th grade class (15-16 years old), but of different courses of study : 67 students belonged to 3 classes of Liceo Scientifico (SL=Scientific Lyceum), 44 students to two classes of Liceo Scientifico OSA opzione scienze applicate (SLOSA=Scientific Lyceum Applied Sciences option) and 26 to one class of Liceo Linguistico (LL=Linguistic Lyceum). The three courses differ in the number of Science

hours per week (3 hours in SL, 5 hours in SLOSA, 2 hours in LL).
Each teacher worked only with her students within the ordinary Chemistry curriculum. The proposed activities on the reactivity of metals were included in a learning unit on the Periodic Table, whose objective is the study of chemical elements properties, introducing redox reactions.
Students had never experienced either the FC or the IBSE methodology and they are used to a traditional transmissive teaching method. Since first year their curriculum included one to three hours of chemistry laboratory per week, according to the their course of study, so they should have quite a good laboratory practice. In the lab, a demonstrative method was generally adopted, and students performed experiments, completely guided by the teachers, only for a confirmation of what had been already learned.

4.2.2 Design of the lessons

A lesson plan according to the 5ELFA model was previously provided and discussed with teachers, with instructions on what to enter in the different steps.
In the most recent studies on the 5ELFA, the engagement, exploration, and explanation phase were implemented outside the classroom, whereas the in-class time was focused on the elaboration and evaluation phase (Jensen, Kummer and Godoy, 2015; Aşıksoy and Ozdamli, 2017). In Svensson and Adawi's research (2015), course design was similar to Jensen et al.'s, but the exploration phase was conducted inside the classroom. In its application of the 5ELFA model to history education, Lo (2017) suggested a cyclic model that performed the exploration, explanation and part of the engagement and evaluation phase outside the classroom. The focus of in-class learning was the elaboration phase and other activities related both to the engagement and evaluation steps (Table 4.1).

PHASE	JENSEN ET AL.	SVENSONN AND ADAWI	LO
ENGAGE	Out-of-class	Out-of-class	In-class/Out-of-class
EXPLORE	Out-of-class	Out-of-class	Out-of-class
EXPLAIN	Out-of-class	In-class	Out-of-class
ELABORATE	In-class	In-class	In-class
EVALUATE	In-class	In-class	In-class/Out-of-class

Table 4.1: The use of 5E Instructional Model in recent Flipped Classroom studies

In our lesson design, only the explain phase was implemented outside the classroom, due to the lack of familiarity of teachers and students both with digital media and with the inquiry methodology. Moreover, in this way teachers could promote students 'curiosity and activate their prior knowledge in the engagement phase and guide the exploration of the concepts more directly, instead of leaving students' exploration unguided outside the classroom (Figure 4.2).

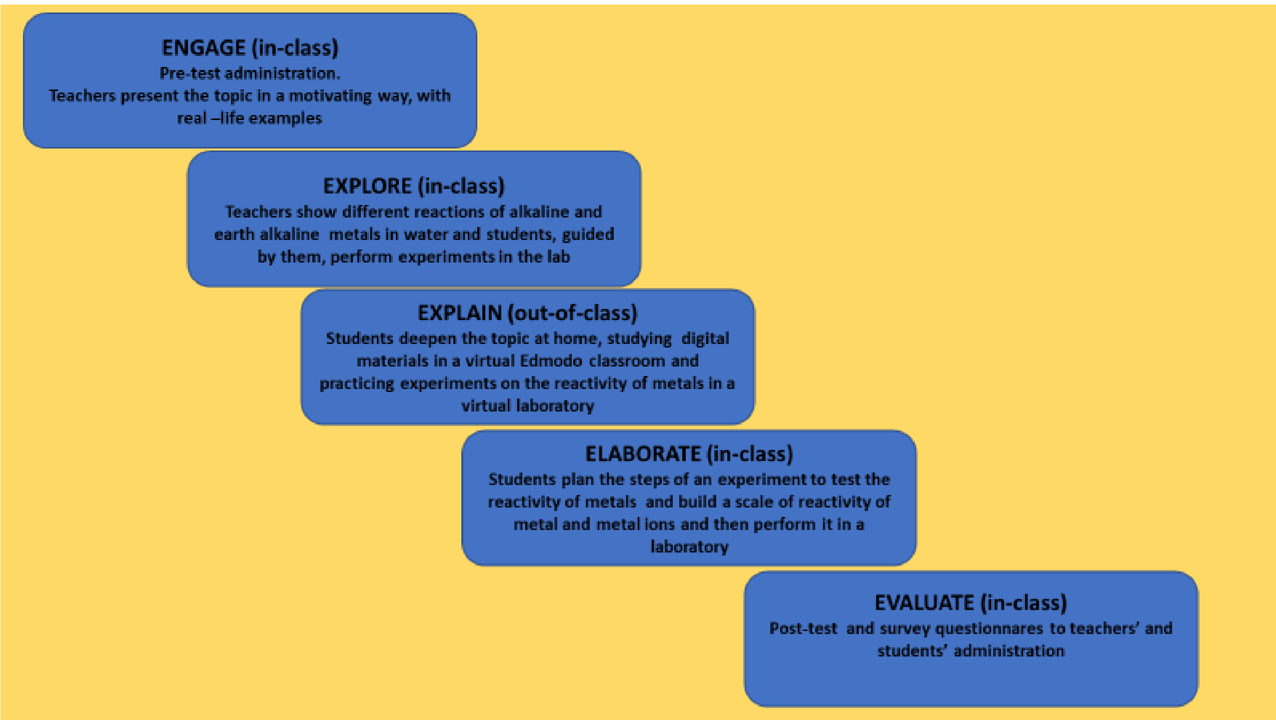


Figure 4.2: The 5ELFA steps of the experimentation

According to the 5E Learning Cycle, this was the structure of the activities:

- **ENGAGE phase (in-class)**

First, the teacher administered the pre-test to students and then presented the topic of the reactivity of metals, soliciting their curiosity and motivation (for example, talking about the different corrosion and acid resistance of metals). In the motivating phase, two short videos were shown on YouTube, one comparing the reactivity of Ag, Cu, Mg, Zn, Al and Fe; Cu and Zn[6] and another on the reactivity of alkaline metals in water[7].

- **EXPLORE phase (in-class)**

The teacher illustrated and explained alkaline and alkaline-earth metals reactions with water. Then, In the laboratory, the students, guided by the teacher, directly experimented the reactions. In this phase, the concept of redox reaction was introduced, to understand the mechanism underlying the different reactions of metals with water. The teacher also introduced the concept that a different reactivity is linked to the chemical properties of the elements and to their different tendency to lose electrons, i.e. to oxidize.

- **EXPLAIN phase (out-of-class)**

The EXPLAIN phase took place outside the classroom, with materials uploaded to a virtual EDMODO classroom, an informal online learning space[8], which also allows communication between the students and the teacher and between the students themselves, promoting collaborative teaching and students-centred learning (Trust, 2017).

Students could deepen their knowledge of the topic at their own pace, watching three original videos (Alkaline metals reactivity with water ; Earth Alkaline metals reactivity and Calcium reaction with water), designed and realized by the Department of Chemistry of UNICAM, following Mayer's design principles of multimedia learning (Mayer and Fiorella, 2014). First, videos length varied between 5 and 15 minutes, according to Mayer’s Segmenting principle, that suggests breaking a long video in a series of short videos to keep students’ attention alive, and to other research’s results (Mayer, 2005; Phillips and Trainor, 2014; Snyder, Paska and Besozzi, 2014).). Second, as people learn better when cues that highlight the organization of the essential material are added (Mayer’s Signaling principle), graphic underlines and voice emphasis on words were used to draw students ’attention to the essential concepts and laboratory procedures. Third, according to Mayer’s personalization principle, a conversational style rather than a formal style was adopted (Clark and Mayer, 2011).

[6] https://www.scienze.rai.it/articoli/tavola-periodica-metalli-modelli-direattivit%C3%A0/7812/default.aspx
[7] https://www.youtube.com/watch?v=jx0eQbBDeG8
[8] https://new.edmodo.com/?go2url=%2Fhome

Furthermore, a virtual laboratory was uploaded, developed by Thomas Greenbowe of the Department of Chemistry and Biochemistry of the University of Oregon[9].

In this laboratory, there are four simulation activities on the reactivity of metals and metal ions: in the first three the reactivity of different metals in solutions of other metals is compared, in the fourth the reactivity with hydrochloric acid.

- **Activity 1: Mg, Cu, Zn, Ag in Mg^{2+}, Cu^{2+}, Zn^{2+}, Ag^{+} solutions;**
- **Activity 2: Fe, Pb, Ni, Sn in Fe^{2+}, Pb^{2+}, Ni^{2+}, Sn^{2+} solutions;**
- **Activity 3: Zn, Cu, Fe, Pb in Zn^{2+}, Cu^{2+}, Fe^{2+}, Pb^{2+} solutions;**
- **Activity 4: Ag, Cu, Ni, Pb, Sn in HCl**

Students are guided to build a scale of reactivity of metals and metal ions by a tutoring sheet, while observing what happens in the virtual laboratory. The virtual laboratory shows the particulate level of the chemical reactions involved and the symbolic representation, according with Johnstone's model .This kind of visualization develops an understanding of chemistry that integrates conceptual knowledge with experimental procedures, lightening as well the cognitive load for students (Doymus et al., 2010; Lee and Osman, 2012; Davenport, 2018). The dynamic simulations have been also successfully used as a pre-lab to prepare students for the chemistry laboratory. (Williamson and Abraham, 1995; Winberg and Berg, 2007). Furthermore, students who used the computer simulation visualization in the pre-lab asked more and more theoretical questions during the laboratory activities than the traditional group and seemed to focus more on the concepts and interpreting what was happening at the particulate level (Hunter, 2019).

At the end of the out-of-class activity, students shared their opinions with the teachers and compared their learning experience with the other classmates.

- **ELABORATE PHASE (in-class)**

In this phase, students applied what they had previously learned, performing a laboratory experience on the same topic of the reactivity of metals, but with different substances. They were required to build the scale of reactivity of Cu, Zn, Al, Fe metals and Cu^{2+}, Zn^{2+}, Al^{3+}, Fe^{2+} metal ions, designing the different steps of the experiments autonomously, gathered in small groups (3-4 students). Szalay and Toth (2016)' s research on modifying traditional practical laboratory activities to ones where experiments have to be partially designed by students, led to the conclusions that these

[9] http://intro.chem.okstate.edu/1515F01/Laboratory/ActivityofMetals/home.html

partly student-designed activities appear to develop experimental design and motivate the lowest achievement group of students, even if used only a few times in the school year , compared to step-by-step traditional laboratory experiments.

At the end of the Elaborate phase, students wrote a lab report that was not evaluated in this research and reviewed and discussed their learning experience with the teacher.

- **EVALUATE PHASE (in-class)**

In the EVALUATE phase, the teacher administered the post-test, with the aim of assessing disciplinary content knowledge and students' ability to design an experiment, compared with what was measured in the pre-test.

At the end of the 5ELFA cycle, teachers and students were asked to fill out two different survey questionnaires.

The in-class activity lasted 7 hours, including time for the pre-test (40 minutes) and for the post-test (40 minutes). Out-of-time class spent by pupils studying on their own the materials in the virtual class is not included.

4.2.3 Data collection

4.2.3.1. Pre-test and post-test

The pre-test was completed in the first lesson and the post-test in the final lesson and students had 40 minutes to complete each test. Students were coded so that their teachers know the identities, but the researchers did not get this information.

The pre-test consisted of 11 items to assess disciplinary content knowledge (DCK) e 1 item to assess the ability to design an experiment (see Appendix 4). The post-test consisted of 8 items to assess disciplinary content knowledge and 2 items to assess the ability to design an experiment (see Appendix 5). In the pre-test students were also asked to write down their gender and the course of study attended.

The teachers were asked to mark students' answers to the pre-test and post-test questions and to record them in an Excel spreadsheet, following the instructions provided. The DCK items were chosen among those present in Cambridge International General Certificate of Secondary Education (Cambridge IGCSE) Chemistry final tests, developed by the University of Cambridge (Norris, 2015). As Cambridge IGCSE programme, a two-year qualification aimed at 14- to 16-year-olds, encourages learner-centred and inquiry-based approaches to learning (Shaw and Bailey, 2011), the related final tests' questions assess both factual knowledge, understanding and their application

(Bloom taxonomy).

The pre-test items concerned knowledge of the sub-microscopic structure of the matter and knowledge related more specifically to the structure and characteristics of metals and some of them proposed an experimental problem. The post-test items referred almost exclusively to knowledge of the reactions of metals and metal ions. All items were 4-options multiple-choice and had been translated from English language by a specialized mother-tongue translator.

Regarding the assessment of the ability to design an experiment, specific examples were not found in the literature, therefore the task included in the pre-test was taken from an experimental research on the application of problem solving in the Chemistry laboratory, conducted by Falasca, Martini and Nota Angeleri, with 14-16 years old students.[10]

The two tasks included in the post-test were instead taken from the 2018 exam test of the Cambridge International AS and A Level Chemistry course, whose syllabus includes the main theoretical concepts which are fundamental to the subject and a strong emphasis on advanced practical skills (Norris, Ryan and Acaster, 2011). The structure of the questions asked to students to guide them in the task derived from Szalay and Toth's research on an inquiry-based approach of traditional 'step-by-step' experiments (Szalay and Toth, 2016).

The pre-test item measuring the ability to design an experiment was as follows (translated from Italian to English):

Task 1. Your teacher gives you a mixture of sand, sea salt and acetone. Design an experiment to separate the three components.

The 2 items measuring the ability to design an experiment in the post-test were as follows (originally in English):

Task 2. Design an experiment to prepare metallic copper from a Cu^{2+} *solution (A scale of reactivity of metals is provided)*

Task 3. Design an experiment to check if Zinc is a more reactive metal than Silver. Refer to the scale provided in the previous task).

4.2.3.2 Survey questionnaires

Students' questionnaire consisted of three parts and 11 questions. After a first part asking demographic information (gender and course of study), in the second section there were

10 http://www.itismajo.it/chimica/SiteAssets/default/Mappe%20concettuali%20PS/Problem%20Solving%20e%20cooperative%20learning%20nella%20didattica%20delle%20scienze%20sperimentali.pdf

questions on which activity they preferred most, which they found more interesting or difficult or they thought more useful for the design of the experiment. In the third part questions concerned their opinion about this approach's potential in increasing their motivation to study chemistry and if they would like to repeat it again with different topics. Finally, in the last question they could express freely their opinions on the experimentation (see Appendix 6). The questionnaires were anonymous and filled out online with Google forms.

Teachers' questionnaire consisted of three parts and 16 questions, After a first part asking demographic information (gender, age, academic degree, course of study), in the second section teachers answered to questions regarding the 5ELFA procedure, developed with students. In the third part, there were questions about teachers' opinion on this new approach, including their perception of weak and strong points. The questionnaires were anonymous and filled out on the Moodle platform hosting the online training course, previously attended by teachers (see Appendix 7).

Some questions were the same in both the questionnaires to allow a comparison between students' and teachers' opinions.

4.2.4 Data analysis

The data obtained from the pre-test and the post-test were analyzed using statistical analysis techniques. Firstly, we determined the scores of all tasks questions, DCK task questions and design tasks questions that each student obtained in the pre-test and post-test.

Since scores attributed to DCK task and design task in the pre-test were different from the post-test's ones (pre-test DCK scores=8; post-test DCK scores=6; pre-test design scores=3; post-test design scores =6), we normalized such values to compare them. Each normalized value was calculated dividing each student's score by the maximum one. Even if the total scores for pre-test and post-test were the same (14), we normalized it as well for presenting the results in a uniform way.

Then we computed means and standard deviation for normalized data collections. Furthermore, we also determined the difference between means. To verify the statistical significance of the difference between means, we applied the two-tailed *t*-test (Student's *t*-test) for correlated means that is used to compare the mean scores of the same group before and after a treatment of some sort is given, to see if any observed gain is

significant (Fraenkel, Wallen and Hyun, 2011).
Finally, we determined the frequency distribution of the scores of pre-test and post-test and we represented such data using the frequency polygons.
All the statistical analysis were accomplished by Excel.
The percentage of the different answers to the teachers' questionnaire and the students' questionnaire were automatically delivered by Moodle and Google Modules systems respectively.

4.2.5 Research questions

The goals of this study were guided by the following research questions (RQs):
RQ1. Is there any significant change in the students' ability to design experiments after the experimentation, measured by the comparison between the design tasks' results in pre-test and post-test? Is there any difference according to the gender and to the different course of study attended?
RQ2.Do students achieve significantly different scores in the post-test comparing to the pre-test, considering all the tasks? Do students achieve significantly different scores in the post-test comparing to the pre-test, considering the tasks measuring disciplinary content (DCK)? Is there any difference according to the gender and to the different course of study attended?
RQ3.How did teachers perceive the 5ELFA approach and what are its pros and cons from the teacher's perspective?
RQ4.How did the students perceive the 5ELFA classroom approach?

4.3 Results and discussion

4.3.1 Results according to the type of tasks

The summarized results of the pre-test and the post-test for the different types of tasks are given in Table 4.2. As stated before, DCK tasks are referred to disciplinary content knowledge.
There are statistically significant differences in the achievement of pre-test and post-test results, both for all the tasks and for each task. Looking at the results of all tasks, a small but significant difference of the intervention is shown (+0.12). This increase of

achievement is most likely due to the significant increase in the ability to design experiments (+0.21), compared to the achievement in the DCK tasks (+0.10). It is then interesting that the 5ELFA approach seems to help students to develop experiment design skills.

TASKS	M Pre-test	SD Pre-test	M Post-test	SD Post-test	Δ	P[a]
All tasks	0.55	0.22	0.67	0.24	+0.12	+
DCK task	0.60	0.23	0.70	0.22	+0.10	+
Design task	0.36	0.35	0.57	0.33	+0.21	+

a +: significant difference (p< o.o1)

Table 4.2: Means (M), standard deviation (SD) and their differences (Δ) of the average results of pre-tests and post-tests, according to the type of task. Legend: DCK=Disciplinary Content Knowledge

4.3.2 Results according to gender

Table 4.3 shows the average results of the pre-tests and the post-tests according to gender in the different type of tasks. Both boys' and girls' achievements increased significantly in the post-test (all tasks) and this appears more significant for girls than for boys. Looking at the results grouped according to the types of tasks, this is probably due to the more significant increase in the ability to design experiments of both boys and girls, more evident for girls. The proposed approach appeared then to help develop experiment designing of both boys and girls, but more significantly for girls.

TASKS	M Pre-test	SD Pre-test	M Post-test	SD Post-test	Δ	P[a]
Boys/All tasks	0.55	0.26	0.64	0.27	+0.09	+
Girls/All tasks	0.55	0.16	0.71	0,15	+0.16	+
Boys/DCK tasks	0,61	0.27	0,69	0.26	+0,08	+
Girls/DCK tasks	0,60	0.15	0,71	0.13	+0,11	+

a +: significant difference (p< o.o1)

Table 4.3: Means (M), standard deviation (SD) and their differences (Δ) of the average results of pre-tests and post-tests, according to gender

4.3.3 Results according to different course of study

Table 4.4 shows the average results of the pre-tests and the post-tests according to the different course of study (Linguistic Lyceum, Scientific Lyceum and Scientific Lyceum Applied Sciences option).

The highest significant increase for all tasks was achieved by the students of SL, followed by SLOSA and LL. As for DCK tasks, there was a significant increase only for the SL, while the decreases in the LL and the slight increase in SLOSA were not statistically significant.

Looking at the design tasks, there were significant increases for all courses of study, more evident for LL. These results appeared to show that the ability to design experiments can be appropriately stimulated even in courses of studies that dedicate less hours to laboratory activities.

TASKS	**M** **Pre-test**	**SD** **Pre-test**	**M** **Post-test**	**SD** **Post-test**	**Δ**	**P[a]**
LL/All tasks	**0.57**	**0.13**	**0.63**	**0.15**	**+0.06**	**+**
SL/All tasks	**0.53**	**0.19**	**0.69**	**0.17**	**+0.16**	**+**
SLOSA /All tasks	**0.56**	**0.18**	**0.67**	**0.18**	**+0.11**	**+**
LL/DCK tasks	**0.65**	**0.13**	**0.64**	**0.10**	**-0.01**	**-**
SL /DCK tasks	**0.57**	**0.19**	**0.75**	**0.13**	**+0.18**	**+**
SLOSA/DCK tasks	**0.63**	**0.17**	**0.66**	**0,13**	**+0.03**	**-**
LL/Design tasks	**0.29**	**0.32**	**0.58**	**0.28**	**+0,29**	**+**
SL /Design tasks	**0.40**	**0.35**	**0.57**	**0,31**	**+0.17**	**+**
SLOSA/Design tasks	**0.32**	**0.38**	**0.56**	**0.34**	**+0.24**	**+**

a +: significant difference (p< o.o1)

Table 4.4: Means (M), standard deviation (SD) and their differences (Δ) of the average results of pre-tests and post-tests, according to the different course of study. Legend: DCK (disciplinary Content Knowledge); LL (Linguistic Lyceum); SL (Scientific Lyceum). SLOSA (Scientific Lyceum Option Applied Sciences).

4.3.4 The distribution of the scores of all the tasks in the pre-test and in the post-test

The frequency distribution of the scores for all the tasks in the pre-test and in the post-test is presented in Table 4.5 and as a graph in Fig. 4.3, in the form of frequency polygons.The frequency polygon for the pre-test is slightly positively skewed, whereas the post-test polygon is slightly negatively skewed, since the longer tail of the distribution goes off to the left. In this case, fewer individuals reach lower scores compared to the ones achieving higher scores (Fraenkel, Wallen and Hyun, 2011).

It is interesting to compare the two polygons obtained for the pre-test and the post-test, as it is evident that the post-test resulted in higher scores, overall, than did the pre-test. In the pre-test there were fewer scores below 8, that is the more frequent score for both the pre-test and the post-test: 29 in the post-test, 60 in the pre-test. Furthermore, if we look at the score over 8, we obtained more cases in the post-test (85) than in the pre-test (51). Then, after the intervention, we obtained an evident shift of the frequency distribution from the lower to the higher scores for all the tasks.

Score	Frequency(Pre-test)	Frequency (Post-test)
p-1	0	0
p-2	1	0
p-3	8	0
p-4	5	2
p-5	14	8
p-6	15	5
p-7	17	14
p-8	26	23
p-9	21	15
p-10	13	21
p-11	6	20
p-12	7	15
p-13	4	10
p-14	0	4

Table 4.5: Frequency distribution of the scores of pre-test and post-test

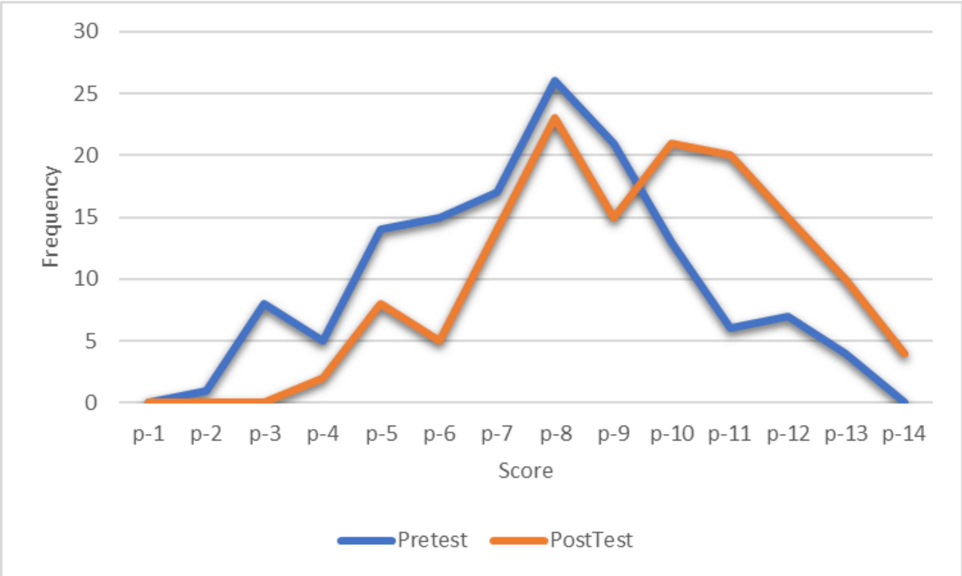


Figure 4.3: Frequency polygons of the scores of pre-test and post-test

4.3.5 The distribution of the marks of the design tasks

The design tasks marks were attributed by the teachers, according to the instructions received from the researchers. There were four answers categories, according to Szalay and Toth's research (Szalay and Toth, 2016):

- *Mark 3: All the steps of the experiment are described. Predicted observations and explanations are provided.*
- *Mark 2: All the steps of the experiment are described, together with observations and explanations, but observations and explanations are not clearly separated.*
- *Mark 1: All the steps of the experiment are described, but either the predicted observations or the explanations is not complete.*
- *Mark 0: In any other case.*

The distribution of students' marks for the design tasks were compared by analyzing the frequency of the correct answers in the pre-test (one question Q1) and in the post-test (two questions Q1 e Q2), as shown in Table 4.6 and in Figure 4.4 and 4.5.

The frequency of students achieving 0 marks decreased from 0.42 to 0.21 for Q1 and from 0.42 to 0.17 for Q2. Furthermore, the frequency of students who received 3 marks increased, from 0.11 to 0. 34 for Q1 and from 0.11 to 0.25 for Q2. Students achieving 1 mark decreased for Q1 (from 0.20 to 0.14) and increased for Q2 (from 0.20 to 0.27). Students achieving 2 points increased slightly (from 0.27 to 0.31) for both Q1 and Q2. Looking at the gender, the post-test results confirmed girls' better performance than boys', more evident for mark 3 compared to the pre-test ((Q1 +0.33 and Q2 +0.22 girls; Q1 +0.14, Q2 +0.8 boys).

In all three courses of study and for both questions, the frequency of students achieving 0 marks decreased compared to the pre-test (in particular, -0.24 Q2 SLOSA and -0.31 Q2 LL). Students receiving 1 mark decreased slightly in the SL and increased only for Q2 SLOSA (+ 0.12) and Q2 LL (+ 0.23). Mark 2' s frequency remained stable, while the frequency of mark 3 improved everywhere (especially, + 0.25 Q1 SLOSA and + 0.42 Q1 LL).

TASKS	Mark 0	Mark 1	Mark 2	Mark 3
All Pre-test (Design Task)	0,42	0,20	0,27	0,11
ALL Post-test (Design Task) Q1	0,21	0,14	0,31	0,34
All Post-test (Design Task) Q2	0,17	0,27	0,31	0,25
Girls Pre-test (Design Task)	0.37	0.20	0.33	0.10
Girls Post-test (Design Task) Q1	0,10	0,12	0,35	0,43
Girls Post-test (Design Task) Q2	0,17	0,22	0,30	0,32
Boys Pre-test (Design Task)	0,47	0,19	0,22	0,12
Boys Post-test (Design Task) Q1	0,30	0,16	0,30	0,26
Boys Post-test (Design Task) Q2	0.17	0,31	0,32	0,20
LL Pre-test (Design Task)	0,50	0,12	0,38	0.00
LL (Design Task) Q1	0,08	0,15	0.35	0,42
LL (Design Task) Q2	0,19	0,35	0,38	0,08
SL Pre-test (Design Task)	0,34	0,22	0,32	0,12
SL Post-test (Design Task) Q1	0,18	0,15	0,42	0,25
SL Post-test (Design Task) Q2	0,16	0,21	0,39	0,24
SLOSA Pre-test (Design Task)	0,50	0,20	0,14	0,16
SLOSA Post-test (Design Task) Q1	0,34	0,11	0,14	0,41
SLOSA Post-test (Design Task) Q2	0,16	0,32	0,16	0,36

Table 4.6: Distribution of frequency of the design task marks in the post-test

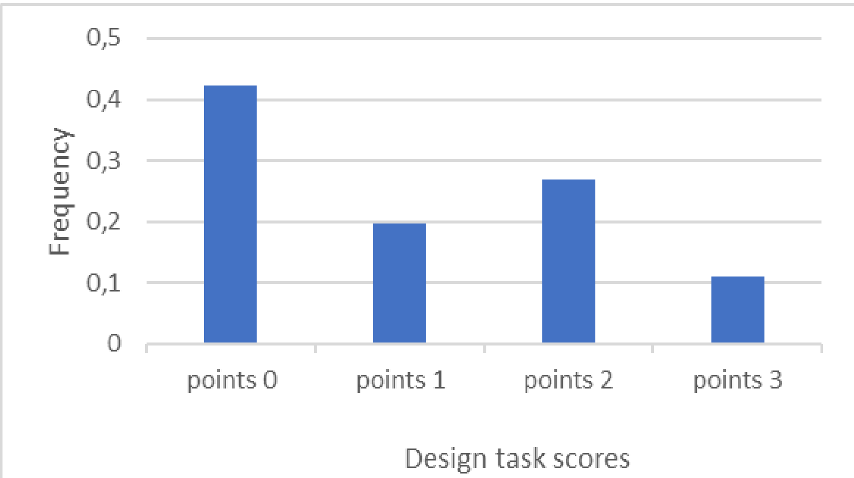


Figure 4.4: Distribution of frequency of the design task marks in the pre-test (one question, all students)

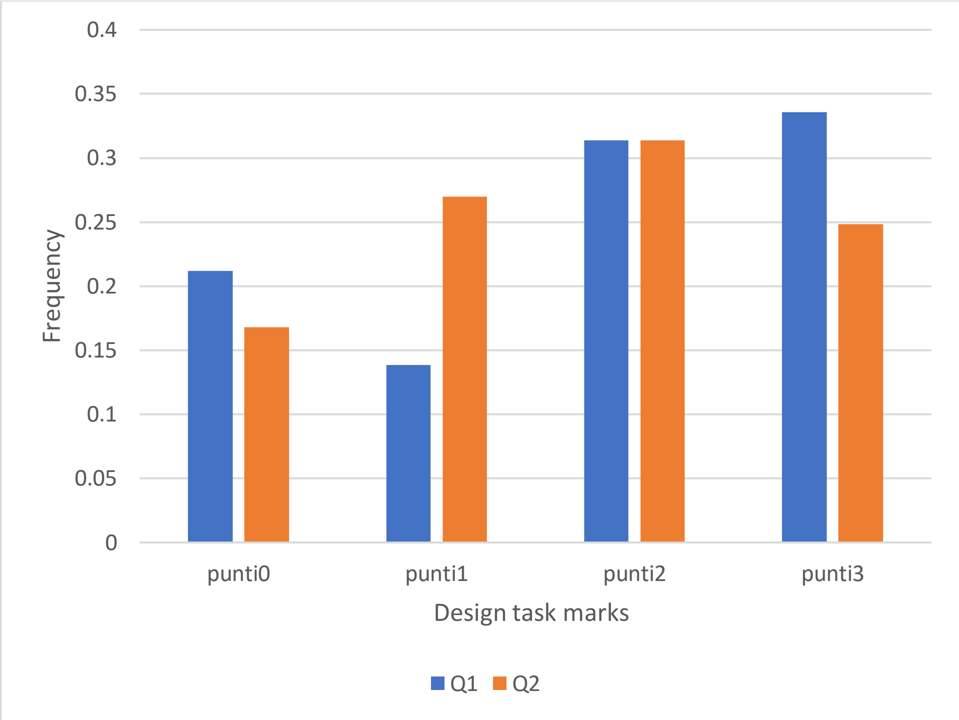


Figure 4.5: Distribution of frequency of the design task marks in the post-test (two questions, all students)

4.3.6 Teachers' perception

All the six teachers answered the questionnaire; they are all females, four are graduates in Biology, one in Chemistry and one in Natural Sciences; one is aged between 46 and 55 and the other five are over 56 years old. Of these, three conducted the research in the SL classes, two in the SLOSA and one in the LL. Only two of them had already applied the 5ELFA methodology in the previous action research, while the others experimented the FC or Inquiry methodology in the past, but not a combination of the two with the 5ELFA approach.

Teachers believed that the most participated activities were the one implemented in the laboratory , both the guided one in the EXPLORE phase (33%) and the autonomous design of the experiment in ELABORATE phase (33%), but also the discussion in-class after studying in the virtual classroom (33%). 66.67% of teachers considered the discussion in class after the EXPLAIN phase the most difficult step for them to organize, while for 16.67% was the presentation of the activities in the ENGAGE phase and for a another 16.67% the setting and use of the EDMODO virtual class.

The comparison between the answers to the questions on the activities of the 5ELFA asked both to the teachers (*What activity do you believe students found more interesting?*

Which activity do you believe students found more difficult? Which activity do you believe students found more useful for the design of the experiment?) and to the students (*Which activity did you find more interesting? More difficult? More useful for the design of the experiment?*) showed the results, reported in Table 4.7.

Question		Teacher's lesson	Laboratory guided by teacher	Virtual lab	Debate after the virtual lab	Autonomous Design and performance of the experiment
What activity do you believe students found more interesting?	Teachers	0,00%	0,00%	50,00%	0,00%	50,00%
	Students	4, 60%	46,90%	2,00%	1,50%	44,60%
Which activity do you believe students found more difficult?	Teachers	0,00%	0,00%	33,33%	16,67%	50,00%
	Students	30,20%	3,10%	14,00%	16,30%	31,00%
Which activity do you believe students found more useful for the design of the experiment?	Teachers	0,00%	33,33%	50,00%	16,67%	
	Students	28,20%	34,40%	15,30%	21,40%	

Table 4.7: Answers to the teachers' and students' survey questionnaire (second part)

From this answers' comparison, it was clear that teachers' perceptions of students' interest in the virtual laboratory is different from theirs, as 46.90 % of students preferred a traditional, teacher guided laboratory, an option that teachers had not considered at all. Teachers' perception of interest in the ELABORATE phase instead agreed with students' opinion, confirming students' greater interest in the laboratory and in more active steps of the experimentation. As the research indicates, using active learning in the FC approach can increase student satisfaction over traditional, non–active learning approaches (Bergstrom, 2011; Tucker, 2012; Olakanmi, 2017).

Even teachers' perception of the difficulties encountered in the virtual lab were different from great majority students' opinion who didn't consider it particularly demanding. Moreover, differently from teachers' opinion, lectures in the ENGAGE phase were considered difficult by 30.20% of the students, probably because conducted with a traditional approach and more references to the symbolic level of chemical phenomena. 31% of students believed that the autonomous design of the experiment was the most difficult step, despite the interest shown, but with a percentage lower than the one expressed by teachers (50%).

For teachers, a new skill, requiring a greater degree of student autonomy, was considered more demanding for students who, instead, found more difficulties in following an almost exclusively theoretical exposition of concepts.

Even the answers to the last question confirmed teachers' and students' different opinion on the usefulness of the virtual laboratory for the autonomous design of the experiment. Possibly for students a virtual laboratory was not a familiar learning methodology and they still needed teachers' guidance, both in the laboratory activity of the EXPLORE phase and in the classroom discussion after the out-of-class phase. Moreover, despite the teacher's theoretical lessons being considered the most difficult by 30.20% of the students and the most interesting by only 4.60%, 28.20% of the students considered them the most useful for the autonomous design of the experiment. As stated by Jensen (2015) in his study on the application of a 5ELFA approach the teacher and/or peer interaction had greater influence on students 'perceptions of learning than the out-of-class activities , probably due to the adjustable method of feedback, available in a face-to-face format as opposed to the predetermined feedback of a virtual environment.

As for the third part of the questionnaire, both teachers and students believed that this methodology made the study of chemistry more interesting, with a higher percentage of students strongly in agreement (27.5%) compared with teachers (16.67%), despite the fact that the percentage of students and teachers considering it also an easier approach to the study of chemistry were lower. Therefore, highlighting that this approach could be more demanding than the traditional ones didn't prevent teachers and students from finding it more motivating (see Table 4.8).

Finally, in large majority, students and teachers expressed their interest in applying this kind of approach to other chemistry topics, with a slightly higher percentage of teachers. Furthermore, teachers believed that this method helps students develop higher skills in addition to the acquisition of knowledge.

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
This methodology makes chemistry more interesting	Teachers	16,67%	83,33%	0,00%	0,00%	0,00%
	Students	27,5%	65.6%	6.1%	0,00%	0,00%
This methodology makes chemistry easier	Teachers	16,67%	66,67%	16,67%	0,00%	0,00%
	Students	19,10%	58,00%	19.10%	3,10%	0,80%
I'd like to apply this methodology to other chemistry topics	Teachers	33,33%	66,67%	0,00%	0,00%	0,00%
	Students	26,00%	55,70%	15,30%	3,1%	0,00%
I believe that this methodology helps students to develop scientific skills	Teachers	50,00%	50,00%	0,00%	0,00%	0,00%

Table 4.8: Answers to the teachers' and students' survey questionnaire (third part)

Regarding the 5ELFA approach, teachers indicated as the strongest point the greater engagement of students in their learning and therefore a more active role and greater autonomy and responsibility.

They believed that the opportunity for students to study in a digital classroom, supported by videos and other materials, and to practice in a virtual laboratory, allowed them to have an overview of the topic, so they could better follow activities in the classroom and especially in the lab, playing an active role in practice and discussion.

In general, teachers' opinion was that awareness in doing activities at school and in analyzing the results of experiments was increased. They found this approach inclusive as students can learn topics according to their times and specific formative needs and also able to relate Chemistry concepts to real-life contexts more motivating for students, as suggested by researchers (Mahaffy, 2004; Sjöström, 2013),

-*Greater engagement of the student who plays an active role in the acquisition of new knowledge and skills*

- *Students, starting from a research question, are more motivated to study and to design an experiment providing the right answer. They can apply the scientific method in its epistemological bases. This approach helps the acquisition of a correct scientific* *attitude.*

-The 5ELFA helps students to become more autonomous and responsible in the study

- This approach brings chemistry closer to real-life, effectively attracting students' interest.

On the other hand, teachers considered as the first issue to be improved a better definition of the times suggested by the researchers for the different phases that were considered insufficient. Furthermore, they expressed the need to encourage more collaboration among students and to enhance guidance for less motivated or lower skilled pupils. Some of them considered the step following the ELABORATE phase a critical one where there was the need to help students consolidate the knowledge acquired in the laboratory.

4.3.7 Students' perception

All students answered the survey questionnaire (132 students; 52.7% Males, 47.3% females; 44.3% SL ; 33.6% SLOSA, 22.1% LL).

This section analyzes the answers to questions addressed only to students. For them, the activities that most contributed to clarifying the concepts on the reactivity of metals were those guided by the teacher, both the lessons (32.8%) and the laboratory activity (21.4%).For this purpose, the virtual laboratory was positively evaluated by 18.3% of the students, followed by the autonomous design of the experiment (15.3%), both activities requiring students' greater autonomy and responsibility in learning.

In the survey, the students could add comments that were consistent with the results from the quantitative part of the survey, and revealed that the students found the 5ELFA approach interesting and motivating:

-I found this experience very interesting and I believe that this method forces students to fully enter in the topic. Even if at the beginning it is really challenging, in the end it turns out to be very exciting and engaging.

-It was a formative experience and, in my opinion, it's very helpful to have a virtual lab for those who have great difficulty in understanding chemistry.

-I found interesting each of the activities performed, especially the virtual lab and the teacher-led lab that help me understand the reactivity of metals.

4.4 Conclusions

To answer RQ1, it could be stated that a positive change was measured in the ability to design experiments as a result of the intervention, as shown by the analysis of the means and the study of the frequency of the different marks achieved by students in the pre-test and in the post-test. There was a significant increase in the ability to design experiments for both boys and girls, more evident for girls, and in all the courses of study attended, with an interesting progression of Linguistic Lyceum's students where usually little time is reserved for laboratory activities.

In this pilot study, it is not possible to allocate this result to a specific phase of the 5ELFA approach, for whose identification a further study could be useful, even conducted with a control group. It is probably the pedagogical model of the 5E learning cycle, based on constructivism theory and inspired by the Information Processing Model (Johnstone, 1997), which allowed students, after an initial phase of orientation and explanation of the concepts, to apply the new knowledge, and also the practical skills developed in the EXPLORE phase, in new, but familiar contexts. The integration of the 5E with the Flipped Classroom allowed students to extend the EXPLAIN step out of class , with the possibility of reviewing the videos of the experiments and preparing for the next activity of designing an experiment with the practice in the virtual laboratory.

From the analysis of teachers' questionnaires, it emerges that, in their opinion, the preliminary practice in the virtual laboratory mainly helped students for the design of the experiment. On the other hand, students gave more weight to all the activities in some way guided by the teacher, including however the in-class debate on the virtual laboratory activities.

In any case, the proposition of an inquiry activity, even if not of the open-ended type, but partially guided and scaffolded by the virtual laboratory, seems to improve students' ability to design an experiment, one of the investigation skills needed for scientific literacy.

It is also interesting that this improvement is more evident in girls than in boys, suggesting a next, more in-depth study. Regarding the different courses of study, the results highlight the achievement of similar design ability to design an experiment, even starting from different pre-test levels, especially for LL students, a course of study in which experimental activity in chemistry is less considered.

Regarding Q2, there is a general improvement both for all the tasks and for DCK tasks, highlighted by the comparison between the averages and by the comparison between the frequency distributions of scores. The progress related to all tasks seems more due to progress in the ability to design an experiment than in DCK tasks, where an improvement is present, but less substantial. This may suggest that this approach contributes less substantially to the acquisition of knowledge, therefore requiring a further debate after the laboratory to consolidate the concepts acquired or the design of further didactic strategies.

Regarding RQ3 and RQ4, the positive acceptance of this approach by both teachers and students has already been highlighted, as well as the emphasis on its ability to motivate students to Chemistry and to develop scientific skills.

In conclusion, even if this approach does not fully develop investigation skills such as open-ended inquiry, it can be a first application of the inquiry method, when teachers and students have not practiced it extensively before and students don't have enough skills.

The positive result of an initial approach to Inquiry which provides guidance and scaffolding to students, as suggested by Criswell (2012) and Szalay and Toth (2016), has been confirmed in this study by pre-test and post-test comparison and by students' response to the survey questionnaire, highlighting the interest in the autonomous planning activities, but still trusting in teachers' support.

Furthermore, this first approach could satisfy the demands of high school teachers, facing challenges as large class size and little time to practice open inquiry. As a matter of fact, the integration with the FC methodology allows to free up time for more collaborative and investigative in-class activities. Hopefully, a first positive approach could encourage teachers to start applying more complex and less guided inquiry activities, opening the way to an effective introduction of inquiry-based learning in chemistry.

Bibliography

- Allen J. B., Barker L. N. and Ramsden J. H., (1986), Guided Inquiry Laboratory, J. Chem. Educ., 63, 533–534.
- Artun, H., & Coştu, B. (2013). Effect of the 5E model on prospective teachers' conceptual understanding of diffusion and osmosis: A mixed method approach. Journal of Science Education and Technology, 22(1), 1-10.

- Aşıksoy, G., & Ozdamli, F. (2017). The Flipped Classroom Approach Based on the 5E Learning Cycle Model-5ELFA. Croatian Journal of Education: Hrvatski časopis za odgoj i obrazovanje, 19(4), 1131-1166.
- Atkin, J. M., & Karplus, R. (1962). Discovery or invention?. The Science Teacher, 29(5), 45-51.
- Berg, C. A. R.; Bergendahl, V. C. B.; Lundberg, B. K. S. Int. J. Sci. Educ. 2003, 25, 351–372.
- Bergmann, J. and Sams, A. (2012) Flip your classroom: Reach every student in every class every day. International Society for Technology in Education.
- Bergmann, J., & Sams, A. (2009). Remixing chemistry class: Two Colorado teachers make vodcasts of their lectures to free up class time for hands-on activities. Learning & Leading with Technology, 36(4), 22-27.
- Bergtrom, G. (2011). Content vs. learning: An old dichotomy in science courses. Journal of Asynchronous Learning Networks, 15(1), 33-44.
- Bishop, J. L. and Verleger, M. A. (2013) The flipped classroom: A survey of the research. In ASEE National Conference Proceedings, Atlanta, GA.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational researcher, 18(1), 32-42.
- Bruck L. B. and Towns M. H., (2009), Preparing Students to Benefit from Inquiry-Based Activities in the Chemistry Laboratory: Guidelines and Suggestions, J. Chem. Educ., 56(7), 820–822.
- Bybee, R. (2000). Teaching science as inquiry, In J. Minstrel, & E. H. Van Zee (eds.). Inquiring into inquiry learning and teaching in science, pp. 20-46. Washington DC: American Association for the Advancement of Science (AAAS).
- Bybee, R. W. (1989). Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction.
- Bybee, R. W., & Landes, N. M. (1988). The biological sciences curriculum study (BSCS). Science and Children, 25(8), 36-37.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. Colorado Springs, Co: BSCS, 5, 88-98.
- Cecchinato, G. (2014). Flipped classroom: innovare la scuola con le tecnologie digitali. Italian Journal of Educational Technology, 22(1), 11-20.

- Ceylan, E., & Geban, O. (2009). Facilitating conceptual change in understanding state of matter and solubility concepts by using 5E learning cycle model. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 36(36).
- Cheung D., (2011), Teacher Beliefs about Implementing Guided-Inquiry Laboratory Experiments for Secondary School Chemistry,J. Chem. Educ., 88, 1462–1468.
- Christopher, C. M. (2013). Improving Chemistry Instruction via the 5-E Learning Model: Inventing, Adapting and Incorporating the First "E.
- Clark, R. C., & Mayer, R. E. (2011). E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning (3rd Edition) San Francisco, CA: John Wiley & Sons.
- Criswell B., (2012), Framing Inquiry in High School Chemistry:Helping Students See the Bigger Picture, J. Chem. Educ., 89,199–205.
- Davenport, J. L., Rafferty, A. N., & Yaron, D. J. (2018). Whether and How Authentic Contexts Using a Virtual Chemistry Lab Support Learning. Journal of Chemical Education, 95(8), 1250-1259.
- Dewey, J. (1910). How we think. Boston: Health & Co.
- Di Fabio, A., Raschi, A., Sebastiani, L., Ugolini, F., & Palazzeschi, L. (2012).ACARISS project: From the knowledge of the environment and risks related to pollution to the guidance of students Il progetto ACARISS: dalle conoscenze sull'ambiente ei rischi connessi.
- Doymus K., Karacop A. and Simsek U., (2010), Effects of jigsaw and animation techniques on students' understanding of concepts and subjects in electrochemistry, Educ. Technol. Res. Dev., 58, 671–691, DOI: 10.1007/s11423-010-9157-2.
- Duran, L. B., & Duran, E. (2004). The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching. Science Education Review, 3(2), 49-58.
- E. D. Heiss, E. S. Obourn, and C. W. Hoffman (1950). Modern Science Teaching, New York: The Macmillan Company, 1950.
- Ercan, O. (2014). Effect of 5E learning cycle and V diagram use in general chemistry laboratories on science teacher candidates 'attitudes, anxiety and achievement. International Journal of Social Sciences and Education, 5(1), 161-175.
- Europea, C. (2006). Raccomandazione del Parlamento europeo e del Consiglio relativa a competenze chiave per l'apprendimento permanente. Estratto da http://eurlex. europa. eu/legal-content/IT/TXT.

- Flaherty, A., O'Dwyer, A., Mannix-McNamara, P., & Leahy, J. J. (2017). Evaluating the Impact of the "Teaching as a Chemistry Laboratory Graduate Teaching Assistant" Program on Cognitive and Psychomotor Verbal Interactions in the Laboratory. Journal of Chemical Education, 94(12), 1831-1843.
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2011). How to design and evaluate research in education. New York: McGraw-Hill Humanities/Social Sciences/Languages.
- Germann, P. J. J. Res. Sci. Teach. 1989, 26, 237–250.
- Gerstein, J. (2015) The flipped classroom model: A full picture. Blog entry, accessed 150524
- Gunstone, R. F. (1991). Reconstructing theory from practical experience. Practical science, 67-77.
- Hancock, C.; Kaput, J. J.; Goldsmith, L. T. Educ. Psychol. 1992, 27, 337–364.
- Herbart, J. F. (1901). Outlines of Educational Doctrine. New York: McMillan Company.
- Hofstein, A. (2004). The laboratory in chemistry education: Thirty years of experience with developments, implementation, and research. Chemistry education research and practice, 5(3), 247-264.
- Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005); Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. Journal of research in science teaching, 42(7), 791-806.
- Jensen, J. L., Kummer, T. A., & Godoy, P. D. D. M. (2015). Improvements from a flipped classroom may simply be the fruits of active learning. CBE—Life Sciences Education, 14(1), ar5.
- Johnstone, A. H. (1983). Chemical education research: Facts, findings, and consequences. Journal of Chemical Education, 60(11), 968.
- Johnstone, AH (1997). Chemistry teaching-science or alchemy? 1996 Brasted lecture. Journal of chemical education, 74 (3), 262.
- Kirschner P. A., Sweller J. and Clark R. E., (2006), Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching, Educ. Psychol.,41(2), 75–86.
- Krajcik, J., Mamlok, R., & Hug, B. (2001). Modern content and the enterprise of science: Science education in the twentieth century. In L, Corno. (ed.), Education

across a century: The centennial volume, pp. 205-238. NSSE: 100th Yearbook of the National Society for the Studyof Education. Chicago: University of Chicago Press.

- Krathwohl, D. R. (2002) A revision of Bloom's taxonomy: An overview. Theory into practice, 41(4), pp. 212-218.
- Lage, M. J., Platt, G. J. and Treglia, M. (2000) Inverting the classroom: A gateway to creating an inclusive learning environment. The Journal of Economic Education, 31(1), pp. 30-43.
- Lee T. T. and Osman K., (2012), Interactive multimedia module with pedagogical agents: Formative evaluation, Int. Educ. Stud., 5(6), 50–64.
- Lewis, J. The Effectiveness of Mini-Projects as a Preparation for Open-Ended Investigations. In Teaching and Learning in the Science Laboratory, Psillos, D., Niedderer, H., Eds.; Kluwer Academic Publishers: Norwell, MA, 2002; 139–150.
- Lo Chung Kwan, "Toward a Flipped Classroom Instructional Model for History education: A Call for Research," International Journal of Culture and History vol. 3, no. 1, pp. 36-43, 2017.
- Liu, T. C., Peng, H., Wu, W. H., & Lin, M. S. (2009). The effects of mobile natural-science learning based on the 5E learning cycle: A case study. Journal of Educational Technology & Society, 12(4), 344-358.
- Mahaffy, P. (2004). The future shape of chemistry education. Chemistry Education Research and Practice, 5(3), 229-245
- Mayer, R. E. (2005). Cognitive theory of multimedia learning. The Cambridge handbook of multimedia learning, 41, 31-48.
- Mayer, R. E., & Fiorella, L. (2014). 12 Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signaling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles. The Cambridge handbook of multimedia learning, 279.
- Meester, M. A. M.; Maskill, H.; Maskill, R. Int. J. Sci. Educ. 1995, 17, 705–719.
- Norris, R. (2015). Cambridge IGCSE® Chemistry Revision Guide. Cambridge University Press.
- Norris, R., Ryan, L., & Acaster, D. (2011). Cambridge International AS and A Level Chemistry Coursebook. Hodder Education.
- O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. The internet and higher education, 25, 85-95.
- Olakanmi, E. E. (2017). The effects of a flipped classroom model of instruction on

students' performance and attitudes towards chemistry. Journal of Science Education and Technology, 26(1), 127-137.

- Örnek, F. (2007). Evaluation novelty in Modeling-Based and interactive engagement ınstruction. Eurasia Journal of Mathematics, Science & Technology Education, 3(3), 231-237.
- Pea, R. D. The Social and Technological Dimensions of Scaffolding and Related Theoretical Concepts for Learning, Education,and Human Activity. J. Learning Sci. 2004, 13 (3), 423–451.
- Phillips, C. R., & Trainor, J. E. (2014). Millennial students and the flipped classroom. Journal of Business and Educational Leadership, 5(1), 102-112.
- Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). Science Education NOW: A renewed pedagogy for the future of Europe, Brussels: European Commission. Recuperado de: http://ec. europa. eu/research/science-society/document_library/pdf_06/report-rocard-onscience-education_en. pdf.
- Roehl, A., Reddy, S. L. and Shannon, G. J. (2013) The flipped classroom: An opportunity to engage millennialstudents through active learning strategies. Journal of Family & Consumer Sciences, 105(2), pp. 44-49.
- Schettini C., Galassi R., Zamponi S., Bossoletti D., Pirani T.(2017). Un approccio integrato Flipped Classroom-Inquiry-Based in un percorso di ricerca-azione sulla reattività dei metalli. In "Atti del XXVI Congresso Nazionale della Società Chimica Italiana" (pg 358)- Società Chimica Italiana (Roma), ISBN 9788886208802- ISBN 9788886208833
- Schettini C., Marchetti F., Di Nicola C., Zamponi S., Galassi R. (2017). Evaluation of the impact of a day long general chemistry laboratory on 4th year high school students , In Proceedings of the 6thInternational Conference "New Perspectives in Science Education" ,(pg 133-136), Libreria Universitaria .it , Edizioni (Padova) , ISBN 978-88-6292-847-2
- Shaw, S., & Bailey, C. (2011). Success in the US: Are Cambridge International Assessments Good Preparation for University Study?. Journal of College Admission, 213, 6-16.
- Sjöström, J. (2013). Towards Bildung-oriented chemistry education. Science & Education, 22(7), 1873-1890.
- Snyder, C., Paska, L. M., & Besozzi, D. (2014). Cast from the past: using

screencasting in the social studies classroom. The Social Studies, 105(6), 310-314.

- Stamp, N., & O'brien, T. (2005). GK—12 partnership: A model to advance change in science education. BioScience, 55(1), 70-77.
- Svensson, L., & Adawi, T. (2015, October). Designing and evaluating a flipped signals and systems course. In European Conference on e-Learning (p. 584). Academic Conferences International Limited.
- Sweller J., (1988), Cognitive Load during Problem Solving:Effects on Learning, Cogn. Sci., 12, 257–285.
- Szalay, L., & Toth, Z. (2016). An inquiry-based approach of traditional 'step-by-step'experiments. Chemistry Education Research and Practice, 17(4), 923-961.
- Tanner, K. D. (2010) Order matters: using the 5E model to align teaching with how people learn. CBE-Life Sciences Education 9.3: 159-164
- Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. School science and Mathematics, 90(5), 403-418.
- Tomperi, P., & Aksela, M. (2014). In-service teacher training project on inquiry-based practical chemistry. LUMAT (2013–2015 Issues), 2(2), 215-226.
- Trust, T. (2017). Motivation, empowerment, and innovation: Teachers' beliefs about how participating in the Edmodo math subject community shapes teaching and learning. Journal of Research on Technology in Education, 49(1-2), 16-30.
- Tucker, B. (2012). The flipped classroom. Education next, 12(1), 82-83.
- Wilder, M., & Shuttleworth, P. (2005). Cell inquiry: A 5E learning cycle lesson. Science Activities, 41(4), 37-43.
- Williamson V. M. and Abraham M. R., (1995), The effects of computer animation on the particulate mental models of college chemistry students, J. Res. Sci. Teach., 32(5),521–534.
- Winberg T. M. and Berg C. A., (2007), Students' cognitive focus during a chemistry laboratory exercise: Effects of a computer simulated prelab, J. Res. Sci. Teach., 44(8), 1108–1133.
- Yalçin, F. A., & Bayrakçeken, S. (2010). The Effect of 5E Learning Model on Pre-Service Science Teachers' Achievement of Acids-Bases Subject. International Online Journal of Educational Sciences, 2(2).

Chapter 5: A blended learning approach to general chemistry modules inspired to Johnstone's triangle for first year academic students.

This chapter was extracted from the manuscript written by C. Schettini, D. Amendola, I. Borsini e R. Galassi, submitted and under review.
It describes the structure of an online tutoring course for first year students of the General and Inorganic course of Biosciences and Biotechnology and Geological, Natural and Environmental Sciences degree courses of UNICAM. The work consists of the analysis and the discussion of the data obtained from the research concerning students' exam success and satisfaction about the course. During the 2017-18 A.Y, the course was designed and made available on the UNICAM Moodle platform with the aim of supporting students' learning process. The topics, grouped into seven modules, were mostly about Stoichiometry with the main goal of revision in order to fill possible knowledge gaps. The research concerned the evaluation of the impact of the course on students' performance (i.e. mid-term exam's scores, successful students' percentage per each year), collected and analyzed through qualitative and quantitative methods in three academic years, one of control and the other two of experimentation.

Abstract

Three academic years have been taking in consideration for the evaluation of the impact of an online tutoring course of general and inorganic chemistry for freshmen students of the University of Camerino (Italy). The online material mainly consists of video tutorials, other open source web tools and multi-choice self-assessment exercises. During the A.Y 2016-2017, the e-learning course was not available yet, but then the online course was first implemented (2017/18) and then fully adopted (2018/2019).The online tutoring support was activated alongside a traditional general chemistry course, adopting a blended mode, with the aims of: (i) homogenizing freshmen's chemistry knowledge (ii) fostering the most appropriate method of study in a multi access modality (ii) implementing the Johnstone's three levels' knowledge and (iii) increasing students' self-confidence, by the means of a self-evaluation training process. Differently from previous studies, the online course herein aimed mainly to develop a correct method of study of chemistry topics, with a punctual description of what-and-how to do. The results, i.e. the exam's scores, the time spent in the platform, the successful students' percentage per each year, have been collected and analyzed thorough qualitative and quantitative methods. Apart a general students' satisfaction perceived by the answers to a survey questionnaire, the analysis of

the data shows an increase of 11 % of students passing the final exam within three exam sessions and an improvement and a positive correlation between the time spent on the platform and the mid-term scores achieved.

5.1 Introduction

The use of ICT in higher education chemistry teaching has expanded rapidly since its first introduction (Dori Y.J. and Rodrigues S., 2013). ICT can support learning processes and facilitate the transition from a teacher-centred instruction towards a flexible student-centred learning process in which students actively build their knowledge using different sources (Brouwer and McDonnell, 2009). Blended learning is a commonly adopted learning approach in higher education, which combines face-to-face teaching with online instruction and feedback. This pedagogical model fosters students to learn in an interactive and collaborative environment, offering flexible time frames that can be personalized to fit individual learning needs (Saltzberg and Polyson,1995).

Learning strategies adopting blended learning models were reported and widely discussed even in the context of higher education (Collis, 2003; Garrison and Kanuka, 2004). Among the wide range of blended learning models reported, the Graham's framework with enhancing blends are the most commonly adopted at university. In this model, technology increases student productivity, extending the amount of information students can learn or increasing the richness of the material (Graham, 2007).

Moreover, according to the Resource-Based Learning (RBL) pedagogical approach, materials can be delivered through study packages in a digital, user-centred learning environment (Hill and Hannafin,2001), helping students to recognize their learning needs, locate suitable resources, assess their progress and manage their learning.

A virtual learning environment (VLE), as a Moodle platform, is a software tool that provides a single framework within which students can access a wide range of online resources, allowing staff and students to interact using different communication tools at any time. Different assessment tools, as in example self-test quizzes, provide instant feedback to learners about the knowledge and the skills acquired in face-to-face lectures. Several authors have described the use of VLEs in Chemistry courses in higher education, often addressed to first year undergraduates, reporting an improvement in student achievement and satisfaction (Vician and Charlesworth, 2003; Lovatt, Finlayson and James, 2007; Williams, Bland and Christie, 2008).

On the other side, from the didactics' point of view, in the first approach to the study of chemistry, students deal with difficulties and relative misconceptions due, for example, to the overlying of three different levels (macro, sub-micro and symbolic), according to Johnstone's model (Johnstone, 1982). More specifically, since the mid-1970s, it has been established that most of the resistant to change students' misconceptions are due to inadequate or inaccurate mental model at the sub-microscopic level (Kleinman, 1987; Lijnse, 1990), even among students who were performing well in formal examinations (Nurrenbern, 1987; Nakhleh and Mitchell, 1993).

Molecular animations, video demonstrations and simulations help students to better correlate all three levels of representation, as described by several authors (Williamson and Abraham, 1995; Sanger and Greenbowe, 1997). Russell et al. (1997) reported that the use of simultaneous-synchronized macroscopic, sub-microscopic and symbolic representations through a specially designed software provides an improvement of students' conceptual understanding and ability to create dynamic mental models. Velazquez-Marcano (2004) described the successful use of both video demonstrations and molecular animations in the conceptual understanding of three chemical phenomena by the students of the first-year chemistry course. The constructivist VisChem Learning design (Tasker and Dalton, 2006) investigated the mental model of the students regarding a substance or reaction at the molecular level before showing animations portraying the phenomenon, enhancing a deeper comprehension of the threefold representation of matter. Task-based video tutorials are another effective way to support students in acquiring fundamental knowledge regarding chemical principles and concepts, optimizing time and resources in chemistry education in universities. Experimental results indicate that online video tutorials are a valuable, flexible and cost-effective tool to improve the ability of the students in chemistry problem solving (Tallmadge and Chitester, 2010; He, Swenson and Lents, 2012; Roggenkämper and Waitz, 2017).

In Italy the development of e-learning system in Universities has taken place in the absence of significant regulatory action but through independent initiatives for elevating the quality of traditional didactics with the support and integration of different online communication (Baldi et al., 2006; Capogna, 2012).

In 2008, the University of Genoa successfully implemented an online support for first year students, undertaking an inorganic chemistry module. Students were required to afford some series of stoichiometry online exercises, supplemented by several face to face tutorials, and to complete a pre-lab online activity incorporating an explanatory video (Cardinale, 2008).

In UNICAM, the degree courses in Biology, Biotechnology, Geology and Natural Sciences are attended by international groups of European and non-European students with different backgrounds in terms of university entry points and prior knowledge of chemistry, and for whom English is not their first language.

In the first semester of the first year, the course in General and Inorganic Chemistry is organized with lectures in the traditional way and with class sizes of more than a hundred students, making hard to give individualized student attention and timely feedback on formative assessment.

A rough analysis of students' performances at the mid-term test and at the final exam of the last ten years (2006-2016) shows that, even though most students pass the exam within one academic year, the scores are low or medium-low for 50-60% of them. These results highlight a superficial knowledge of the chemistry topics covered and, above all, difficulties in critical thinking and problem solving skills, even more evident in the resolution of stoichiometric problems, as already referred in educational research (Gulacar et al.,2013).Moreover, first year students have incomplete mental models and often represent scientific problems in a superficial way showing problems in understanding and correlating the three levels described by Johnstone.

The heterogeneity of the initial levels of students, coming from different education systems and the related widely varying interest and motivation in the subject, combined to a mostly memory-based method and a limited attitude to self-evaluation, represent further challenges for lecturers (Zusho, Pintrich and Coppola, 2003).

It becomes clear that for many of current students, learning chemistry is a complex and demanding process that requires something extra beyond the material presented in a textbook or lecture.

Therefore, in 2017, we decided to implement a supplemental online tutoring course, in order to fill the background's gaps and to support students in their first weeks of learning path, providing guidance and organization for study in the period afore the mid-term test of stoichiometry. Our general aim was to improve student performance in terms of exam's success, consisting of both grade level and time spent to get the exam. Additional learning targets lie on the development of learning skills such as to interrelate the chemistry levels of learning, to accelerate the adoption of a proper method of study, to develop sensitivity to a self-evaluation process.

For this purpose, we have chosen a blended learning approach, in which e-learning is integrated into the teaching, the learning, the assessment and a real-time feedback of the topics, beyond to a face-to-face teaching which is still retained.

Based on the previous experiences of the use of the Moodle platform in the teaching-learning process of chemistry described in literature (Lovatt, Finlayson and James, 2007; Benedict and Pence, 2012; Milner-Bolotin,2012; Lau González et al., 2014), we integrated them in an innovative way, designing a course in a virtual learning environment that not only delivered the needed inorganic chemistry and stoichiometry contents for the mid-term test, but that aimed to: (i) illustrate the method for solving the stoichiometry exercises through video tutorials and with the help of an "Overview" section, which details the step-by-step procedure showed in the video tutorial; (ii) show representations of the Johnstone's three levels involved in the chemical phenomena related to each stoichiometric exercise, through videos of laboratory experiments (macro level) and computer animations (sub-microscopic level).

Since the 2017/18 A.Y., the online tutoring course was structured in seven modules, designed, prepared and uploaded in a Moodle platform and delivered on the UNICAM e-learning platform.

First year students of natural sciences, earth sciences, biology and biotechnology in two different academic years (2017/2018 and 2018/2019) have practiced the modules as a preparation for the mid-term stoichiometry test. The course provides two mid-term exams on stoichiometry and a final exam on the general chemistry themes.

In this study, the platform's design and the results of these two years are discussed to evaluate the impact of the VLE in terms of exam success and the degree of students' satisfaction with the blended learning approach.

The evaluation of students' usage of the online tutoring course has been examined through the following research questions:

a. *Will students use the online resources available through Moodle and, if so, how they use them?*

b. *Do students who access the online material have a better general performance in the mid-term evaluation test and in the final exam?*

c. *How do students perceive the effect of online resources on their examination performance and chemical concepts' understanding?*

d. *What is students' opinion regarding online tutoring?*

To obtain answers to these research questions, a blended teaching model has been planned and adopted. The didactic model was structured with classical frontal lessons delivered together tutoring materials (Figure 5.1). These latter indicate step by step how to face up the chemical reactions study correlating the three levels of chemistry, approaching the problem solving and the issue of the self-assessment. The mid-term results were extrapolated from the platform and examined on comparison with those obtained when the platform was not adopted yet.

Moreover, the outputs of the final exams of the different academic years together to the answers to a survey questionnaire uploaded in the Moodle platform were analyzed.

The results are herein shown and discussed.

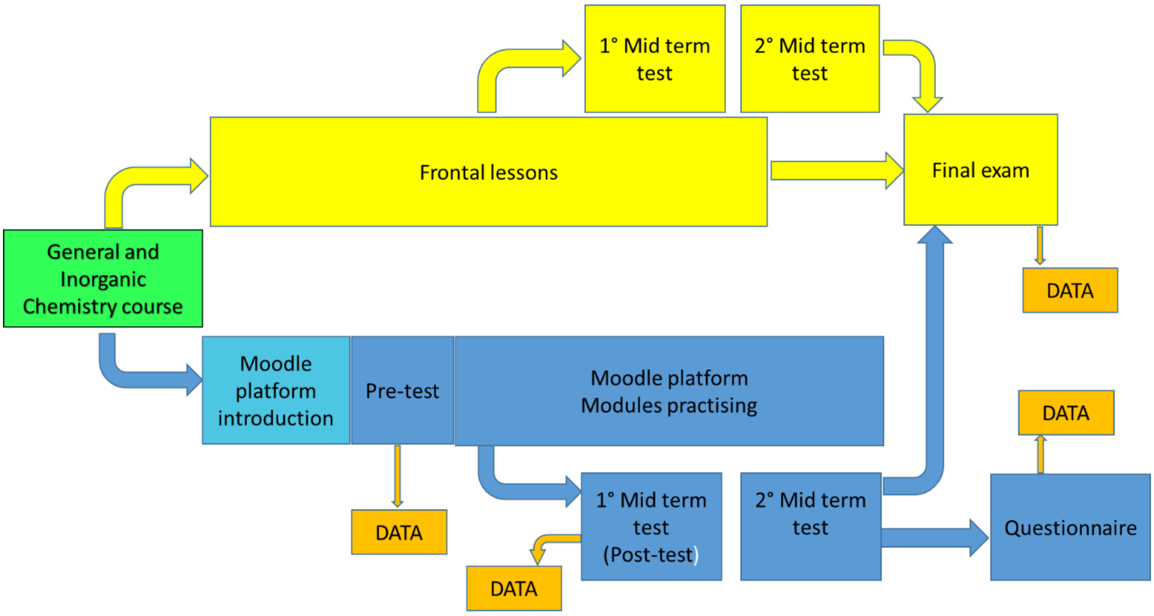


Figure 5.1.: Sketch of the course structure in the academic years taken in consideration in this study. In yellow the learning's structure of 2016/2017 A.Y. and in blue that for 2017/2018 and 2018/2019 A.Y. The orange arrows detail the didactic steps producing the data for the herein discussion.

5.2 Methodology

The online tutoring course design has been preceded by an accurate identification of the first part course's topics and related stoichiometric problems that students found more difficult and/or for which poorer performances in the final exam were recorded. Within the course, seven study packs or modules are included, each one addressing one of the detected issues. Our goal was to promote deeper conceptual understanding by prompting students to connect quantitative calculations to chemical processes at the sub-microscopic level (e.g., the level of atoms and molecules) and to outcome at the macroscopic level (e.g., final concentrations, color, temperature). The VLE used in this study is a Moodle, a web based Course Management System, that it is an open source software that can be freely downloaded from the web and allows the educator to develop a course with multiple functions, including file hosting, quizzes, assignments, chats, discussion forums, glossaries and questionnaires.

Our course includes the following sections:

1. **An initial test of 30 multiple-choice items**, checking students' general and inorganic chemistry basic knowledge;
2. **Three Forums for student-teacher interaction**: a "News Forum" for general notices, a "Technical Forum" for technical problems and an "Interaction Forum with the course tutor and the professor", for more detailed explanations and scaffolding;
3. **A "Prerequisites" section** with some preparatory materials (significant figures, units of measure, etc.);
4. **Seven Modules**, organized as described below, inserted simultaneously at the opening of the VLE;
5. **A mid-term evaluation test** of 24 multiple-choice items, in six different equivalent versions, administered to all enrolled students, whose structure is explained in Appendix 8;
6. **A survey questionnaire**, consisting of 43 questions aiming to acquire variables of interest to the study and to test students' perception and satisfaction (Appendix 9);

All course materials are delivered in English. The initial and the mid-term test were performed by students in the classroom, with mobile devices (mobile, tablet, laptop).

5.2.1 Structure of Modules

The seven modules were designed to allow students to rapidly interconnect the three levels of representation in chemistry.

After the title of the task, the macroscopic level is being introduced using short videoclips of the experiment related to the assignment. The sub-microscopic level of the phenomena is being visualized via computer animations, found in chemistry didactics' websites. To understand the symbolic level, a video tutorial guides the students, step-by-step, in solving the stoichiometry exercises, related to the investigated chemical phenomena (Table 5.1).

	TITLE OF THE MODULE	VIDEOTUTORIAL ON HOW TO SOLVE THE ASSIGNMENT	VIDEO OF THE EXPERIMENT RELATED TO THE ASSIGNMENT	SUB-MICROSCOPIC VIEW
M. 1	Net Ionic Equation for an Acid-Base Reaction	Write the balanced, overall equation and the net ionic equation for the reaction of $Ca(OH)_2$ with HCl.	$Ca(OH)_2$ titration with HCl	Neutralization reaction between HCl and NaOH
M. 2	Mass Relation in Chemical Reaction	Al reacts with gaseous Cl_2 to form Al_2Cl_3. (a) If 35 g of Al reacts with excess Cl_2, how many grams of Al_2Cl will form? (b) How many grams of Cl_2 will react completely with 42,8 g di Al?	Reaction of Al with Cl_2	Temperature varying structures of Al_2Cl_3
M. 3	Oxidation-Reduction Reaction	Balance the net ionic equation for the reaction between metallic Zn and $AgNO_3$.	Reaction between Zn and $AgNO_3$	Galvanic cell animation Zn + Ag
M. 4	Writing the Equation for a Precipitation Reaction	Is an insoluble product formed when aqueous solutions of K_2CrO_4 and $AgNO_3$ are mixed? If so, write the balanced equation.	Double Replacement Reactions	Reaction between $K_2CrO_4(aq)$ and $Ba(NO_3)_2$ (aq)
M. 5	A reaction with a limiting reactant	80 g of Al is placed in a solution that contains 40 g of H_2SO_4. H_2 gas and $Al_2(SO_4)_3$ are produced in this reaction. (a) Identify the limiting reactant; (b) What mass of $Al_2(SO_4)_3$ can be produced? (c) What is the mass of excess reactant that remains after the reaction is complete?	Al metal reacts with concentrated H_2SO_4	1. A reaction where the reactants are in the same ratio as the coefficients in the balanced equation and the reaction goes to completion. 2. A reaction with a limiting reactant and excess reactant remaining at the end of the reaction
M. 6	Theoretical and Percentation Yield	32 g of C_2H_6 is placed in a container with 39 g of O_2 gas. 28 g of CO_2 are collected at the end of the reaction. Identify the limiting reactant and calculate the percent yield.	Combustion of C_2H_6	Combustion of C_2H_6
M. 7	Recognizing the Common Types of Reactions	Recognize the common types of reaction	Types of chemical reactions lab	Five major chemical reaction (synthesis, decomposition, single displacement, double displacement, combustion)

Table 5.1: List of the seven modules and their contents

Video tutorials are based on voice and handwriting, simulating teacher's exposition and addressing students with different backgrounds of knowledge and problem solving skills. Handwriting is accomplished by using a Wacom tablet. The videos have an average duration of 15 minutes and the file size is from 100 to 150 MB. In the video tutorials, detailed step-by-step explanations show the solution of the assigned problems or exercises, along with the principles and formulas of the symbolic level needed for the specific task. Key information about the followed method of analysis and solution, as well as theoretical references, are included in the videos, with the aim to make the student able to apply the method to similar cases, once mastered the required skills.

Within each module other sections have been added to complete the learning path:

• A "*Background knowledge*" section, which lists the knowledge and skills required to afford the study of the module, so that students can check and fill their gaps;

• An "*Overview*" section, which details the steps needed to solve the stoichiometric exercise illustrated in the video tutorial;

• An "*Other materials to support learning*" section, in which more learning support materials (interactive guides, tutorials, tables, etc.) are added;

• A "*Multiple-choice exercises*" section, with a multiple-choice test of 10 randomly selected questions on the topics of the module, to allow students' self-assessment.

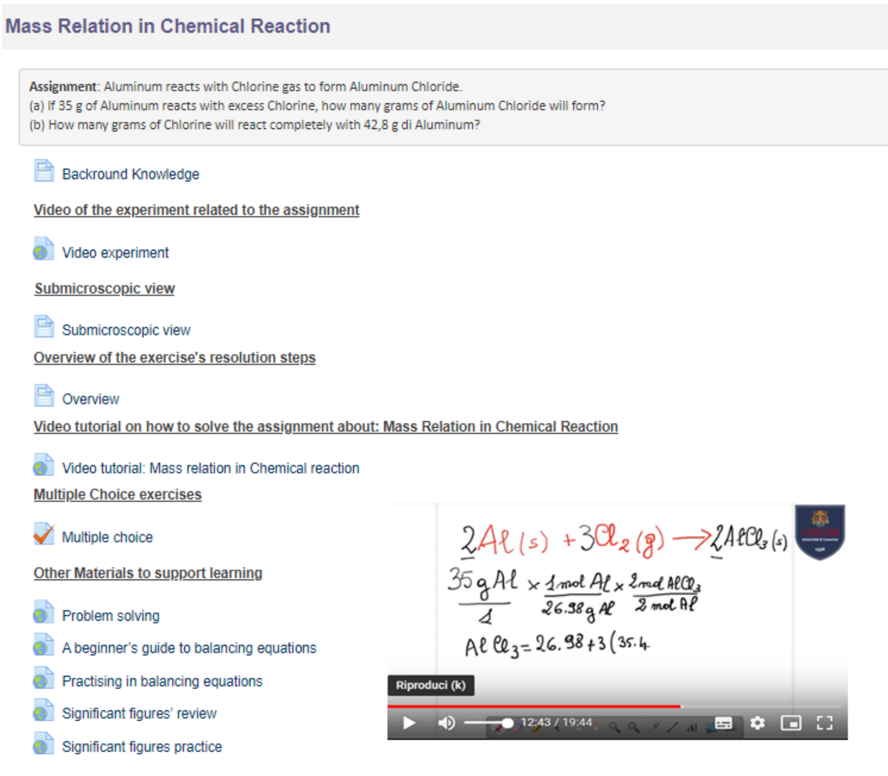


Figure 5.2: "Mass Relation in Chemical Reactions" module screenshot. In the inset image a screenshot of the video tutorial.

5.2.2. Participants

In the first edition of the course (A.Y. 2017/18), 185 students of both degree courses (140 students of biology and biotechnology and 45 students of geology and natural sciences) were enrolled on the platform and its use was highly encouraged, even not mandatory.

In the second edition of the course (A.Y. 2018/19) 155 students of both degree courses (118 students of biology and biotechnology and 37 students of geology and natural sciences) were enrolled on the platform. However, the data were analyzed without distinguishing the frequency course.

The percentage of enrolled females (2017/2018 61.08%; 2018/2019 57.42%) on the total number of students was higher than the males (2017/2018, 38.92%; 2018/2019, 42.58%) in both editions, but decreased from one edition to another, while that of males increased (+3.66%).

Regarding their nationality, most of the students enrolled in the two degree courses were Italian in both editions (2017/2018 62.70%; 2018/2019 72.26%), followed by Non-European countries' students (2017/2018 31.35%; 2018/2019 20.65%) and Other European's countries students (2017/2018 5.95 %; 2018/2019 7.10 %). The statistical analysis of the students' mid-term test evaluations also examined the results of the students enrolled in the 2016/17 academic year when the VLE was not yet present. The main characteristics of the students enrolled in the three academic years examined are described in the table below (Table 5.2).

A.Y.	**Number of students**	**% M**	**% F**	**% Italian students**	**% European students**	**% Non European students**
2016-2017	186	54.06	45.94	60.5	4.37	35,13
2017-2018	185	38.92	61.08	62.70	5.95	31.35
2018-2019	155	42.58	57.42	72.26	7.10	20.65

Table 5.2: Demographic characteristics of students enrolled in A.Y. 2016/17, 2017/18, 2018/2019

5.2.3 Data collection and data analysis methodology

The results of the research are based on the data extracted from the Moodle platform. The statistical analysis of the mid-term evaluation test administered to the students and the analysis of the results of a questionnaire on the students' subjective perception of the VLE learning activity, are all related to the second edition of the course (A. Y. 2018/19). As a matter of fact, the A.Y. 2017/18 edition was a pilot study whose results (Schettini et al., 2018) improved the next full scale implementation.

Specifically, we analyzed:

(i) The students' pattern of usage of the platform, numbering the logging hits of the VLE different sections and of each section of the module;

(ii) The improvement of the results in the mid-term evaluation test for the students who used the e-learning course (A.Y. 2018/2019);

(iii) The percentage of the students who passed the exam in the first three sessions;

(iv) The data collected through an online questionnaire on the students' experience and perception about the blended learning activity, proposed to the students at the end of the laboratory activity.

As for (i), we also compared the number of accesses of the second edition with those of the pilot one, even relative to gender and nationality. We have analyzed the learning analytics extracted from the Moodle platform after the practising of the course by the students and organized them in tables that represent the number of log to different resources and activities, in order to obtain the level of interaction that students have with each of them.

As for (ii), we compared the mid-term exam's results obtained from the students of the 2018/2019 A.Y. , who had available the tutorial course on the Moodle platform, with the results obtained from the students of the 2016/2017 A.Y. that have not available the e-learning course. To do that we applied the statistical analysis test of Snedecor-Fisher, where the values of F and F-crit can demonstrate if a significant difference between the analyzed samples of students exists (more details in Appendix 10).

As for (iii), we have considered for the three academic years under analysis the percentage of students passing the final exam within the first three exam sessions, comparing and discussing in both qualitative and quantitative way the obtained results.

As for (iv), the questionnaire consisted of 43 questions and was divided into 4 sections: (a) Personal data; (b) Behaviours; (c) Intentions/preferences/Opinions; (d) Open questions, comments. The first section (a) collects basic demographic information (age, gender, country of origin, degree course) and data regarding digital and English language skills. The second section (b) contains five questions to elicit qualitative data on students' previous e-learning experience and mode of use of the current VLE. The third section (c) consists of 19 Likert-type statements and one closed question, regarding students' satisfaction and perception of the online course advantages and any difficulty related to materials' comprehension and usage. Finally, in the fourth section (d) we have asked the students to give their general opinion on the platform through five open questions, while the last eight Likert-type statements investigate the preferred class modality of the students, and how the students use personal devices and social networks in the preparation for the exams. Only 50% of the active students answered the questionnaire (66 students), their demographic characteristics (age, gender, country of origin, course degree, English language knowledge, digital skills and previous e-learning experience) are following described.

5.3 Results and discussion

5.3.1 Do students use the online resources available through Moodle and, if so, how they used them?

In the first edition of the course, 110 (over 185) students logged in to Moodle platform and accessed to its resources (hereinafter referred to as *active* students), whereas they were 132 (over 155) in the second edition. Comparing the two editions, the number of active students on the platform increased (+25.70), even if there was a decrease in the number of students enrolled (-16.22%).

The percentage of active females (2017/2018, 57.27%; 2018/2019, 55.30%) on the total number of active students was slightly higher than the males (2017/2018, 42.73 %; 2018/2019, 44.70%) in the two editions and slightly decreased from one edition to another, while there was a small increase in the males' percentage (+1,97).

On the other hand, the percentage of active males in the total of males (2017/2018, 65.28%; 2018/2019, 89.39 %) was definitely greater than the percentage of active females versus the total of females (2017/2018, 55.72%; 2018/2019, 82.02%), and both increased from one edition to another (Males +24.11 %; Females +26.27 %), with greater participation of females who became more active in the second edition.

In 2018 and in 2019 Italian students represented the largest proportion of active students (2017/2018, 62.70%; 2018/2019, 72.26%), compared to active students' total extent, followed by Non-European countries' students (2017/2018, 31.35 %; 2018/2019, 20.65%) and Other European countries' students (2017/2018, 5.95%; 2018/2019, 7.10%).

On the other hand, in 2017/2018 the most active students on the platform, compared to same nationality students' total number, were Other EU countries students (72.73%), followed by Italians (64.66%) and those coming from NON-EU countries (46.55%). In

2018/2019, the most active students on the platform, compared to same nationality 's total number, were still Other EU countries' students (90.91%, with an increase of 18.18%), now followed by Non-European countries students (87.50%, with a significant increase of 40.95%) and by Italian students (83.93% with an increase of 19.27%).

In general, during the fully implemented Moodle platform year, that is 2018/2019, students used the platform in preparation for the mid-term test, but even more between it and the final examination (230% increase in the number of log hits after the mid-term test date).

52.90% of the students enrolled took the mid-term test (82 out of 155) and all were active students, constituting 62.12% (82 out of 132). The fact that 100% of active students took the mid-term test can mean either that the platform made them more self-confident or indeed that, being the most motivated and conscientious, they would still have addressed it, even without the online resources.

In this study, we analyzed only the data of the second edition of the online course (2018/2019 A.Y.). An indication of overall usage can be obtained from the log of hits, demonstrating the general level of interaction students had with each resource (Table 5.3), even if it is possible that a student can access to the same resource several times.

RESOURCES	**HITS**
Module 1-Net Ionic Equation for an Acid-Base Reaction	1709
Module 2-Mass Relation in Chemical Reaction	1164
Module 3-Oxidation-Reduction Reaction	1001
Module 4-Writing the Equation for a Precipitation Reaction	879
Module 5-A reaction with a limiting reactant	746
Module 7-Recognizing the Common Types of Reactions	720
Module 6- Theoretical and Percentation Yield	678
PREREQUISITES	182
FORUM NEWS	0
TECHNICAL FORUM	0
FORUM FOR INTERACTION	0

Table 5.3: Total Moodle resources hits

The ranking of the modules with the highest number of accesses reflects the order in which these are placed into the platform, except for Module 7. The fact that the latter modules have been less visited may be due to the insufficient time students had available for their study before the exam so, following the list, they failed to complete all the modules. Moreover, students didn't use the forums at all, preferring the traditional explanation face-to-face in the classroom.

Table 5.4 shows which modules' sections were the most accessed in total. “Multiple-choice exercises” had the greatest number of hits, followed by "Other materials to support learning" and "Video tutorial". As shown in Figure 5.3, this ranking is the same within each module.

SECTIONS	**HITS**
Multiple-choice exercises	5453
Other materials to support learning	632
Video tutorial	282
Background knowledge	200
Overview	151
Video of the experiment	101
Sub-microscopic view	78

Table 5.4: Total Modules’ sections hits

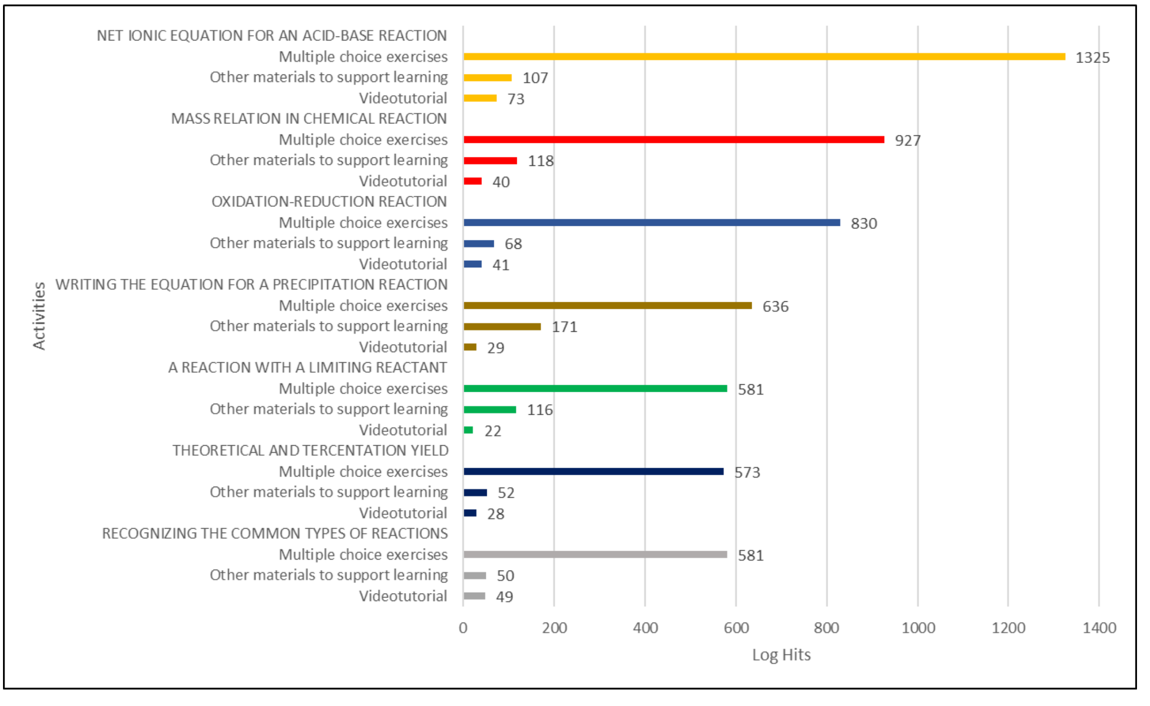


Figure 5.3: Lateral histogram of each Module’ s sections hits

The multiple-choice exercises were delivered on the platform at the same time as the other resources and for each of them students had an unlimited number of attempts. They were not used for formal assessment and students received solutions only after submitting their answers. Students’ preference for multiple-choice exercises revealed the need to assess their knowledge and to receive an immediate feedback that facilitates the understanding and learning process. Furthermore, the possibility of receiving systematic feedback gave the students the ability to complete their preparation before facing both the mid-term test and the final exam. Indeed, as these self-assessment activities are aimed to provide students information on the knowledge acquired, other authors have emphasized the use of self-assessment resources allowing the reorganization of students' self-learning strategy (Bell and Volckmann, 2007; Lovatt, 2007; Kennepohl and Guay, 2010; Lau Gonzalez et al., 2014).

5.3.2. Do students who access the online material have a better general performance and results in the mid-term evaluation test and in the final exam?

Regarding the analysis of the results in the mid-term evaluation test for the students who used the e-learning course (A.Y. 2018/2019), although this study is mostly of a descriptive nature, we have subjected the educational system described above to a Confirmatory Statistical Analysis, (Schreiber et al., 2006), using data from mid-term tests of 2016-17, 2017-18, 2018-19 A.Y.

The statistical treatment is based on the following hypotheses:

- Since students of the current academic year participated in the test and students of previous years do not participate, we can assume that the three groups analyzed are independent and equivalent samples of the same population. The level of validity of this hypothesis is related to the sensitivity of the measure we performed on the system.
- Furthermore, all the mid-term test contains 25 questions, and everyone has an equivalent formulation in each academic year (an example is reported in Appendix 8), so we can consider equivalent the tests, from the statistical point of view.
- Finally, we verified the homoschedasticity of the variances, that is, if the groups have a significant difference in the variances, through the test on the Bartlett B (k) random variable (k number of groups involved in the research) (Bartlett, 1937; Markowski and Markowski, 1990; Mason, Gunst and Hess, 2003). The data elaboration regarding Bartlett's random variable B calculation and variance homogeneity test are reported in Appendix 10.

According to the collected data and the function (F), described in Appendix 10, we followed this procedure:

1) we normalized the score achieved by a student, dividing the sum of the

dichotomous scores of each item, 0 or 1, by the number of items, i. e. 25;

2) we considered the result achieved by each student as correlated with the application of the teaching methodology to which he was subjected, linked to the specific academic year attended;

3) we compared the results of the three academic years by submitting them to the analysis of ANOVA (Maria Kozielska, 2004) and then, as above mentioned, to the test based on the random variable F.

In Table 5.5. the data obtained by applying this statistical method to the student's mid-term scores of the three academic years herein taken in consideration are reported. The results at the 5% significance level show that the experimental value of F is higher than its critical value with a significance value of 2 per thousand, which assures us that the three groups are significantly different.

ONE FACTOR ANOVA				
SUMMARY				
GROUPS	*STUDENTS*	*SUM of normalized score*	*MEAN of normalized score*	*VARIANCE*
2016-2017	99	55,7833	0,5634	0,0494
2017-2018	83	50,9600	0,6139	0,0358
2018-2019	81	54,4250	0,6719	0,0332

ONE FACTOR ANOVA						
ANALISYS						
ORIGIN OF THE VARIATION	*SS*	*DoF*	*MS*	*F*	*SIGNIFICANCE VALUE*	*F crit*
BETWEEN GROUPS	0,5240	2	0,2620	**6,5266**	**0,0017**	**3,0305**
WITHIN GROUPS	10,4390	260	0,0401			
TOTAL	10,9630	262				

Table 5.5: Top, number of students for each academic year, sum of the normalized score (0-1), average of the normalized score and variance. Bottom, statistical test of Snedecor - Fisher: the values of F and F-crit (in bold) show that the average ratings of the groups are significantly different. Legenda: SS=sum of squares; DoF=Degree of Freedom; MS=mean of squares.

Applying the same method of analysis to the data of 2016-17 and 2018-19 A.Y. , that are the academic years in which the two methodologies (classic and blended) were performed in their complete form, a stronger difference in the skills acquired by students is observed (Table 5.6).

ONE FACTOR ANOVA				
SUMMARY				
GROUPS	*Number of students*	*SUM of normalized score*	*MEAN of normalized score*	*VARIANCE*
2018-2019	81	54,4250	0,6719	0,0332
2016-2017	99	55,7833	0,5634	0,0494

ONE FACTOR ANOVA						
ANALISYS						
ORIGIN OF THE VARIATION	*SQ*	*DoF*	*MQ*	*F*	*SIGNIFICANCE VALUE*	*F crit*
BETWEEN GROUPS	0,5239	1	0,5239	**12,4345**	**0,0005**	**3,8942**
WITHIN GROUPS	7,5000	178	0,0421			
TOTAL	**8,02**	**179**				

Table 5.6: Top, number of students for each academic year, sum of the normalized score (0-1), average of the normalized score and variance. Bottom, statistical test of Snedecor -Fisher: the values of F and F-crit (in bold) of the academic years 2016-2017 and 2018-2019 show that the differences in the averages of the scores acquired by the students in the two examined academic years are considerable from a statistical point of view.

The analysis of the data obtained with the Snedecor-Fisher method highlights an appreciable improvement of the student's performance in the academic year where the platform was fully implemented.

Finally, we focused our attention on the correlation between the results obtained in the mid-term test of 2018-19 A.Y. and the time spent on the platform.

The dispersion graph shows a positive correlation between time spent on the platform and mid-term test scores (figure 5.4). The data have been evaluated according to the $\chi^2$with the hypothesis that the variables are independent (see Appendix 10). The result provides 15.63 for the value of χ^2, while the critical value of χ^2, with a degree of significance of 5% and 16 degrees of freedom, is 26.3. The observed value corresponds to a 50% of the probability that the two observed variables, time and score, are dependent from each other. From the statistical point of view, this analysis represents another evidence of the positive effect of the platform on the students' performance.

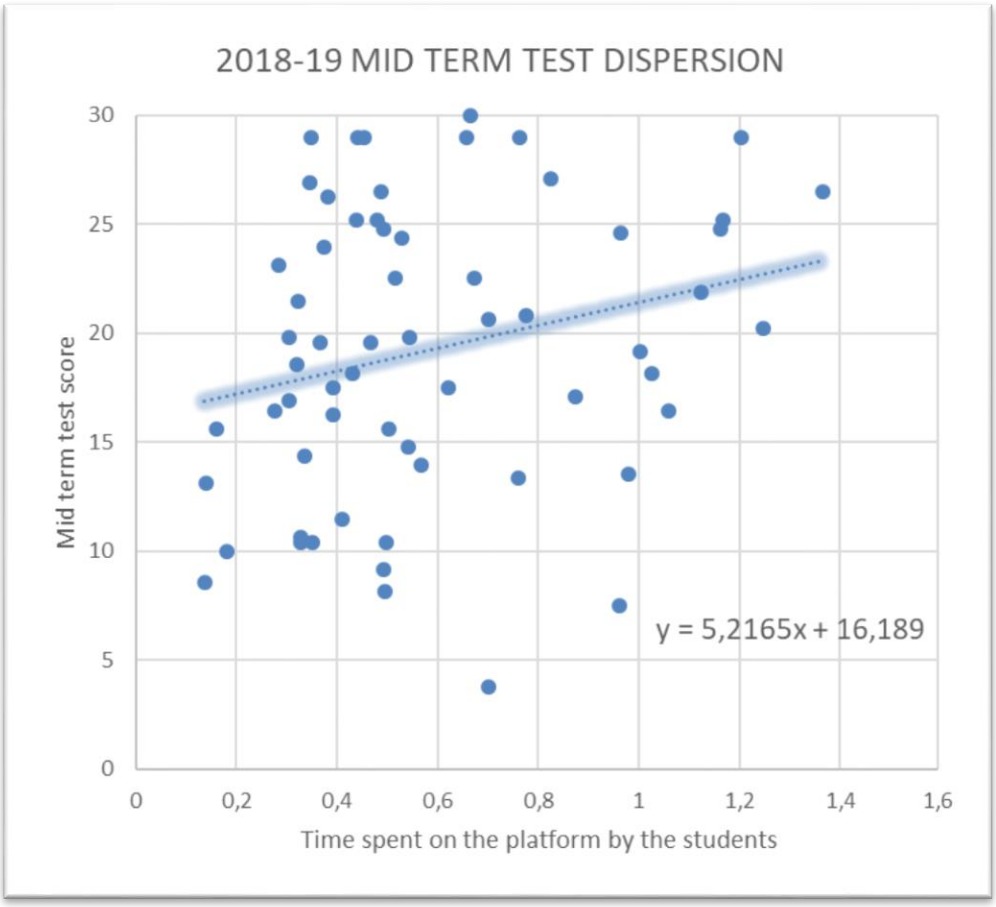


Figure 5.4: Dispersion graph for time (hours) over score (0-30). On the x-axis the time spent on the platform (1 = 24 hours), on the y-axis the students' mid-term score

Regarding students' performances at the final exam of general and inorganic chemistry, the percentage of first year students passing the exam within the first three sessions of exams in the three academic years taken in consideration was analyzed. If we compare the data, we can assess that in the 2016/2017 A.Y., the percentage of students passing the exam was as low as 19%. Thanks to the additional support to help students in their study organization and to give further explication of the basic knowledge needed, this percentage was then increased in 2017-2018 A.Y, where the percentage of students passing the exam was 31%, while in 2018-2019 A.Y. the percentage was 30%, very similar to the previous year, showing a net increase of 11 % (Figure 5.5).

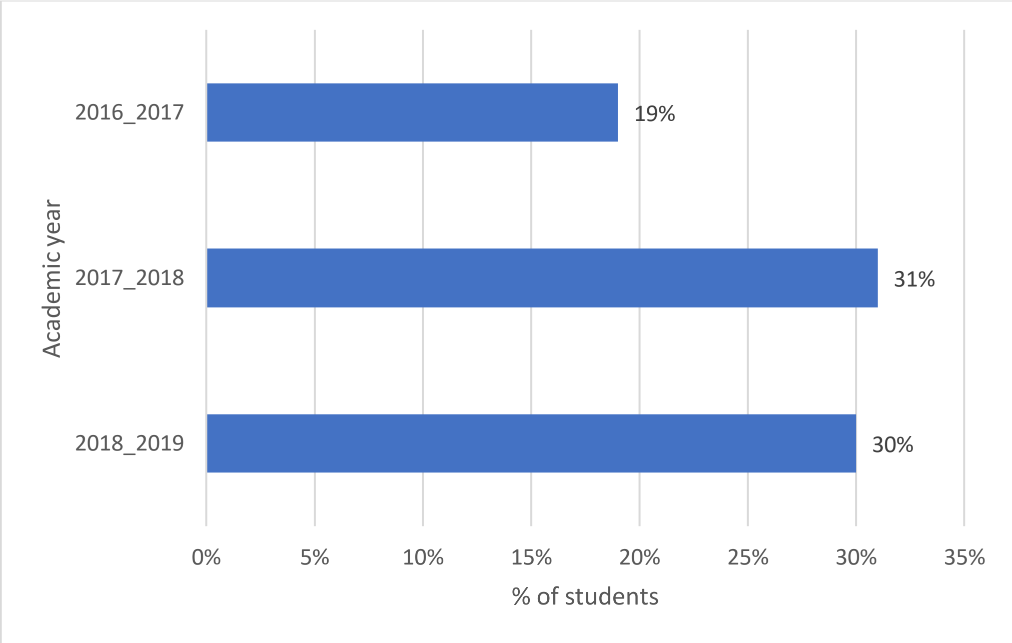


Figure 5.5: Percentage of first year students passing the final exam of general and inorganic chemistry, within the first available three sessions of exams, in the three A.Y. taken in consideration.

5.3.3 How do students perceive the effect of online resources on their examination performance and chemical concepts' understanding?

This study reports only the second edition's data, even for the students' survey, as a higher percentage of students answered the questionnaire (50% of active students) if compared to the previous edition.

The demographic characteristics of students' sample answering the questionnaire, (age, gender, country of origin, course degree, English language knowledge, digital skills and previous e-learning experience) are presented in table 5.7.

Characteristics		Demographic (%)
Age (years)	18	7,58
	19	56,06
	20	15,15
	21	9,09
	over 21	12,12
Gender	Female	77,27
	Male	22,73
Course Degree	Biosciences and Biotechnology	87,88
	Geology	12,12
Country of origin	Italy	72,73
	Other European Countries	4,55
	Non EU-Countries	22,73
English Language knowledge	Mother tongue	10,61
	Excellent	19,70
	Good	59,09
	Elementary	10,61
Digital Skills	Excellent	12,12
	Good	59,09
	Elementary	28,79
Tutoring online previous experience	Yes	19,70
	No	80,30

Table 5.7: Description of the students' sample answering the questionnaire

Students were not limited in the way they approached the platform, so we were interested in which approaches they preferred: 77.27% reported working on their own, 12.12 % with a colleague and 10.61% in a group. This seems reflecting the characteristics of an academic environment in which group working is not generally preferred.

Students were then asked about the resources they used in preparation for the mid-term test: 48.48% reported they studied from book, teacher's notes and slides and platform; 27.27 % from book and teacher's notes and slides; 7.58 % from notes and slides and platform; another 7.58% only from notes and slides, 4.55% only from the book, while nobody studied only from the platform. This last fact is not surprising as the platform contains material with basilar learning backbone. So aside the more traditional resources, like the book or the teacher's notes, the platform has been used by the majority of the sample to set up their incipient method of study.

First, students were asked to report on their perception of usefulness of the platform as a whole and of the different module's sections and results are showed in Table 5.8 (legend : SDA = strongly disagree; DA = disagree; NAND = neither agree nor disagree; A = agree; SA = strongly agree).

	SDA	DA	NAND	A	SA
THE PLATFORM HAS BEEN USEFUL FOR THE TEST	0,00	9,09	37,88	30,30	22,73
The VIDEOS HAVE BEEN USEFUL FOR THE TEST	4,55	16,67	40,91	27,27	10,61
The SUBMICROSCOPIC VIEWS HAVE BEEN USEFUL FOR THE TEST	10,61	16,67	50,00	12,12	10,61
THE OVERVIEW OF THE EXERCISE'RESOLUTION STEPS HAS BEEN USEFUL FOR THE TEST	0,00	6,06	24,24	27,27	42,42
THE VIDEO TUTORIALS HAVE BEEN USEFUL FOR THE TEST	1,52	13,64	28,79	21,21	34,85
THE MULTIPLE-CHOICE EXERCISES HAVE BEEN USEFUL FOR THE TEST	1,52	4,55	19,70	22,73	51,52
OTHER MATERIALS HAVE BEEN USEFUL FOR THE TEST	3,03	6,06	39,39	31,82	19,70
THE PLATFORM HAS BEEN USEFUL FOR TOPICS' DEEPER AWARENESS	1,52	10,61	39,39	31,82	16,67
I HAD NO DIFFICULTY IN UNDERSTANDING VIDEOS	3,03	4,55	36,36	30,30	25,76
I HAD NO DIFFICULTY IN UNDERSTANDING THE SUBMICROSCOPIC LEVEL	3,03	19,70	36,36	25,76	15,15
I HAD NO DIFFICULTY IN UNDERSTANDING VIDEO TUTORIALS	3,03	7,58	31,82	28,79	28,79
MY PREVIOUS KNOWLEDGE WAS ADEQUATE TO UNDERSTAND PLATFORM MATERIALS	7,58	19,70	25,76	31,82	15,15
MY PREVIOUS KNOWLEDGE WAS ADEQUATE TO ADDRESS THE INITIAL TEST	4,55	18,18	31,82	30,30	15,15
MY PREPARATION WAS ADEQUATE TO ADDRESS THE MULTIPLE-CHOICE EXERCISES	4,55	16,67	25,76	37,88	15,15
THE DIFFICULTY OF THE FINAL TEST WAS COMPARABLE TO MULTIPLE-CHOICE EXERCISES'LEVEL	4,55	9,09	30,30	43,94	12,12

Table 5.8: Students' perceptions on the platform's usefulness and difficulty

Most of the students considered useful for the mid-term test the platform as a whole (A + SA = 53.03%), also for the topics' deeper awareness (A + SA = 48.49%; NAND = 39.39%), according with other studies' results on chemistry blended learning courses (Lovatt, Finlayson and James, 2007; Tekane, Pilcher and Potgieter, 2019).

The ranking of the perceived usefulness of the different modules' sections (A + SA: Multiple-choice exercises 74.25%; Overview 69.69%; Video tutorials 56.06%; Other materials 51.52%; Videos of the experiment 37.88%; Sub microscopic views 22.73%) almost reflected the log hits' ranking (Table 5.4).

It is noticeable that students reported greater difficulties in understanding the sub-microscopic level (SDA + DA = 22.73%), compared to video tutorials (SDA + DA = 10.61%) and videos of experiments (SDA + DA = 7.55%). This could explain the lower number of accesses and the lower perceived usefulness, possibly due to a lack of familiarity with this type of representation of chemical phenomena, with respect to the macro and symbolic level. Being first year and first-semester students, simultaneous shift between the three levels of chemistry represents a long-term educational goal, rather difficult to achieve in just over a month of study without an adequate background. Regarding the accessibility of materials, students mostly considered adequate their previous knowledge to understand the material (A + SA: 46.97%; NAND 25.76%; SDA + DA: 27.28%) and also to respond to the initial test (A + SA: 45.45%; NAND 31.82%; SDA + DA: 22.73%) and to the multiple-choice exercises (A + SA 53.03; NAND 25.76%; SDA + DA 21.22%). Finally, most of the students reported the same level of difficulty in the mid-term test and in multiple-choice exercises (SA + A 56.06%), confirming their validity for an adequate preparation. As a matter of fact, the mid-term test was designed according to the modules' structure and considering the three Johnstone's levels. The overall difficulty of the mid-term test was weighted with tests administered in the past (see Appendix 8).

Some responses to the two most meaningful open questions in the questionnaire from 2017/18 and 2018/19 editions, asking students to comment on the best features of the platform and how it could be improved, are reproduced below.

These show that different students liked different aspects of the online course and most of them required additional materials, even for the remaining parts of the course.

Q31. What did you like most about the platform?

"*The multiple-choice questions for self-evaluation were very useful for testing myself in a way similar to the exam"*

"You can check at home if you're studying in the right way by test yourself with exercises and self- evaluation"

"The video tutorial to solve exercises of all types"

"I really liked the fact it provides different ways to deal with the topic and practice"

"Videos of Laboratory Experiments"

"The exercises' resolution steps"

Q32. What would you add to the platform?

"Other exercises, supporting videos and explanations of the exercises"

"More video tutorials"

"Step to step solutions of the multiple-choice questions"

The students' appreciation for the possibility of learning independently and self-assessing demonstrates they possess self-regulation skills and that therefore they are 'proactive in their efforts to learn because they are aware of their strengths and limitations, "(Zimmerman, 2002, p. 65).

5.3.4 What are students' opinions regarding online tutoring?

Five statements in the questionnaire explored the students' perceptions about online tutoring and their suggestions for future improvement. Results in percentage are shown in Table 5.9.

	SDA	DA	NAND	A	SA
ONLINE TUTORING CAN REPLACE TRADITIONAL LECTURES	30,30	25,76	24,24	12,12	7,58
ONLINE TUTORING HELPS ME BETTER UNDERSTAND COURSE MATERIALS	3,03	13,64	31,82	36,36	15,15
ONLINE TUTORING HELPS ME BETTER UNDERSTAND COURSE REQUIREMENTS	0,00	12,12	30,30	39,39	18,18
I HOPE MORE COURSE MODULES AVAILABLE ON THE PLATFORM	3,03	1,52	24,24	27,27	43,94
I HOPE MORE ONLINE TUTORING COURSES AVAILABLE	1,52	3,03	30,30	28,79	36,36

Table 5.9: Student's perception on online tutoring facility

Although the majority of students (SDA + DA = 56.06%) believed that online tutoring could not replace traditional lectures, most of them considered it useful for understanding both the course materials (A + SA = 51.51 %) and knowledge and skills' requirements (A + SA = 58.17%). With a high percentage (A + SA = 71.21%), students agreed with the need of more online modules covering the other course 's topics and, in general, with the delivery of a higher number of online tutoring courses (A + SA = 65.15%). These first results underline as the students' perception on platform's use was absolutely the expected ones (Vishnumolakala et al., 2017; Abrahim et al., 2019; Stowe, 2019). Freshmen students felt the need to be guided for their very first approach to study chemistry, for their knowledge gap filling and for the detection of an efficient method to succeed in chemistry exam.

Furthermore, when asked about the preferred class modality, they chose to a great extent lectures, blended with equal or minimal use of online facilities (figure 5.6). In detail, 48 % of students opted for a blended learning with equal distribution of online content and face-to-face lessons, while only 12 % indicated entirely face to face modality as the preferred one and 5 % would like only online contents.

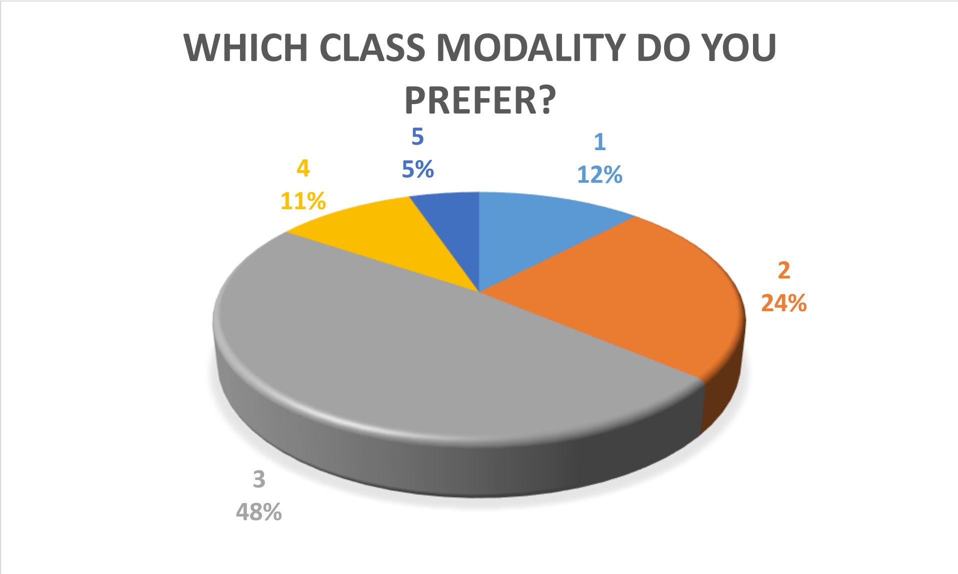


Figure 5.6: Students' opinions on the didactic experience and their preferences. The number relative to the entries represent: 1 (pale blue): entirely face-to-face, 2 (red): minimal use of the web, mostly held in face-to-face format, 3 (grey): an equal mix of face-to-face and web content, 4 (orange): extensive use of the web, but still some face-to-face class time, 5 (dark blu): entirely online with no face-to-face time

A further development of this study was carried out with, Dr. Daniela Amendola and Dr. Giacomo Nalli of the University of Camerino, with the aim to analyze also the students' emotional aspects in the use of the course, necessary for an optimal activities' design, as feelings can influence motivation and therefore students' final performances (Sheng, Wang and Sheng, 2009).

The work consisted in the realization of an intelligent software able to extract students' feeling from the analysis of the answers to the survey questionnaire's open questions, related to the course's and platform's features that were appreciated or not by the students.

The execution of the software ended with the automatic delivery to the course' s lecturer of an e-mail indicating the number of opinions that produced negative, positive and neutral feelings, together with the sending of an Excel sheet containing the comments of the students who experienced negative feelings.

Even the results of this further analysis showed a general students' satisfaction, since out of 132 answers given by the students, 86 were positive, 28 neutral and 18 negative. These data can be useful to verify how much the material provided via e-learning is functional for students. Knowing in this way students 'needs and difficulties, the course designer can modify, where and if necessary, the structure of the course itself, in order to make students' feelings positive and therefore increase their motivation (Ortigosa, Martin and Carro, 2014).

The work was accepted and will be presented at the "Moodle Moot Italia Conference", addressed to all Italian Moodle users, to be held in Verona on 5 and 6 December 2019 (Nalli G., Amendola D., Schettini C., Galassi R., 2019. *Tool per la classificazione dei sentimenti degli studenti implicati in moduli didattici universitari in modalità e-learning*).

Conclusions

First year students in an academic course are obviously very different from each other with heterogeneous backgrounds, both from a cultural and a cognitive point of view.

In general, this is expressed with a plurality of approaches to learning and difficulties in organizing their study.

Moreover, in the first semester of the first year, students are distracted by many issues, often concerning adaptation to a new lifestyle as well as the building of a new social life.

Furthermore, data extrapolated from input tests (pre-test) performed by freshmen, assessing their basic knowledge in chemistry, reveal a variable percentage of students who do not reach the minimum requested, therefore requiring the so-called additional educational objectives (OFA).

For the first semester of the first year's lecturers, the need to convey to students a proper study approach (for example, the use of modelling, the use of specific language, the implementation of problem solving skills) becomes therefore a priority. Hence, any resources, available to students and accessible at any free moment, becomes an opportunity to encourage and motivate them to the study of chemistry topics. The preparation of tools and materials on VLEs, as discussed in this study, responds to the aforementioned needs by providing a tutoring support to all students, regardless of their incoming situation, with the result that they perceive it useful and satisfying, without detracting from the value of face-to-face teaching.

However, from this research data, we can highlight some peculiar aspects. For instance, students like to study online, even though not exclusively, but surely what they prefer is the possibility to have multiple access to a quick self-assessment. This leads us to consider that freshmen probably first approached the study of a topic quickly, perhaps roughly, and then deepened the knowledge of what they failed in the self-assessment test by practising the tutorials to succeed in the mid-term exam.

Furthermore, after passing the mid-term exam and spending extra time on the Moodle

platform, only a smaller percentage of students left the chemistry course to attend other courses. This is highlighted by the higher percentage of students (+11%), passing the final exam in the first exam sessions, once they have practiced the platform.
Moreover, the analysis of the mid-term test scores shows that the three years 'students groups were significantly different in term of learning outcomes, with a noticeable improvement of students' performance in the academic year where the platform was fully implemented. A further analysis demonstrates also a positive correlation between the time spent on the platform and the mid-term test scores.
In conclusion, we can consider a Moodle platform as a useful device, giving students the possibility to study materials, released without time limitation and in a customizable way. Moreover, lecturers can receive an immediate feedback about students' commitment and self-assessment outcomes, with the opportunity to interact with them in the forums as well. In this study, we implemented a Moodle platform with tutoring modules that covers only the topics afforded in the first part of the course, with the double aim to assist students in finding a rigorous method of study with their own pace and in achieving satisfactory results.

Bibliography

- Abrahim, S., Mir, B. A., Suhara, H., Mohamed, F. A., & Sato, M. (2019). Structural equation modeling and confirmatory factor analysis of social media use and education. International Journal of Educational Technology in Higher Education, 16(1), 32.

- Baldi, M., De Santis, A., Falcone, D., Gambi, E., & Spinsante, S. (2006, September). A T-learning platform based on digital terrestrial television. In 2006 International Conference on Software in Telecommunications and Computer Networks (pp. 347-351). IEEE.

- Bartlett, M. S. (1937). Properties of sufficiency and statistical tests. Proceedings of the Royal Society of London. Series A-Mathematical and Physical Sciences, 160(901), 268-282.

- Bell, P., & Volckmann, D. (2011). Knowledge surveys in general chemistry: confidence, overconfidence, and performance. J. Chem. Educ., 88(11), 1469-1476.

- Benedict, L., & Pence, H. E. (2012). Teaching chemistry using student-created videos and photo blogs accessed with smartphones and two-dimensional barcodes. Journal of Chemical Education, 89(4), 492-496.

- Brouwer, N. and McDonnell, C. (2009). Online Support and Online Assessment for Teaching and Learning Chemistry. in Eilks, I. & Byers, B. (Eds.), Innovative Methods of Teaching and Learning Chemistry in Higher Education. Cambridge UK: RSC Publishing, pp. 123-152

- Capogna, S. (2012). University and E-learning Classes in Italy. E-Learning and Digital Media, 9(2), pp. 143-156

- Cardinale, A. M. (2008). A way to improve undergraduate engagement when learning chemistry: An online support for exercises and pre-lab activities. Message posted to online workspace for this chapter at www. surfgroepen. nl/sites/ECTN/default. aspx.

- Collis B., (2003), Course redesign for blended learning: modern optics for technical professionals, Int. J. Cont. Eng. Educ. Life. Learn., 13 (1-2), 22-38.

- Dori Y.J., Rodrigues S., Schanze S. (2013) How to Promote Chemistry Learning Through the use of Ict. In: Eilks I., Hofstein A. (eds) Teaching Chemistry – A Studybook. Sense Publishers, Rotterdam.

- Garrison, D. R. and Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education, Internet High. Educ., 7(2), 95-105.

- Graham, C. R. and Robison R. (2007). Realizing the transformational potential of blended learning: Comparing cases of transforming blends and enhancing blends in higher education. in Picciano A.G. and Dziuban C.D. (Eds), Blended Learning: Research Perspectives. New York: The Sloan Consortium, pp 83-110.

- Gulacar, O., Overton, T. L., Bowman, C. R., & Fynewever, H. (2013). A novel code system for revealing sources of students' difficulties with stoichiometry. Chem. Educ. Res. Pract., 14(4), 507-515.

- Gunst, Richard; L., Hess, James (2003). Statistical design and analysis of experiments: with applications to engineering and science. Wiley. p. 98. ISBN 0471372161. OCLC 856653529

- He, Y., Swenson, S. and Lents, N. (2012). Online video tutorials increase learning of difficult concepts in an undergraduate analytical chemistry course. J. Chem. Educ., 89(9), 1128-1132.

- Hill, J. R. and Hannafin, M. J. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning, Educ. Technol. Res. Dev., 49(3), 37-52.

- Johnstone, A. H. (1982). Macro and micro chemistry. Sch Sci Rev, 64, 377-379.

- Johnstone A. H., (1991), Why is science difficult to learn? Things are seldom what they seem, J. Comp. Assist. Learn., 7, 75-83.

- Johnstone, A. H. (1997). Chemistry teaching-science or alchemy? 1996 Brasted lecture. J. Chem. Educ., 74(3), 262.

- Kennepohl, D., Guay, M., & Thomas, V. (2010). Using an online, self-diagnostic test for introductory general chemistry at an open university. J. Chem. Educ., 87(11), 1273-1277.

- Kleinman R.W., Griffin H.C. and Kerner N.K., (1987), Images in chemistry, J. Chem. Educ., 64, 766-770.

- Maria Kozielska (2004) Developing creativity of students in a computer-assisted learning process, Eur. J. Phys., 25 (2), 279-285

- Lau González, M., Jáuregui Haza, U., Pérez Gramagtes, A., Fariñas León, G., & Le Bolay, N. (2014). Supporting students' learning to learn in general chemistry using Moodle. J. Chem. Educ., 91(11), 1823-1829.

- Lijnse P.L., Licht P., Waarlo A.J. and de Vos W. (Eds.), (1990), Relating macroscopic phenomena to microscopic particles, Proceedings of Conference at Utrecht Centre for Science and Mathematics Education, University of Utrecht, and references therein.

- Lovatt, J., Finlayson, O. E. and James, P. (2007). Evaluation of student engagement with two learning supports in the teaching of 1st year undergraduate chemistry, Chem. Educ. Res. Pract., 8, 390-402.

- Markowski, C. A., & Markowski, E. P. (1990). Conditions for the effectiveness of a preliminary test of variance. The American Statistician, 44(4), 322-326.

- Mason, R. L., Gunst, R. F., & Hess, J. L. (2003). Statistical design and analysis of experiments: with applications to engineering and science (Vol. 474). John Wiley & Sons.

- Milner-Bolotin, M. (2012). Increasing interactivity and authenticity of chemistry instruction through data acquisition systems and other technologies. J. Chem. Educ., 89(4), 477-481.

- Nakhleh M.B., (1992), Why some students don't learn chemistry, J. Chem. Educ., 69, 191-196.

- Nakhleh M.B. and Mitchell R.C., (1993), Conceptual learning vs problem solving, J. Chem. Educ., 70, 190-192.

- Ortigosa, A., Martín, J. M., & Carro, R. M. (2014). Sentiment analysis in Facebook and its application to e-learning. Computers in human behavior, 31, 527-541.

- Roggenkämper, D. and Waitz, T. (2017). Connecting Exercises and Video Tutorials to Support Teaching/Learning Processes in University Chemistry

Education. Libreriauniversitaria. it Edizioni, New Perspectives in Science Education, Florence, Italy, 16-17 March 2017, (p. 290).

- Russell, J. W., Kozma R. B., Jones, T., Wykoff, J., Marx, N. and Davis, J. (1997). Use of simultaneous-synchronized macroscopic, microscopic, and symbolic representations to enhance the teaching and learning of chemical concepts, J. Chem. Educ., 74(3), 330.

- Saltzberg, S. Polyson, S. (1995). Distributed learning on the world wide web. Syllabus Journal, 9(1), 10-12.

- Sanger, M. J. Greenbowe, T. J. (1997). Students' misconceptions in electrochemistry regarding current flow in electrolyte solutions and the salt bridge, J. Chem. Educ. , 74(7), 819-823.

- Schettini C., Zamponi S., Galassi R. and Amendola D. (2018). Online tutorial modules to address students to a timely adoption of an appropriate method for studying key concepts of General Chemistry in an undergraduate course. Libreria universitaria. it Edizioni, New Perspectives in Science Education, Florence, Italy, 16-17 March 2017, (pg 172-176).

- Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modelling and confirmatory factor analysis results: A review. J. Educ. Res., 99(6), 323-338.

- Shen, L., Wang, M., & Shen, R. (2009). Affective e-learning: Using “emotional” data to improve learning in pervasive learning environment. Journal of Educational Technology & Society, 12(2), 176-189.

- Stowe, R. L., & Cooper, M. M. (2019). Assessment in Chemistry Education. Isr. J. Chem. 59, 598 – 607

- Tallmadge, W. and Chitester, B. (2010). Integrating concepts using online tutorials in a freshman chemistry course, Transformative Dialogues: Teaching and Learning Journal, 4(2), 1-7.

- Tasker, R. and Dalton, R. (2006). Research into practice: Visualisation of the molecular world using animations, Chem. Educ. Res. Pract., 7(2), 141-159.

- Tekane, R. R., Pilcher, L. A. and Potgieter, M. (2019). Blended learning in a second year organic chemistry class: students' perceptions and preferences of the learning support, Chem. Educ. Res. Pract., DOI: 10.1039/C9RP00099B.

- Velázquez-Marcano, A., Williamson, V. M., Ashkenazi, G., Tasker, R. and Williamson, K. C. (2004). The use of video demonstrations and particulate animation in general chemistry, J. Sci. Educ. Technol., 13(3), 315-323.

- Vician, C. and Charlesworth, P. (2003). Leveraging technology for chemical sciences education: an early assessment of WebCT usage in first-year chemistry courses, J. Chem. Educ., 80 (11), 1333-7.

- Vishnumolakala, V. R., Southam, D. C., Treagust, D. F., Mocerino, M., & Qureshi, S. (2017). Students' attitudes, self-efficacy and experiences in a modified process-oriented guided inquiry learning undergraduate chemistry classroom. Chem. Educ. Res. Pract, 18(2), 340-352.

- Williams, N. A., Bland, W. and Christie, G. (2008). Improving student achievement and satisfaction by adopting a blended learning approach to inorganic chemistry, Chem. Educ. Res. Pract., 9 (1), 43 – 50.

- Williamson, V. M. and Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students, J. Res. Sci. Teach., 32(5), 521-534.

- Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. Int. J. Science Educ., 25(9), 1081-1094.

List of Publications during the doctoral course

- Schettini C., Amendola D., Borsini I., Galassi R. (2019). A blended learning approach for general chemistry modules inspired to Johnstone's triangle for first year academic students (submitted under review)

- Schettini C., Galassi R., Quadrini M. (2019). An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology, (submitted under review)

- Schettini, C., Zamponi S., Marchetti F., Di Nicola C., Galassi R., & Markic, S. (2018). A Learning by Doing Laboratory Based on Johnstone's Model: A Motivating Approach to Chemistry for High School Students. In: I. Eilks, S. Markic & B. Ralle (Eds.): Building bridges across disciplines (p. 209-214). Aachen, Germany: Shak

- Schettini C., Zamponi S., Galassi R., Amendola D (2018). OnLine Tutorial Modules to Address Students to a Timely Adoption of an Appropriate Method for Studying Key Concepts of General Chemistry in an Undergraduate Course. In Proceedings of the 7th International Conference "New Perspectives in Science Education" (pg 172-176), Libreria Universitaria .it, Edizioni (Padova), ISBN: 978-88-6292-976-9-ISSN: 2420-9732

- Schettini C., Galassi R., Zamponi S., Amendola D., Bossoletti D., Pirani T., (2017). Action-research Teacher Training Course for in-service Chemistry teachers using a Flipped Classroom- IBSE approach. In Proceedings of the 7th Eurovariety "European variety in University Chemistry Education" (pg 114), R&D center of printing engineering, the University of Belgrade, ISBN 978-86-7132-065-8

- Schettini C., Galassi R., Zamponi S., Bossoletti D., Pirani T. (2017). Un approccio integrato Flipped Classroom-Inquiry-Based in un percorso di ricerca-azione sulla reattività dei metalli. In "Atti del XXVI Congresso Nazionale della Società Chimica Italiana" (pg 358) - Società Chimica Italiana (Roma), ISBN 9788886208802- ISBN 9788886208833

- Schettini C., Piergiovanni L., Siga N. (2017). Flipped in rete. Casa Editrice Sapyent S.r.l.s. (Bologna), ISBN 978-88-99943-32- 5 (e-book)

- Schettini C., Marchetti F., Di Nicola C., Zamponi S., Galassi R. (2017). Evaluation of the impact of a day long general chemistry laboratory on 4th year high school students, In Proceedings of the 6thInternational Conference "New Perspectives in Science Education",(pg 133-136), Libreria Universitaria .it , Edizioni (Padova) , ISBN 978-88-6292-847-2

Appendix 1

A Learning by doing laboratory based on Johnstone's model

Students’ test

Test in ingresso e in uscita per gli studenti del PLS.

Nome………………………………………Cognome……………………………………………
Scuola………………………………………………………………………………………………….

1. Un gas ideale è:

ING. USC.

□ □ un gas non inquinante
□ □ un gas nobile
□ □ un modello teorico da cui ricavare le leggi dei gas

2. Il gas idrogeno si può formare:

□ □ per reazione dei metalli alcalini e alcalini terrosi con acqua
□ □ per reazione dei metalli con acqua
□ □ per vaporizzazione dell'acqua in una reazione esotermica

3. Il calcio è:

□ □ un elemento poco reattivo
□ □ un metallo alcalino terroso
□ □ un metallo alcalino

4. L'idrossido di Calcio è :

□ □ solubile in acqua
□ □ insolubile in acqua
□ □ solubile in una soluzione acquosa di idrossido di sodio

5. La legge dei gas ideali correla in maniera direttamente proporzionale :

□ □ la pressione e il volume
□ □ la pressione e il numero di moli
□ □ il volume e il numero di moli

6. Nella reazione dell'Alluminio con il $CuCl_2$ chi si ossida e chi si riduce?:

ING. USC. ING. USC.

□ □ si ossida l'Alluminio □ □ si riduce l'Alluminio
□ □ si ossida il Rame □ □ si riduce il Rame

□ (ingresso) scrivi la reazione e bilanciala :

□ (uscita) scrivi la reazione e bilanciala :

7. Tra questi sali indicare quali sono solubili in acqua e quali no:

	ING.	USC.	ING.	USC.
$MgSO_4$	□	□ Solubile	□	□ Insolubile
$Ba(NO_3)_2$	□	□ Solubile	□	□ Insolubile
$Pb(NO_3)_2$	□	□ Solubile	□	□ Insolubile

8. Dalla Reazione del $Pb(NO_3)_2$ + KI si forma :

□ □ un sale solubile
□ □ un sale insolubile
□ □ due sali non reagiscono

9. In una reazione all'equilibrio:

□ □ i prodotti sono in quantità inferiore dei reagenti
□ □ tutte le specie della reazione devono essere presenti
□ □ i prodotti devono essere in quantità superiore dei reagenti

10. In un sistema all'equilibrio, che influenza ha l'aggiunta di un reagente alla sinistra dello schema di reazione?:

□ □ fa spostare l'equilibrio verso destra
□ □ nessun effetto
□ □ fa spostare l'equilibrio verso sinistra

Appendix 2

"The online chemical experiments: Instructions for use" course

Teachers' questionnaire

QUESTIONARIO DI MONITORAGGIO FINALE DEL CORSO
“ESPERIMENTI DI CHIMICA ONLINE: ISTRUZIONI PER L’USO”

1 I video della piattaforma Moodle del corso “Esperimenti di chimica online: istruzioni per l’uso” messi a disposizione in questo corso, sono secondo te un utile strumento per approfondire temi sulla didattica della chimica? **Sì No**

2 Suggeriresti di ampliare l’offerta di video simili nella piattaforma Moodle e da utilizzare secondo le modalità proposte? **Sì No**

3 Suggeriresti di ampliare l’offerta di video simili da mettere a disposizione dei docenti della scuola per costruire una piattaforma della scuola o tua personale da usare e modificare in maniera indipendente? **Sì No**

4 Se ritieni utile l’inserimento di nuovi video, in quale area tematica della chimica (chimica generale, chimica inorganica, chimica analitica, chimica organica, chimica applicata)? Lascia un commento

5 Se ritieni utile l’inserimento di video che riguardino temi della chimica trasversali ad altre discipline, potresti fare degli esempi?

6 In linea generale, gli esperimenti descritti sono inerenti ai percorsi didattici da te affrontati nell’anno scolastico appena concluso? **Sì No**

7 Se credi che gli esperimenti descritti siano inerenti ai percorsi didattici da te affrontati nell’anno scolastico appena concluso, potresti lasciare qualche nota in merito?

8 Se non credi che gli esperimenti descritti siano inerenti ai percorsi didattici da te affrontati nell’anno scolastico appena concluso, potresti lasciare qualche nota in merito?

9 I video della piattaforma Moodle messi a disposizione in questo corso, sono stati utilizzati durante le tue lezioni? 1. **Molto 2. Poco 3. Una volta 4. Mai**

10 Puoi specificare il motivo per il quale non li hai utilizzati?

11 Puoi specificare in quale occasione e le modalità di uso?

12 Nel caso tu abbia usato anche solo sporadicamente i video, hai inserito nella valutazione conseguente domande derivanti dall’osservazione dell’esperimento? **Sì No**

13 Hai mai mostrato agli studenti i video descritti in lingua inglese? **Sì No**

14 Vuoi lasciare qualche nota in merito ai video in lingua inglese?

15 Se dovessi autovalutarti, ritieni che l’osservazione o l’uso in classe dei video sia stata utile per la tua formazione? 1. **Sì 2. No 3. Più sì che no 4. Più no che sì**

16 Vuoi lasciare qualche commento sull'utilità riguardo l’osservazione o l’uso in classe dei video per la tua formazione?

17 Ritieni utile per la tua formazione il materiale didattico messo a disposizione a corredo dei video? 1. **Sì 2. No 3. Più sì che no 4. Più no che sì**

18 Hai mai consultato il materiale didattico messo a disposizione? **1. Sì 2. No 3. Qualche volta 4. Mai**

19 Hai utilizzato gli esempi di problem solving proposti in alcune sezioni del materiale didattico nelle tue lezioni? **1. Sì 2. No 3. Qualche volta 4. Mai**

20 Hai utilizzato gli esempi di trasversalizzazione su altre discipline dei concetti chimici nelle tue lezioni? **1. Sì 2. No 3. Qualche volta 4. Mai**

21 Hai citato in qualche occasione gli esempi relativi alla vita reale citati nel materiale didattico nelle tue lezioni? **1. Sì 2. No 3. Qualche volta 4. Mai**

22 Hai utilizzato in qualche occasione i richiami teorici del materiale didattico per revisionare o completare le impostazioni teoriche delle tue lezioni? **1. Sì 2. No 3. Qualche volta 4. Mai**

23 Hai utilizzato le schede di valutazione fornite nel materiale didattico per valutare l'osservazione dei video da parte dei tuoi studenti? 1**. Sì 2. No 3. Qualche volta 4. Mai**

24 Ritieni che l'impostazione generale della elaborazione della sezione materiale didattico sia corretta e utile? 1. **Sì 2. No 3. Più sì che no 4. Più no che sì**

25 Vuoi lasciare qualche commento sulla correttezza e l'utilità riguardo l'impostazione generale della elaborazione della sezione "materiale didattico"?

26 Hai avuto modo di consultare o comunque utilizzare il materiale preparato in lingua inglese? **Sì No**

27 Perchè non hai avuto modo di consultare o comunque utilizzare il materiale preparato in lingua inglese?

28 Hai visionato l'esempio del calcolo del numero di Avogadro? **Sì No**

29 Perchè non hai visionato l'esempio del calcolo del numero di Avogadro?

30 Hai seguito in streaming il webinar? **Sì No**

31 Hai visto la registrazione del webinar? **Sì No**

32 Del programma del webinar, quale argomento ti è sembrato più interessante? **1. Problem solving nel laboratorio di chimica 2. L'approccio IBSE nella didattica sperimentale della chimica 3. Le prove autentiche di chimica e la valutazione autentica 4. Il Progetto Europeo Scientix**

33 Dei temi proposti in questo seminario informativo, quali aspetti, se ve ne sono, non ti erano noti? **1. Problem solving nel laboratorio di chimica 2. L'approccio IBSE nella didattica sperimentale della chimica 3. Le prove autentiche di chimica e la valutazione autentica 4. Il Progetto Europeo Scientix**

34 Dei temi proposti, quale ti sembra più opportuno per un eventuale approfondimento? **1. Sono stati tutti interessanti 2. Metodologie online 3. Approcci metodologi 4. Pianificazione del percorso didattico 5. Altro**

35 In base alla scelta dei temi proposti nella domanda precedente, vuoi lasciare dei suggerimenti per un eventuale approfondimento?

36 Per quanto riguarda le informazioni discusse nel webinar, nei temi che ti erano già noti hai comunque percepito informazioni addizionali dal webinar? 1. **Sì 2. No 3. Più sì che no 4. Più no che sì**

37 Il webinar è anche un'azione per identificare quali delle metodologie discusse potrebbero essere affrontate in un nuovo corso di formazione. Quali dei seguenti aspetti della didattica, potrebbero essere approfonditi in un nuovo eventuale corso**? 1. Problem solving 2. IBSE 3. Flipped Classroom 4. Preparazione di piattaforme personali con materiale didattico tipo Moodle 5. Uso di software per classi virtuali 6. Percorsi di didattica sperimentale 7. Altro**

38 Quanto ritieni importante la didattica sperimentale nell'insegnamento della chimica? **1. Fondamentale 2. Molto 3. Nella media 4. Poco 5. Irrilevante 6. Altro**

39 Quanto ritieni importante l'insegnamento della chimica nell'ambito del corso di Scienze? **1. Fondamentale 2. Molto 3. Nella media 4. Poco 5. Irrilevante 6. Altro**

40 Quanto ritieni importante contestualizzare i concetti chimici nella vita reale, nelle altre discipline e nella chimica applicata? **1. Fondamentale 2. Molto 3. Nella media 4. Poco 5. Irrilevante 6. Altro**

41 In generale, quale giudizio generale hai sviluppato su questo corso di formazione**? 1. Eccellente 2. Molto buono 3. Buono 4. Nella media 5. Sufficiente 6. Appena sufficiente 7. Insufficiente 8. Completamente inefficace**

42 In generale, hai dei suggerimenti da inoltrare al coordinatore di questo corso di formazione? **Sì No**

43 In generale, hai delle critiche metodologiche da segnalare al coordinatore di questo corso di formazione? **Sì No**

44 Raccomanderesti la frequenza di questo corso di formazione ai tuoi colleghi, se a pagamento? **Sì No**

45 Nell'ambito della tua formazione professionale, hai dei suggerimenti per UNICAM-sezione Chimica al fine di sviluppare azioni più efficaci per un corso di formazione per docenti? **Sì No**

46 Se dovessi autovalutarti sulla formazione conseguita con la frequenza di questo corso, su quali aspetti credi di avere avuto il migliore upgrade? **1. Competenze Moodle 2. Conoscenza di nuove opportunità disponibili online 3. Miglioramento conoscenze disciplinari di base 4. Arricchimento degli esempi da discutere durante le lezioni teoriche 5. Miglioramento della contestualizzazione dei temi di chimica generale nella vita reale 6. Miglioramento della trasversalizzazione dei concetti di chimica con altre discipline 7. Approccio applicativo di nuove metodologie didattiche 8. Conoscenza di nuove metodologie didattiche 9. Altro**

47 Inserisci nuovi aspetti sui quali che credi di aver avuto il miglior upgrade

48 Dai un voto alla tua formazione complessiva raggiunta su: uso piattaforma MOODLE **10 9 8 7 6 5 4 3 2 1 0**

49 Lascia un commento riguardo la tua formazione complessiva raggiunta su: uso piattaforma MOODLE

50 Dai un voto alla tua formazione complessiva raggiunta su: uso e studio dei video di esperimenti **10 9 8 7 6 5 4 3 2 1 0**

51 Lascia un commento riguardo la tua formazione complessiva raggiunta su: uso e studio dei video di esperimenti

52 Dai un voto alla tua formazione complessiva raggiunta su: Conoscenza delle metodologie didattiche di tipo sperimentale citate nel corso **10 9 8 7 6 5 4 3 2 1 0**

53 Lascia un commento riguardo la tua formazione complessiva raggiunta su: Conoscenza delle metodologie didattiche di tipo sperimentale citate nel corso
54 Dai un voto alla tua formazione complessiva raggiunta su: Miglioramento delle conoscenze delle materie di base **10 9 8 7 6 5 4 3 2 1 0**
55 Lascia un commento riguardo la tua formazione complessiva raggiunta su: Miglioramento delle conoscenze delle materie di base
56 Dai un voto alla tua formazione complessiva raggiunta su: Trasversalizzazione dei concetti trattati **10 9 8 7 6 5 4 3 2 1 0**
57 Lascia un commento riguardo la tua formazione complessiva raggiunta su: Trasversalizzazione dei concetti trattati
58 Dai un voto alla tua formazione complessiva raggiunta su: Arricchimento di esempi di concetti chimici nella vita reale **10 9 8 7 6 5 4 3 2 1 0**
59 Lascia un commento riguardo la tua formazione complessiva raggiunta su: Arricchimento di esempi di concetti chimici nella vita reale
60 Dai un voto alla tua formazione complessiva raggiunta su: Approccio al problem solving nei temi trattati **10 9 8 7 6 5 4 3 2 1 0**
61 Lascia un commento riguardo la tua formazione complessiva raggiunta su: Approccio al problem solving nei temi trattati

Appendix 3

"The online chemical experiments: Instructions for use" course

Assessment rubric

RUBRIC DI VALUTAZIONE UNITA' FORMATIVA

DIMENSIONI	INDICATORI
INSERIMENTO NEL CONTESTO	• Adeguatezza della proposta alle caratteristiche dei destinatari e ai prerequisiti di riferimento
STRUTTURA DEL PERCORSO	• Individuazione delle conoscenze, abilità e competenze da far acquisire agli alunni • Descrizione della/e metodologie • Descrizione delle fasi del percorso
COERENZA DELLA PROPOSTA DIDATTICA	• Coerenza del percorso con la/le finalità prevista/e • Coerenza della/e metodologia/e prevista/e • Pertinenza dell'attività di laboratorio prescelta • Individuazione dei tempi • Significatività dei collegamenti interdisciplinari e dei collegamenti con contesti di vita reale • *Presenza di strategie inclusive per alunni BES-Bisogni Educativi Speciali (eventuali)*
COERENZA DELLA VALUTAZIONE	• Significatività delle prove di verifica in relazione alle conoscenze, abilità e competenze da acquisire • Individuazione del metodo di valutazione
UTILIZZO DEI MATERIALI DEL CORSO E ORIGINALITA' DEL PERCORSO	• Adeguatezza dei materiali del corso utilizzati • Originalità del percorso elaborato a partire dagli input del corso
UTILIZZO DI ALTRI MATERIALI (eventuali)	• *Adeguatezza e contributo di altri materiali utilizzati*

Appendix 4

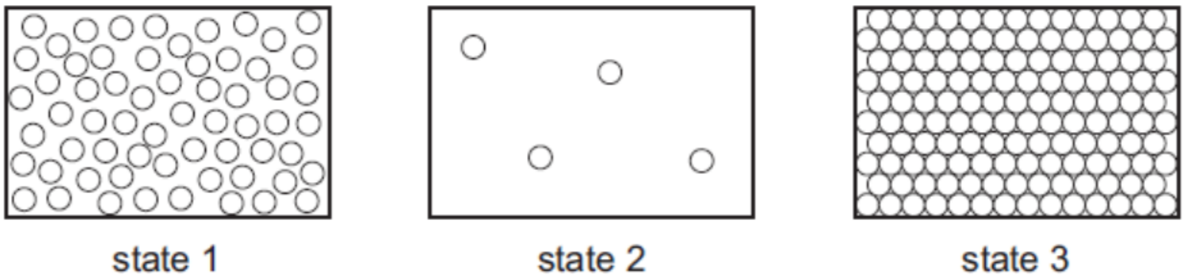
“An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology”

Pre-test

PRE-TEST

Nome della scuola___________________________
Classe______________________________________
Indirizzo____________________________________
Docente_____________________________________
Studente_____________________________________

1. **La figura mostra la disposizione delle particelle in tre stati fisici differenti della sostanza X.**



Quale affermazione sugli stati fisici della sostanza X è corretta?

a. Le particelle nello stato 1 vibrano intorno a posizioni fisse
b. Lo stato 1 si trasforma nello stato 2 per diffusione
c. Lo stato 2 si trasforma direttamente nello stato 3 per condensazione
d. La sostanza nello stato 3 ha un volume fisso

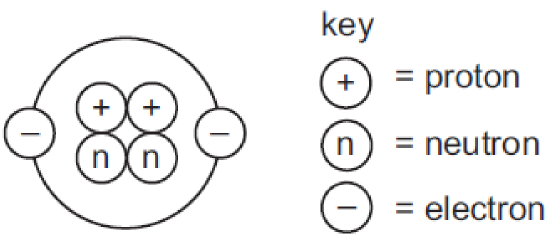
2. **Che cosa è sempre vero per una sostanza pura?**

a. bolle sempre a 100 °C
b. contiene un unico tipo di atomo
c. ha un punto di fusione netto
d. è solida a temperatura ambiente

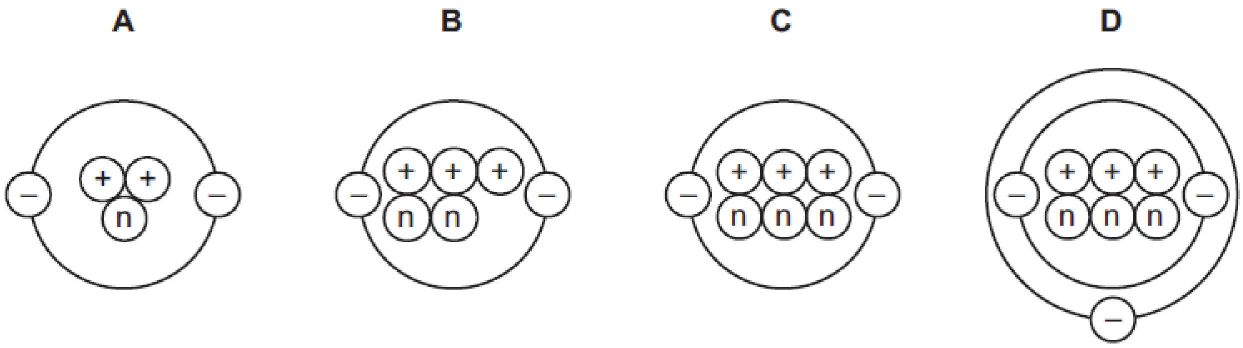
3. **Quale affermazione sulla Tavola periodica è corretta?**

a. Gli elementi dello stesso gruppo hanno lo stesso numero di gusci elettronici
b. Contiene elementi ordinati per numero di protoni crescente
c. I metalli sono sulla destra e i non metalli sulla sinistra
d. Gli elementi più reattivi si trovano in fondo ad ogni gruppo

4. **La figura mostra la struttura di un atomo.** (proton=protone; neutron=neutrone; electron=elettrone)



Quale figura mostra la struttura di un isotopo di questo atomo?



5. **Quando lo Iodio è riscaldato cambia il suo stato da solido a aeriforme. Quando l'ammoniaca liquida è raffreddata cambia il suo stato in solido. Quando il ghiaccio è riscaldato diventa acqua liquida. Quali termini descrivono questi passaggi di stato?**

	Quando lo Iodio è riscaldato	Quando l'ammoniaca liquida è raffreddata	Quando il ghiaccio è riscaldato
A	Ebollizione	Solidificazione	Fusione
B	Solidificazione	Sublimazione	Ebollizione
C	Sublimazione	Condensazione	Solidificazione
D	Sublimazione	Solidificazione	Fusione

6. **Bruciare un combustibile è una reazione ESOTERMICA. Cosa si intende con il termine ESOTERMICA?**
   a. La produzione di un gas
   b. Il rilascio di energia
   c. L'assorbimento di calore
   d. La diminuzione della massa del combustibile
7. **Quale affermazione sui gas nobili NON è corretta?**
   a. I gas nobili sono formati da molecole biatomiche
   b. I gas nobili sono gas poco reattivi
   c. I gas nobili hanno l'ultimo livello elettronico pieno
   d. Il gas nobile Neon è usato negli apparecchi illuminanti
8. **L'anidride carbonica e il metano sono entrambi gas serra che contribuiscono al cambiamento climatico. Quale affermazione spiega in che modo i gas serra contribuiscono al cambiamento climatico?**
   a. Assorbono il calore irradiato dalla Terra
   b. Assorbono il calore irradiato dal Sole
   c. Assorbono la radiazione luminosa del Sole
   d. Causano le piogge acide
9. **Il ferro è un metallo. La struttura del ferro è descritta come un reticolo di ioni positivi in un mare di elettroni. Quale delle seguenti affermazioni sul ferro è corretta?**
   a. Il ferro conduce l'elettricità perché gli elettroni sono liberi di muoversi
   b. Il ferro ha un alto punto di fusione dovuto a forti legami covalenti
   c. Il ferro è una lega
   d. Il ferro è malleabile perché gli strati di atomi possono scivolare gli uni sugli altri
10. **Una bicicletta d'acciaio che è stata lasciata all'aperto per molti mesi ha iniziato ad arrugginire. Che cosa NON ridurrà la velocità di corrosione?**
   a. Rimuovere la ruggine e dipingere la bicicletta
   b. Rimuovere la ruggine e conservare la bicicletta in un luogo asciutto e coperto
   c. Rimuovere la ruggine e strofinare la bicicletta con un panno oleato
   d. Rimuovere la ruggine e strofinare la bicicletta con un panno pulito e umido
11. **La filtrazione è una tecnica di laboratorio utilizzata per:**
   a. separare i componenti di un miscuglio omogeneo
   b. far reagire i componenti di un miscuglio
   c. separare i gas presenti in una soluzione
   d. separare i componenti di alcuni miscugli eterogenei

12. **Avete a disposizione un miscuglio formato da sabbia, sale da cucina e acetone. Progettate un esperimento per separare i tre componenti.**

1. Questo è l'esperimento che avrei condotto

____
____
____
____
____

2. Avrei osservato questo

____
____
____
____
____
____

3. Spiegazione per quello che avrei osservato

____
____
____
____
____

Per favore, fornisci i seguenti dati:

1. Maschio ☐ Femmina ☐
2. I tuoi voti nel precedente anno scolastico in Matematica____________ Scienze naturali________________

Grazie per l'impegno!

Appendix 5

“An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology”

Post-test

POST-TEST

Nome della scuola___________________________

Indirizzo________________________________

Classe_______________________________________

Docente______________________________________

Studente______________________________________

1. **Progetta un esperimento per preparare del rame metallico da una soluzione di ioni rame Cu+2 . Ti viene fornita la scala di reattività dei metalli.**

$K \rightarrow K^+ + e^-$

$Ba \rightarrow Ba^{2+} + 2e^-$

$Ca \rightarrow Ca^{2+} + 2e^-$

$Na \rightarrow Na^+ + e^-$

$Mg \rightarrow Mg^{2+} + 2e^-$

$Al \rightarrow Al^{3+} + 3e^-$

$Zn \rightarrow Zn^{2+} + 2e^-$

$Cr \rightarrow Cr^{3+} + 3e^-$

$Fe \rightarrow Fe^{2+} + 2e^-$

$Ni \rightarrow Ni^{2+} + 2e^-$

$Sn \rightarrow Sn^{2+} + 2e^-$

$Pb \rightarrow Pb^{2+} + 2e^-$

$H_2 \rightarrow 2H^+ + 2e^-$

$Cu \rightarrow Cu^{2+} + 2e^-$

$As \rightarrow As^{3+} + 3e^-$

$Ag \rightarrow Ag^+ + e^-$

$Hg \rightarrow Hg^{2+} + 2e^-$

$Au \rightarrow Au^{3+} + 3e^-$

meno reattivo

2. Questo è l'esperimento che avrei condotto

____
____
____
____

2. Avrei osservato questo

____
____
____
____
____

3. Spiegazione per quello che avrei osservato

____
____
____
____

2. **Progetta un esperimento per verificare se lo Zinco è un metallo più reattivo dell'Argento. Fai riferimento alla scala di reattività dell'esercizio 6.**

Questo è l'esperimento che avrei condotto

____
____
____
____

Avrei osservato questo

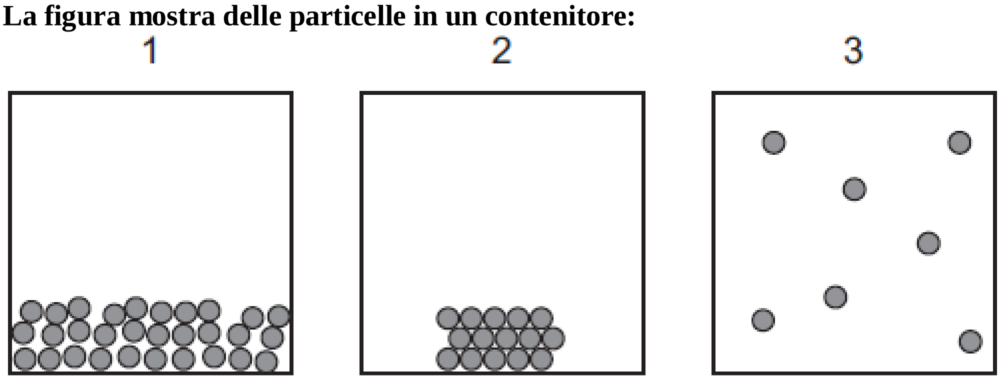
____
____
____
____

Spiegazione per quello che avrei osservato

____
____
____
____

3. **Il Ferro ha numero atomico 26. E' presente con gli isotopi ^{54}Fe, ^{56}Fe, ^{57}Fe e ^{58}Fe. Quale affermazione spiega perché questi isotopi hanno tutti le stesse proprietà chimiche?**
   a. Hanno numeri di massa simili
   b. Hanno lo stesso numero di elettroni nei livelli più esterni
   c. Hanno lo stesso numero di neutroni nel nucleo
   d. Hanno lo stesso numero di protoni nel nucleo
4. **Quale elemento è classificato come non metallo nella tavola periodica?**
   a. Calcio
   b. Cloro
   c. Cromo
   d. Rame
5. **Il rame è un metallo. Quali affermazioni sul rame sono corrette?**
   1. Il rame è malleabile perché gli strati di ioni sono in posizioni fisse e non possono muoversi
   2. La struttura del rame consiste di ioni negativi in un reticolo
   3. Il rame conduce l'elettricità perché gli elettroni possono muoversi attraverso il metallo
   4. Gli elettroni tengono insieme gli ioni rame nel reticolo per attrazione elettrostatica.

   a. 1 e 2 b. 2,3 e 4 c. solo 2 e 3 d. solo 3 e 4
6. **Una soluzione è formata a temperatura ambiente sciogliendo vigorosamente abbastanza soluto solido in modo che rimanga indisciolto del solido nella parte inferiore della soluzione. Quale affermazione di seguito è corretta?**
   a. la soluzione è insatura.
   b. la soluzione è sovrassatura.
   c. la soluzione è satura.
   d. nessuna delle precedenti.
7. **La figura mostra delle particelle in un contenitore:**



Quale dei due diagrammi mostra il processo di EVAPORAZIONE?

A 1 → 2 **B** 1 → 3 **C** 2 → 3 **D** 3 → 1

8. E' mostrata l'equazione chimica per una reazione di ossidoriduzione.

$$2Fe^{3+} + Zn \rightarrow 2Fe^{2+} + Zn^{2+}$$

Quali affermazioni sono corrette?

1. Fe^{+3} è ridotto a Fe^{+2}
2. Zn ossida gli ioni Fe^{+3}
3. Fe^{+3} è un agente ossidante

a. 1, 2 e 3   b. solo 1 e 2   c. solo 1 e 3   d. solo 2 e 3

9. Il metallo X è più reattivo, ovvero più facilmente ossidabile, del metallo Y. Il metallo Y è più reattivo del metallo Z. Quale affermazione è corretta?

a. Quando il metallo X è inserito in una soluzione del solfato di Y, non vi è reazione
b. Quando il metallo X è inserito in una soluzione del solfato di Z, avviene una reazione
c. Quando il metallo Y è inserito in una soluzione del solfato di Z, non vi è reazione
d. Quando il metallo Z è inserito in una soluzione del solfato di X, avviene una reazione

10. Sono date le equazioni ioniche per quattro reazioni:

$$Z + X^{2+} \rightarrow Z^{2+} + X$$

$$Z + 2W^{+} \rightarrow Z^{2+} + 2W$$

$$X + 2W^{+} \rightarrow X^{2+} + 2W$$

$$Y + Z^{2+} \rightarrow Y^{2+} + Z$$

Quale è l'ordine di reattività dei quattro metalli W, X, Y e Z?

	Più reattivo ---------------------Meno reattivo			
A	W	X	Z	Y
B	X	W	Y	Z
C	Y	Z	X	W
D	Z	W	X	Y

Per favore, fornisci i seguenti dati:

Maschio ☐   Femmina ☐

Grazie per l'impegno!

Appendix 6

“An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology”

Students’ survey questionnaire

QUESTIONARIO MONITORAGGIO ALUNNI

1. **GENERE**
   Maschio
   Femmina
2. **TIPOLOGIA DI LICEO FREQUENTATA**
   Liceo linguistico
   Liceo scientifico
   Liceo scientifico OSA
3. **HAI PARTECIPATO A TUTTE LE ATTIVITA' DELLA SPERIMENTAZIONE?**
   A. Sì, a tutte
   B. Solo a quelle in classe
   C. Solo a quelle nella classe virtuale

4. **QUALE ATTIVITA' TI E' SEMBRATA PIU' INTERESSANTE?**

   A. Le lezioni in classe del docente sulla reattività dei metalli
   B. L'attività di laboratorio guidata dal docente sulla reattività dei metalli alcalino-terrosi
   C. L'utilizzo del laboratorio virtuale
   D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
   E. La progettazione e l'esecuzione dell'esperimento
   F. Altro____

5. **QUALE ATTIVITA' TI E'SEMBRATA PIU' DIFFICILE?**
   A. Le lezioni in classe del docente sulla reattività dei metalli
   B. L'attività di laboratorio guidata dal docente sulla reattività dei metalli alcalino-terrosi
   C. L'utilizzo del laboratorio virtuale
   D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
   E. La progettazione e l'esecuzione dell'esperimento
   F. Altro____

6. **QUALE ATTIVITA' TI E' SEMBRATA PIU' CHIARIFICATRICE DEI CONCETTI SULLA REATTIVITA' DEI METALLI?**
   A. Le lezioni in classe del docente
   B. L'attività di laboratorio guidata dal docente
   C. L'utilizzo del laboratorio virtuale
   D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
   E. La progettazione e l'esecuzione dell'esperimento
   F. Altro____

7. **QUALE ATTIVITA' E' STATA PIU' UTILE PER LA PROGETTAZIONE DELL'ESPERIMENTO?**
   A. Le lezioni in classe del docente
   B. L'attività di laboratorio guidata dal docente
   C. L'utilizzo del laboratorio virtuale
   D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale

8. **QUESTA METODOLOGIA RENDE PIU' INTERESSANTE LO STUDIO DELLA CHIMICA**

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

9. **QUESTA METODOLOGIA RENDE PIU' FACILE LO STUDIO DELLA CHIMICA**

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

10. **VORREI SPERIMENTARE ALTRI PERCORSI DI CHIMICA CON QUESTA METODOLOGIA**

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

11. **IL PERCORSO MI HA SPINTO A STUDIARE DI PIU' LA CHIMICA**

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

12. **COMMENTO**

____
____
____
____
____

Grazie per la partecipazione!

Appendix 7

“An inquiry-based approach to the reactivity of metals integrated with Flipped Classroom methodology”

Teachers’ survey questionnaire

QUESTIONARIO MONITORAGGIO DOCENTI

1) **Titolo di studio**
   o Laurea in Chimica
   o Laurea in Scienze Biologiche
   o Laurea in Scienze Naturali
   o Laurea in Scienze Geologiche
   o Altro:
2) **Genere**
   o M
   o F
3) **fascia di età**
   o 25 - 35
   o 36 - 45
   o 46 - 55
   o > 56
4) **QUALE ATTIVITA' DEL PROGETTO CREDI CHE GLI ALUNNI ABBIANO TROVATO PIU' INTERESSANTE?**
   A. Le lezioni in classe del docente
   B. L'attività di laboratorio guidata dal docente
   C. L'utilizzo del laboratorio virtuale
   D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
   E. La progettazione e l'esecuzione dell'esperimento
   F. Altro____
5) **QUALE ATTIVITA' DEL PROGETTO CREDI CHE GLI ALUNNI ABBIANO TROVATO PIU' DIFFICILE?**

A. Le lezioni in classe del docente
B. L'attività di laboratorio guidata dal docente
C. L'utilizzo del laboratorio virtuale
D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
E. La progettazione e l'esecuzione dell'esperimento
F. Altro____

3) IN QUALE FASE GLI ALUNNI HANNO PARTECIPATO PIU' ATTIVAMENTE?

A. Le lezioni in classe del docente
B. L'attività di laboratorio guidata dal docente
C. L'utilizzo del laboratorio virtuale
D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
E. La progettazione e l'esecuzione dell'esperimento
F. Altro____

4) QUALE ATTIVITA' RITIENI SIA STATA PIU' UTILE AGLI ALUNNI PER LA PROGETTAZIONE DELL'ESPERIMENTO?

A. Le lezioni in classe del docente
B. L'attività di laboratorio guidata dal docente
C. L'utilizzo del laboratorio virtuale
D. Il confronto in classe con i docenti e i compagni dopo lo studio nella classe virtuale
E. Altro____

5) IN QUALE ATTIVITA' CON LA CLASSE HAI INCONTRATO MAGGIORI DIFFICOLTA'?

A) La presentazione delle attività nella fase ENGAGE
B) L'attività di laboratorio nella fase EXPLORE
C) Il setting e l'utilizzo della classe virtuale EDMODO
D) Il confronto in classe dopo lo studio in piattaforma
E) L'attività di laboratorio nella fase ELABORATE

6) AVEVO GIA' UTILIZZATO QUESTA METODOLOGIA CON I MIEI STUDENTI

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

7) **QUESTA METODOLOGIA RENDE PIU' INTERESSANTE LO STUDIO DELLA CHIMICA**

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

8) **QUESTA METODOLOGIA RENDE PIU' FACILE LO STUDIO DELLA CHIMICA**

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

9) RITENGO CHE QUESTA METODOLOGIA AIUTI GLI STUDENTI AD APPROFONDIRE LE PROPRIE COMPETENZE DI CHIMICA

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

10) VORREI SPERIMENTARE ALTRI PERCORSI DI CHIMICA CON QUESTA METODOLOGIA

Fortemente in disaccordo	In disaccordo	Né in accordo né in disaccordo	In accordo	Fortemente in accordo

11) **QUALI SONO, SECONDO TE, I PUNTI DI FORZA DI QUESTA METODOLOGIA?**

____

____

____

____

12) **QUALI SONO, SECONDO TE, GLI ASPETTI DA MIGLIORARE DI QUESTA METODOLOGIA?**

____

____

____

____

Appendix 8

“A blended learning approach to general chemistry modules inspired to Johnstone’s triangle for first year academic students”

Description of the mid-term test

Description of the Mid- term test

In the three academic years considered in this study, the course started in the second week of October and the mid- term test was scheduled in the first week of December.

In 2018/2019 A.Y. , the Moodle platform was available for students right from the beginning of the course, affording general issues about chemical reactions. After two weeks of course this topic becomes current and in three weeks (18 hours of lessons more or less) all the concepts covering the formalism, the balancing, the classification of reactions, the mole ratio and the stoichiometric calculations relative to this topic were afforded and practiced. During the rest of the course, these topics were further deepened, as long as other issues were studied such as thermochemistry, chemical bonding, thermodynamics and so on.

In 2018/2019 A.Y., the mid-term test contains 25 items, fractioned in 1-10 items about the nomenclature and chemical formulas, 11-19 items about the classification and balancing of reactions and its sub-microscopic level, questions 20 and 21 about molecular and empirical formulas and 22-25 about stoichiometric calculations on reaction yield and mole ratio in reactions also with gas evolution. The items are multiple-choice questions, with a structure similar to the self-evaluation exercises of the platform. Conversely, in A.Y 2017/2018, the platform was implemented only after the first month of the course and the mid-term test was similar to that administered in 2018/2019 A.Y.

In 2016/2017 A.Y. the tutoring course was not available, and the mid-term test afforded the same topics in a reduced number of 10 questions. As in example, in Table.1A is reported the questions for 2016/2017 A.Y., followed by the description of the corresponding mid-term test questions for the 2018/2019 A.Y.

Formula	**name**	**mark**
OF_2		
H_2CO_3		
$Sb(NO_3)_3$		
As_2S_5		
SeO_3		
$Ba(HCO_3)_2$		
$Fe(OH)_3$		
$PbCrO_4$		
$PtCl_4$		
$InCl_3$		
formula	**name**	**mark**

	Sodium cyanide	
	Mercury(I) chloride	
	Ammonium nitrate	
	Iodine(III) oxide	
	Auric oxide	
	Dinitrogen trioxide	
	Calcium Orthosilicate	
	Chromium(II) carbide	
	Cupric sulfate	
	Borane	

Table 1A: Table for nomenclature items for the 2016-2017 mid-term test.

Below is reported the corresponding mid-term test question for the 2018/2019 A.Y.:

1. What is the correct formula of the compound potassium periodate?

Make your choice:

a. KIO4

b. KIO2

c. KIO

d. KIO3

2. What is the correct formula for magnesium thiosulfate?

Make your choice:

a. MgS2O3

b. MgHSO4

c. Mg(HSO4)

d. MgSO3

3. What is the correct formula for barium sulfide?Make your choice:

a. BaSO3

b. BaS

c. BaSO4

d. Ba(HS)2

4. What is the correct formula for ammonium ortophosphate?

   Make your choice:

a. (NH4)(PO4)

b. (NH4)(H2PO4)

c. (NH3)2(PO4)

d. (NH4)3PO4

5. What is the correct formula for Phosphane ?Make your choice:

a. PH_3

b. P_2H_4

c. CH_4

d. HF

6. What is the formula for Zinc sulfate?Make your choice:

a. $ZnSO_4$

b. ZnS

c. $ZnSO_3$

d. ZnS_2

7. What is the formula for orthosilicic acid?Make your choice:

a. H_4SiO_4

b. H_2SiO_3

c. H_2SiO_2

d. H_2SiO_4

8. What is the formula for stannous hydroxide?Make your choice:

a. $Sn(OH)_4$

b. $Sn(HCO_3)$

c. SnOH

d. $Sn(OH)_2$

9. What is the formula for potassium permanganate?Make your choice:

a. K_2MnO_3

b. K_2MnO_4

c. $KMnO_4$

d. $KMnO_3$

10. What is the formula for Rubidium sulfide?Make your choice:

a. RbS_2

b. $RbSO_3$

c. $RbSO_4$

d. Rb_2S

Appendix 9

“A blended learning approach to general chemistry modules inspired to Johnstone’s triangle for first year academic students”

Students’ survey questionnaire

SURVEY QUESTIONNAIRE

Part 1 Personal Data

AGE

GENDER F M

COUNTRY OF ORIGIN

DEGREE COURSE

ENGLISH LANGUAGE KNOWLEDGE (ELEMENTARY, GOOD, EXCELLENT, MOTHER TONGUE)

DO YOU HAVE ANY ENGLISH LANGUAGE CERTIFICATE? IF SO, NAME THE EXAMINATION BOARD AND QCER CERTIFICATE LEVEL (B1/B2/C1/C2)

DIGITAL SKILLS (ELEMENTARY; GOOD, EXCELLENT;

TYPE OF ICT CERTIFICATE, IF ANY)

Part 2 Behaviours

1. **HAVE YOU EVER EXPERIENCED TUTORING ONLINE OR OTHER KIND OF E-LEARNING BEFORE? IF SO, WHICH KIND OF EXPERIENCES DID YOU HAVE?**
2. **IN PREPARATION FOR THE TEST, YOU HAVE STUDIED:**

A. ONLY FROM THE BOOK
B. ONLY FROM THE NOTES AND SLIDES
C. ONLY FROM THE PLATFORM
D. FROM BOOK, NOTES AND SLIDES
E. FROM BOTH THE BOOK AND PLATFORM
F. FROM NOTES, SLIDES AND PLATFORM
G. FROM BOOK, NOTES, SLIDES AND PLATFORM

3. **HAVE YOU EXPLORED THE DIDACTIC MATERIAL ON THE PLATFORM?** (YES/NO)
4. **IN PREPARATION FOR THE TEST, YOU HAVE USED ONE OR MORE OF THE FOLLOWING FUNCTIONS:**

A. VIDEOS (A LOT/ A LITTLE/NEVER)
B. SUBMICROSCOPIC VIEW (A LOT/ A LITTLE/NEVER)
C. OVERVIEW OF THE EXERCISE’S RESOLUTION STEPS (A LOT/ A LITTLE/NEVER)

D. VIDEO TUTORIAL ON HOW TO SOLVE THE ASSIGNMENT (A LOT/ A LITTLE/NEVER)
E. MULTIPLE CHOICE EXERCISES (A LOT/ A LITTLE/NEVER)
F. OTHER MATERIALS (A LOT/ A LITTLE/NEVER)

5. IN PREPARATION FOR THE TEST YOU HAVE USED THE MATERIAL ON THE PLATFORM:

A. ON YOUR OWN
B. WITH A COLLEAGUE
C. IN A GROUP

PART 3. INTENTIONS/PREFERENCES/OPINIONS

1. THE PLATFORM HAS BEEN USEFUL IN PREPARATION FOR THE TEST:

1 2 3 4 5 (1=STRONGLY DISAGREE; 2=DISAGREE; 3=NEITHER DISAGREE NOR AGREE; 4=AGREE; 5=STRONGLY AGREE)

2. THE VIDEOS HAVE BEEN HELPFUL FOR THE TEST

1 2 3 4 5

3. THE SUBMICROSCOPIC VIEWS HAVE BEEN HELPFUL FOR THE TEST

1 2 3 4 5

4. LOOKING AT THE STEPS LEADING TO THE SOLUTION OF THE EXERCISES HAS BEEN USEFUL FOR THE TEST

1 2 3 4 5

5. THE VIDEO TUTORIALS ON HOW TO SOLVE THE ASSIGNMENT HAVE BEEN USEFUL FOR THE TEST

1 2 3 4 5

6. THE MULTIPLE CHOICE EXERCISES HAVE BEEN USEFUL FOR THE TEST

1 2 3 4 5

7. OTHER MATERIALS HAVE BEEN USEFUL FOR THE TEST

1 2 3 4 5

8. I HAD NO DIFFICULTY IN UNDERSTANDING THE MATERIALS PRESENTED IN THE VIDEOS (MACRO LANGUAGE)

1 2 3 4 5

9. I HAD NO DIFFICULTY IN UNDERSTANDING THE SUBMICROSCOPIC LEVEL

1 2 3 4 5

10. I HAD NO DIFFICULTY IN UNDERSTANDING THE PROCEDURE FOR THE SOLUTION OF THE EXERCISES (VIDEOTUTORIALS)

1 2 3 4 5

11. MY PREVIOUS KNOWLEDGE OF CHEMISTRY WAS ADEQUATE FOR UNDERSTANDING PLATFORM MATERIALS

1 2 3 4 5

12. MY BASIC PREPARATION, OBTAINED AS A RESULT OF THE FREQUENCY OF LECTURES, WAS ADEQUATE TO ADDRESS THE EXERCISES PERFORMED ON THE PLATFORM

1 2 3 4 5

13. MY PREVIOUS KNOWLEDGE OF CHEMISTRY WAS ADEQUATE TO ANSWER THE SELF EVALUATION QUIZ

1 2 3 4 5

14. THE DIFFICULTY LEVEL OF THE TEST WAS COMPARABLE TO THE LEVEL OF THE PLATFORM EXERCISES

1 2 3 4 5

15. I HOPE MORE MODULES RELATED TO THE COURSE WILL BE MADE AVAILABLE ON THE PLATFORM

1 2 3 4 5

16. I HOPE WE CAN HAVE ONLINE TUTORING AVAILABLE FOR OTHER COURSES OFFERED BY UNIVERSITY OF CAMERINO

1 2 3 4 5

17.ONLINE TUTORING CAN REPLACE THE TRADITIONAL CLASSROOM EXPLANATION OF THE EXERCISES

1 2 3 4 5

18.BY USING THE PLATFORM I DEVELOPED A DEEPER AWARENESS OF WHAT I HAD LEARNED FROM THIS COURSE

1 2 3 4 5

19.IN GENERAL, HOW SATISFIED WERE YOU WITH THE PLATFORM?

A. VERY SATISFIED

B. GENERALLY SATISFIED

C. NEITHER

D. GENERALLY DISSATISFIED

E. VERY DISSATISFIED

Part 4 Open questions/Comments

1. WHAT DID YOU LIKE MOST ABOUT THE PLATFORM?

2. WHAT DID YOU LIKE LEAST ABOUT THE PLATFORM?

3. WHAT WOULD YOU ADD TO THE PLATFORM?

4.WHAT WOULD YOU CHANGE ON THE PLATFORM?

5. WHAT ADVICE WOULD YOU GIVE TO A STUDENT NEW TO THIS COURSE?

6. WHICH CLASS MODALITY DO YOU PREFER?

A. ENTIRELY FACE-TO-FACE
B. MINIMAL USE OF THE WEB, MOSTLY HELD IN FACE-TO-FACE FORMAT
C. AN EQUAL MIX OF FACE-TO-FACE AND WEB CONTENT
D. EXTENSIVE USE OF THE WEB, BUT STILL SOME FACE-TO-FACE CLASS TIME
E. ENTIRELY ONLINE WITH NO FACE-TO-FACE TIME

7. ONLINE TUTORING HELPS ME BETTER UNDERSTAND COURSE MATERIAL

1 2 3 4 5

8. ONLINE TUTORING HELPS ME BETTER UNDERSTAND COURSE REQUIREMENTS

1 2 3 4 5

9. MY PERSONAL DEVICES (E.G. CELL PHONE, TABLET, ETC) HELP ME WITH LEARNING

1 2 3 4 5

10. SOCIAL NETWORKING APPLICATION (E.G. FACEBOOK, TWITTER) HELP ME WITH LEARNING

1 2 3 4 5

11. I AM A MULTITASKER

1 2 3 4 5

12. I HAVE STRONG TIME MANAGEMENT SKILLS

1 2 3 4 5

13. I AM MOTIVATED TO SUCCEED

1 2 3 4 5

Appendix 10

“A blended learning approach to general chemistry modules inspired to Johnstone’s triangle for first year academic students”

Statistical Analysis

STATISTICAL ANALYSIS OF THE DATA

1. Snedecor-Fisher test

The Snedecor-Fisher test requires that the variances of different populations are equal and this can be checked by mean of Bartlett's test, involving the statistical variable:

$$B(K) = \frac{(N-k)lnS_p{}^2 - \sum_{i=1}^{k}(n_i-1)lnS_i{}^2}{1+\frac{1}{(3k-1)}\left(\sum_{i=1}^{k}\frac{1}{n_i-1}-\frac{1}{N-k}\right)} \qquad (equation\ 1A)$$

where $N = \sum_{i=1}^{k} n_i$, n_i is the number of statistical units of sample i, k is the number of the groups analyzed, $S_p{}^2 = \frac{1}{N-k}\sum_i (n_i - 1)S_i{}^2$ is the pooled estimate for the variance and $S_i{}^2$ is the variance of sample i.

The test uses the fact that B (k) approximates the random variable $\chi^2(k-1)$ if the involved groups are at least 3. We must remember that the variable χ^2 with k degrees of freedom is the sum of k squared Gaussian random variables, all with mean 0 and variance 1.

In our study, the statistical analysis, at the significance level of 5%, produced the following results: $B\ (3) \cong 4.05$, $B_{critical}\ (3) \cong 5.99$.

So, being $B_{critical}(3) > B\ (3)$, we rejected the hypothesis that the variances are significantly different.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		2016-2017	2017-2018	2018-2019			df	2	count(B2:D2)-1				
2		0,77	0,6	0,88			B-num	4,065934657	E102*E105-SUM.PRODUCT(B102:D102;B105:D105)				
3		0,67	0,56	0,84			B-den	1,003818685	1+1/(2*H2)*(SUM(B103:D103)-E103)				
4		0,50	0,56	0,48			B	4,050467197	H2/H3				
5		0,83	0,48	0,84									
6		0,33	0,84	0,64			alfa	0,05					
7		0,67	0,64	0,72			p-value	0,131963013	CHISQ.DIST.RT(H4;H1)				
8		0,77	0,64	0,8			B-crit	5,991464547	CHSQ.INV.RT(H6;H1)				
9		0,43	0,56	0,48			sig	OMOGENEOUS	IF(H8>H4;"OMOGENEOUS";"NOT OMOGENEOUS")				
10		0,50	0,64	0,68									
101	mean	14,0867	15,3494	16,79784									
102	df	98	82	80	260								
103	1/df	0,010204	0,012195	0,0125	0,003846								
104	var	30,87683	22,40082	20,76975	25,08907								
105	ln(var)	3,430006	3,109098	3,033498	3,222432								

Figure A1: Bartlett's random variable B calculation and variance homogeneity test: the screen shot of the Excel sheet shows the formulas used for the calculation

The hypotheses formulated allowed us to use the Snedecor-Fisher statistical test [(1)] based on the random variable

$$F(k) = \frac{\sum_{i=1}^{k} n_i \frac{(\bar{Y}_i - \bar{Y})^2}{k-1}}{\sum_{i=1}^{K} \sum_{j=1}^{n_i} \frac{(Y_{i,j} - \bar{Y}_i)^2}{N-k}} \qquad \textit{(equation 2A)}$$

where k is the number of groups, $\bar{Y}_i$ is the average of statistical variable Y of the group i, n_i is the number of statistical units of the group i, $\bar{Y}$ is the total overage. Then we compared through the F variable the average score of three groups mid-term exams administered in the three academic years to draw information and conclusions. The results are discussed in Chapter 5.

2. χ2 Analysis

By considering the dispersion graph for time (hours) over score (0-30) and its analysis, to give a more accurate interpretation of its meaning, we have collected the data in five classes for each of the two statistical observables, i.e. the student's evaluation and the time spent on the platform.

With the frequencies observed we calculated the random variable chi squared

$$\chi^2 = \frac{(O_{i,j} - T_{i,j})^2}{T_{i,j}} \qquad \textit{(equation 3A)}$$

where $O_{i,j}$ and $T_{i,j}$ are respectively the observed and the theoretical frequencies on the sample; we recall that the theoretical frequencies are calculated in the hypothesis that the statistical observables involved are all independent. The results are discussed in the manuscript.

References

(1) George W. Snedecor, William G. Cochran; Statistical Methods; Iowa State University Press, Ames, Iowa, 1989.