Substantia
An International Journal of the History of Chemistry

Firenze University Press
www.fupress.com/substantia

Feature Article

Distance Education in Chemistry during the Epidemic Covid-19

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Abstract. During the epidemic Covid-19, in most of the countries schools of all grades and univesities had to face a long period of closure without interrupting the educational mission. Distance education, which has been introduced first in UK in the Nineteen century as "correspondence learning" and then in USA and Australia, with the institution of "Open Universities" (i.e. MOOC and e-learning platforms), became the only way to guarantee the continuity in teaching during the pandemic Covid-19. The present contribution is a short overview of the literature about limits and advantages of distance education of chemistry, in particular at high school and university levels, with a focus on the experiences and peculiarities of the distance education in the period of the Covid-19 emergency.

Keywords. Distance Learning, Distance Teaching, Distance Education, Chemistry, Didactics, Interactive Teaching Approaches, E-learning, M-learning, Open Learning.

OPEN ACCESS

Citation: V. Domenici (2020) Distance Education in Chemistry during the Epidemic Covid-19. *Substantia* 4(1) Suppl. 1: 961.
DOI: 10.13128/Substantia-961

Received: Jun 09, 2020

Revised: Jun 18, 2020

Just Accepted Online: Jun 25, 2020

Published: Jun 25, 2020

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

A short history of distance education

Distance learning and distance education have quite a long history, starting from the "correspondence courses",[1,2] born during the Nineteenth century, and intended for students who were not able to attend the schools, mainly due to the vast distances of the country. The first correspondence education and distance training courses were developed in UK, USA and Australia.[1,2]

The next step of the history of distance education is related to the new idea of "Open University", developed to get a wider access of students to high school studies and university courses. In the middle of the Twentieth century, first in UK, several institutions designed new types of open courses in different disciplines with the main purpose to create a learning alternative to the traditional face-to-face education, specifically intended for those who had no possibilities to attend schools for social or economic reasons. Open University programs allowed a sensibly increase of the number of students as never before: up to hundreds of thousands of students for each institution every year. The possibility to raise the number of students having free access to higher education is in line with the concept of "mass education", which characterizes the teaching systems since the beginning of the Twentieth century.[3]

More recently, the idea of open courses was introduced both in the European and Anglo-Saxon countries in connection with the "lifelong learning" concept[3,4] as a constitutive part of the educational policies.[5] The basic idea is that citizens learn during their whole life, not only in formal contexts (i.e. at school, at the University or during professional training courses), but also in non-formal environments[3,4] (i.e. visiting a museum, taking part of cultural, social or sport activities, letting informed on the web, and so on). Nowadays, internet and social media are considered central in life-long learning as well as in distance education.[4] The development of internet and related technologies, in fact, opened up to many different programs and tools, usually referred as e-learning and m-learning, if they imply the use of mobile devices, such as smartphones and tablets.[6]

Since 2012, the idea of "Open University" has evolved thanks to the new digital technologies into the so-called "Massive Online Open Courses" (MOOC)[7,8] which were firstly conceived by several Universities in USA, such as the *MIT OpenCourseWare* (MIT OCW), a project of online courses organized by the Massachusetts Institute of Technology (MIT). Since then, several MOOC programs have been provided in many Universities and Academies all over the World covering almost all disciplines and educational fields. One of the consequences of MOOC was the possibility to have an unlimited number of students and to allow the attending of specific courses to adults, workers and people who, for several reasons, would not have had this chance, otherwise.

Open science courses and science MOOCs[9] were developed too, mainly using to two modalities: synchronous and asynchronous approaches. The first mode implies the presence of students at the same time of the online course, either through videoconferences, live-streaming, forum or other interactive tools. The second mode of delivery of the online course, on the contrary, does not require the presence of students at the same time, and it is characterized by higher flexibility. In principle, students can listen or watch pre-recorded video-lessons, or perform online quiz without a definite time schedule, answer to questions by e-mail messages and so on. As reported in several works,[6,7] the two modes can also be used together; moreover, these typical online activities can also be combined with face-to-face teaching modalities: in such cases, the educational approach is referred as "blended learning".[10]

These new ways of teaching, in particular the blended learning and the online learning modes, were object of several studies aiming to investigate their effectiveness with respect to more traditional ones, as reported in ref. 6 and therein. These studies mainly focused on the effect of online learning and blended learning in terms of specific learning outcomes, student engagement, learning perception and metacognitive objectives and they substantially showed that these distance education modalities are at least as effective as face-to-face ones. However, as discussed in the following parts, additional work is needed to investigate their effectiveness in specific disciplines, such as chemistry.

Another important aspect of distance education is related to its accessibility. In principle, as also stated in the UNESCO declaration,[8] distance education and online learning should follow several criteria in order to enhance, and not limit, the access to education. As reported in ref. 11: "*Students in distance learning courses represent a variety of racial and ethnic backgrounds, ages, native languages, and learning styles. In addition, increasing numbers of students with disabilities participate in regular precollege and postsecondary courses. Their disabilities include blindness, low vision, hearing impairments, mobility impairments, learning disabilities, and health impairments*."

The free access to all students and the equality of accessibility are probably the major tasks of distance education in the next future.

Distance education in chemistry: methods, tools and effectiveness

Not surprisingly, distance learning in chemistry has been introduced several decades ago, as well as computer simulations and digital software have been largely used in many research fields of chemistry since the Seventies of the previous century.[12] The first critical overview[12] about distance learning in chemical education was published in 1999, showing how chemistry teachers took advantage from computing quite soon. For instance, online activities related to the creation of virtual workgroups or the sharing of multimedia, such as digital video and molecular 3D animations, were largely introduced both at the high school and university levels, in combination with face-to-face and hands-on activities.[13] The new technological teaching modes demonstrated to be quite effective in chemical education concerning the level of interactivity and participation of students to the classroom activities. On the other hand, the main limitations of distance learning in chemistry seem to be related to the need of a specific teaching training and of a radical change of educational models.[12] Moreover, from these studies,[12-19] it is evident that distance education in chemistry implies the availability of new and ad-hoc educational materials and, more important, a completely free access to digital tools and internet and/or mobile devices.[12,13]

It's worth noticing that in the case of distance education at the University level, in several countries, online courses in chemistry[16] and distance education were encouraged based on economic reasons.[13]

The need to organize chemical laboratories for an increasing number of students, especially in the case of first-

year undergraduate students, stimulated the development of virtual laboratories and e-learning programs to reduce their cost and to allow students to attend the classes online, for instance in case the students could not access to the university campus. As observed in the previous paragraph, the countries characterized by large geographical distances, such as USA and Australia, were the first developing specific digital tools and virtual environments for distance education in chemistry.

Examples of virtual laboratories of general chemistry and organic chemistry are reported in the literature,[13,15,18,19] giving rise to interesting findings. In particular, some of these studies[18,19] can be considered very useful in terms of organization of the materials, description and availability of free digital tools, assessment schemes and on-line resources. Unfortunately, so far, few studies exist concerning the effectiveness of virtual laboratories in chemistry compared with hands-on laboratories.

Chemical education during the pandemic Covid-19

The situation related to the pandemic Covid-19 caused the closure of schools and Universities in many countries, for different periods depending on the specific seriousness and risks perceived in different countries and to political choices. As reported in a note by UNESCO[20], at the beginning of March 2020: "*School closures in thirteen countries to contain the spread of COVID-19 are disrupting the education of 290.5 million students globally, a figure without precedent*". Distance learning and distance education appeared to the most the only way to assure the continuity of education and learning of students at all school and university grades. However, based on former considerations, several countries were certainly more prepared than others to face up this emergency.

Concerning chemical education, distance education for high school and university students was characterized mainly by synchronous video-lessons provided by chemical teachers who had to organize and prepare the educational materials by themselves, in most of the cases without the help and assistance of the school and university systems. Most of these activities were performed on e-learning platforms (i.e. the *moodle* platform) or websites designed for videoconferences (i.e. google meet, Microsoft teams, Zoom, Skype and so on); they were often suggested by the schools and universities, with a certain variability of access modality. Obviously, in some countries, the availability of digital tools, devices and virtual programs, as well as the previous experiences and teachers' training programs on distance education in chemistry were of great help during the pandemic Covid-19. It is quite significant that most of the interactive tools and software concerning virtual laboratories and chemical molecular simulations are in English. A great number of free resources were already available in several web-sites; many distance learning and online teaching resources were provided, for instance, by the Chemical Education Division of the American Chemical Society.[21,22] The same association launched a special issue of the Journal of Chemical Education, aiming to share best practices in chemical education about distance learning and distance teaching during the emergency.[23] Other national chemical societies, such as the Royal Society of Chemistry in UK and the Italian Chemical Society in Italy,[24] started sharing chemical laboratory experiences and free on-line resources to be used for distance teaching. An interesting consequence of the emergency related to the unusual educational situation is the exponential increase of shared teaching experiences among teachers' groups and associations. This also happened in chemical education: many chemical teachers started recording and sharing their own video-lessons, videos about hands-on and laboratory experiences, performed at home, by using common and everyday-life materials.[25,26]

Figure 1. A chemistry distance lesson during the Covid-19 pandemic in Italy. Resource: Wikicommon.[25]

In a way, thanks to the web and to the social networks, the unusual situation contributed to create a "*virtual community of teachers in chemical education*".

On the other hand, the long period of school and university closure, in particular in some countries as in Italy, revealed all the limitations of teaching modalities based on distance education only. This is particular evident for those educational activities which imply a manual training, such as chemical and instrumental laboratories. An additional issue is related to the absence of empathy and psychological implications of distance education, which were clearly get worse due to the dramatic contest and general level of diffuse anxiety related to the Covid-19 emergency.

To conclude, the complete substitution of distance education to traditional education can be justified due to the global emergency caused by the epidemic Covid-19, however, as already put in evidence in the previous reflections, a "blended learning" approach should be preferred in the next future.

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