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ATTEMPTS, SUCCESSES AND FAILURES OF DISTANCE LEARNING IN THE TIME OF COVID-19

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■ ABSTRACT

Over 1.7 billion students around the world have had their education disrupted by the spread of Coronavirus disease worldwide. Schools and universities have not faced this level of disruption since World War II. The COVID-19 pandemic presented a colossal challenge for teachers to urgently and massively adapt all their classes to distance learning in order to maintain educational continuity with the same quality. Even if some teachers and certain classes were ready to face the situation, a large majority had to adapt their teaching and learning in a very short time without training, with insufficient bandwidth, and with little preparation. This unexpected and rapid transition to online learning has led to a multiplication of teachers' strategies for distance learning in lectures, tutorials, project groups, lab work and assessments. The purpose of this paper is to present the feedback from students and teachers who participated in the lockdown semester of two different groups of a 5-year program in Chemistry, Environment and Chemical Engineering (100 students) at INSA Toulouse (France). The analysis has highlighted some great successes and some failures in the solutions proposed. Consequently, some guidelines can be given to help us all to learn the lessons of such a singular experience in order to face the unexpected future with more knowledge and more successful distance learning. Teachers have shown very strong resilience during this crisis, at the cost of significant personal commitment. They admit that they have learned more about distance education in two months than in the last 10 years.

■ GRAPHICAL ABSTRACT



■ KEYWORDS

General Public < Audience, Distance Learning / Self Instruction < Pedagogy, Inquiry-Based / Discovery Learning < Pedagogy, Collaborative / Cooperative Learning < Pedagogy, Student-Centered Learning < Topics

36 ■ INTRODUCTION

37 Distance education has been in existence for at least a century. During this time, the
38 medium has changed from pencil and paper correspondence courses by post¹ to real-
39 time Internet courses². Distance education courses were originally developed to involve
40 students³ who did not have ready access to a School or University, had restricted hours
41 for course participation, or simply disliked the conventional “school” environment. An
42 important foundation of distance education is the theory of independent study⁴, which
43 suggests that successful teaching can take place even though teacher and learner are
44 physically separated during the learning process. In this model, the roles of students and
45 teachers are different from those they played in traditional education systems: the
46 teachers are no longer the sole owners of knowledge, and become facilitators to support
47 student learning, while students have to develop their collaborative efforts. The
48 proliferation of the smartphone and videoconferencing systems, with the development of
49 the Internet and the 4G/5G network⁵ have provided access to both information and
50 contacts that were previously unavailable. Some works⁶ have shown that, on average,
51 students retain 25-60% of the new material presented when learning online, compared
52 to only 8-10% in a traditional classroom and require 40-60% less time to learn.⁷ (This
53 could be explained by the fact that students can learn at their own pace, when they want,
54 going back and re-reading, skipping, or accelerating.) It took decades^{8,9} to build this
55 model and adapt it to these students (given that each individual has a specific situation:
56 full time employment, high motivation, personal stress, etc.^{10,11}). The main barriers
57 associated with such a model were issues of communication between student and
58 institution, isolation¹², tutoring, laboratory work, access to books, and informatics
59 issues, including training of staff and the need for technical support,² or even difficulties
60 of access to a sufficiently high-performance Internet connection. The design of specific
61 study materials for distant students has been revealed as a key factor for the success of
62 such a model. Many educators have worked on developing innovative specific tools in the
63 last decade, such as the use of videos,^{13,14} the web,¹⁵⁻¹⁷ the creation of real-time
64 experiments,¹⁸ or the development of online games with serious educational objectives¹⁹⁻

65 28. The latest technological developments, such as Virtual Reality (VR)^{26,29-32} or
66 Augmented Reality (AR)³³⁻⁴¹ have emerged as interactive, promising and engaging tools
67 for chemical education that are adaptable for distance learning.

68 In December 2019, a new strain of coronavirus caused a cluster of cases of a respiratory
69 disease, which has been referred to as coronavirus disease 2019 (COVID-19). According
70 to media reports,⁴² more than 200 countries and territories have been affected by COVID-
71 19, with major outbreaks occurring in Central China, Iran, Western Europe, Brazil and
72 the United States, and the disease was characterized as pandemic by the World Health
73 Organization on March 11th, 2020⁴³. The COVID-19 pandemic has affected educational
74 systems worldwide, leading to the near-total closures of schools, universities and colleges.
75 Most governments around the world have temporarily closed educational institutions to
76 contain the spread of COVID-19. Approximately 1.725 billion learners were affected by
77 university closures in response to the pandemic. In response, UNESCO recommended
78 the use of distance learning programs.^{44,45} The COVID-19 pandemic presented a colossal
79 challenge to educators to adapt all their classes urgently and massively to distance
80 learning in order to maintain educational continuity with the same level of quality. In the
81 context of the health crisis linked to the COVID-19 epidemic, a plan for educational
82 continuity was set up in France by the Ministry of Higher Education, aiming at
83 maintaining the continuity of teaching by guaranteeing that institutions offer their
84 teaching modules in e-learning form to enable students to follow their courses at home.
85 Within this framework, national tools are made available (FUN MOOC, thematic digital
86 universities, etc.) and are available for educators. Even though some educators and some
87 classes were ready to face the situation, a large majority had to adapt their teaching and
88 learning in a short time, with no training, insufficient bandwidth, and little preparation.
89 Moreover, the existing distance courses were not created for conventional students or for
90 the Y/Z generation⁴⁶. This population was born into a world of information technology
91 and is therefore much more connected to the world⁴⁷⁻⁴⁹. They prefer to work in groups
92 with hands-on experience^{50,51}. They have few time constraints and many more sources of
93 entertainment. They did not choose this way of learning, and so they may not be as

94 motivated as the students that chose distance learning in the past. In the case of COVID-
95 19, the sudden decision to impose lockdown obliged educators and students to stay at
96 home, thus inducing inequalities, ominous for both students and educators. For
97 students, the family support for logistics (shopping, preparation of meals, etc.) is different
98 between students who have returned to their families and those who remain isolated in
99 their small rooms close to the campus. The former have more comfortable and social
100 conditions, and can be supported by their family. However, some of these students have
101 to share their computer or connection time with other family members, which reduces
102 their working time for real-time on-line learning, and leads them to work on courses on
103 demand or to often have group meetings at night. Similarly, teachers' working conditions
104 are variable, depending on their personal accommodation, their access to the home
105 network, the composition and constraints of their family unit (children, other persons
106 working at home, need to support vulnerable people), and the means available to them
107 at home. They often have to mobilize their own means (apart from a laptop), without
108 dedicated equipment and without institutional help concerning their working conditions.
109 This unplanned, unprepared and rapid move to online learning led to a multiplication of
110 strategies by educators for distance learning to be able to replace, within a short period,
111 classes, tutorials, project groups, lab works and assessments with different, recently
112 acquired technologies. The purpose of this paper is first to present some attempts and
113 the corresponding feedback from users in order to enable lessons to be learnt from this
114 unique experience of education in the time of the COVID-19. Secondly, this work aims at
115 helping the academic educational community to learn from the experience and prioritize
116 a forward-thinking and scholarly approach to the practical solutions implemented.

117

118 ■ **METHOD & CONTEXT**

119 The lockdown occurred in the middle of the semester, on March 16th (semester started
120 on January 27th, 2020 and ended on June 5th, 2020) and obliged the educators to adopt
121 different strategies to ensure the continuity and the content of the teaching program
122 without loss of quality. The study focuses on a the semester organized for 3rd- and 4th-

123 year students following a 5-year program in Chemistry, Environment and Chemical
124 Engineering (a total of 104 students in the 2019/2020 academic year) in the Chemical
125 Engineering Department at INSA Toulouse (National Institute of Science and Technology
126 of Toulouse), France. These students were part of a highly motivated, concerned group,
127 who had already acquired working methods, and were able to work autonomously. The
128 usual teaching method before lockdown comprised lectures, tutorials and lab work that
129 occupied similar proportions of their time. This study is based on an inventory of the
130 many different strategies imagined, set up and applied by educators during the semester.
131 A sixteen-question online survey in French was carried out at the end of the semester to
132 evaluate the feedback from students on each strategy proposed, with responses based
133 on a Likert⁵² scale (Figures 1&2). The survey also included 8 open-ended questions on
134 the main parts (classes, tutorials, lab work, projects, assessments, distance learning,
135 proposal, educator involvement) that were asked after a series of 3-6 questions on each
136 topic. Participants were approached twice by Email and the response rate was 85%. All
137 the students were in France in the same time zone (Central European Time, CET) during
138 the semester. Teachers were also consulted by means of a 10 question online survey (N
139 =15, response rate was 75%). The data from the online surveys were entered into a
140 Microsoft Excel spreadsheet and were collated. All responses were analyzed and the
141 results are presented in the next section.

142 ■ CLASSES AND TUTORIALS

143 Different strategies were attempted for distance classes. In the urgency of the first two
144 weeks of the situation, many classes were transformed into sessions in which the
145 students worked alone, reading the class documents (slideshow, book, etc.) or specific
146 documents sent by the educators. A majority of students (76.1%) did not enjoy using
147 this technique (Fig 1.a Q1) and thought the presence of an educator who gave
148 explanations when necessary was beneficial to help them to deeply understand the
149 courses. Nevertheless, some students (9.1%) appreciated this way of learning, which
150 could be done on demand (e.g. when the student was most available, and repeated

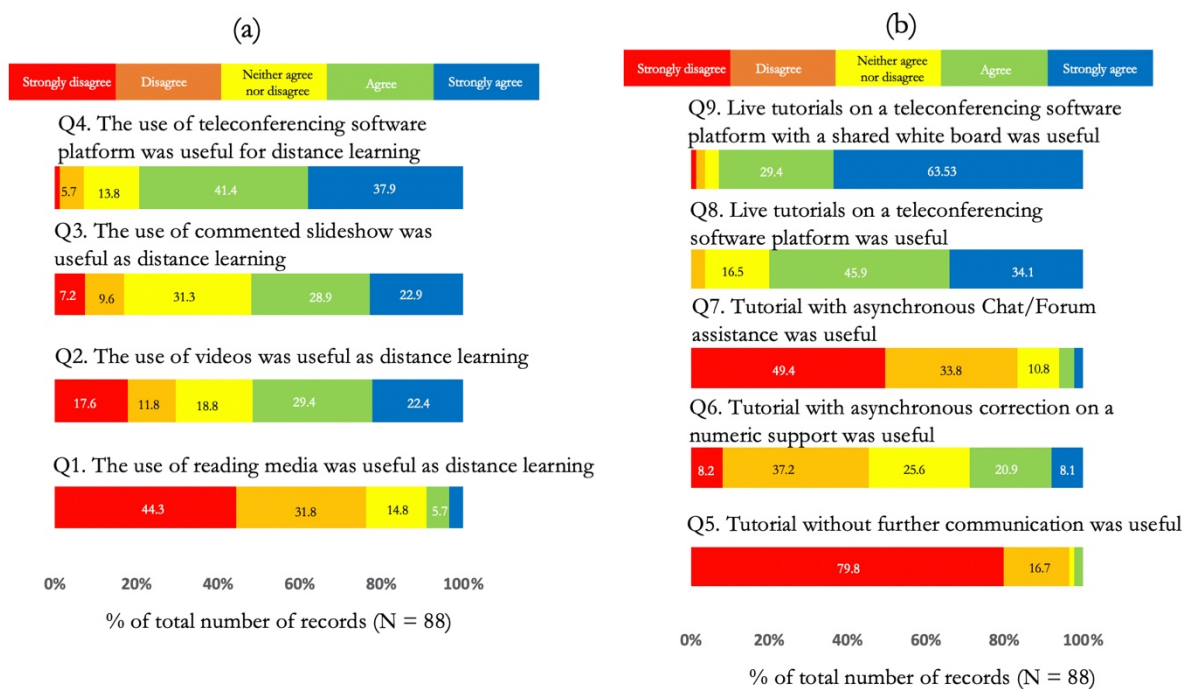
151 as many times as necessary) and also helped them to develop their autonomy skills.
152 Another approach that was developed early in the beginning of the pandemic was the
153 use of videos of slideshows blended with an explanation by the educators (Fig 1.a Q2)
154 and completed with videos from the Internet to flesh out specific points. All the
155 material was available on a free, open-source learning management system (Moodle)
156 and was also available on paper at the request of students. This technique was much
157 more appreciated by students (51.8 vs 29.4%). Providing a video support made it
158 possible for students to watch it several times, which helped them to organize their
159 own time and also to concentrate for a long period. For students, this represented an
160 opportunity to develop their own skills, and their sense of creativity and adaptation.
161 After a week, some educators proposed a commented slideshow (free option in
162 Microsoft PowerPoint software – audio is triggered on each slide - Fig 1.a Q3). This
163 led to large files being shared via the file transfer service or the video hosting platform
164 of the University (<https://prismes.univ-toulouse.fr>). This last option had the advantage of
165 allowing the video capsule to be embedded directly in the teaching web platform (such
166 as Moodle), thus avoiding losing students who were inevitably attracted by other
167 supports when they were on commercial video platforms (commentary section, other
168 videos, advertising, etc.). A similar number of students agreed that the use of these
169 commented slideshows was useful as a course (51.8%) and fewer disagreed (16.9%).
170 This solution seemed to be more efficient for educators as the audio recording was
171 faster and seemed to be less refused by the students than the reading approach. In
172 both cases, students appreciated being able to work at their own pace and to listen
173 to the explanations as many times as necessary to understand the course.
174 Nevertheless, the students pointed out the advantage of keeping a form of direct
175 interaction with the teacher and gradually progressing in the course to have an
176 experience that was as close as possible to the face-to-face classes. Some students
177 also said that the video lectures were better than the audio ones. Indeed, the video
178 format attracts more attention than an audio lecture. However, technically speaking,

179 it should be noted that video files should not be shared by file transfer in their original
180 format, as these video files exceed several gigabits and they must be shared on online
181 video-sharing platforms to alleviate the storage burden.

182 After two weeks of distance learning, all educators were granted a license for video
183 telephony and online chat services through a cloud-based peer-to-peer software
184 platform (Zoom Video Communications – Fig 1.a Q4). It is worth noting that a large
185 majority thought this solution was helpful for distance learning (79.3%) and was the
186 best way to mimic traditional classes closely, allowing the educators to give live
187 answers to students' questions. However, some students (6.9%) encountered
188 difficulties with this system. Class rhythm could sometimes be too fast, shy students
189 did not dare to ask the educators to explain, other students had difficulty in paying
190 attention to a screen for more than an hour (inattention could lead to a breakup in
191 the classes and a decrease in motivation) and not all students had a calm place to
192 study. A positive benefit was obtained with the chat, which allowed many questions
193 to be collected during the lesson and groups of questions to be answered at a defined
194 frequency. It clearly helped to collect questions from students who had never asked
195 such questions in a conventional lecture. It is interesting to note that the use of video
196 communications forced students to discipline themselves by cutting off their
197 microphones when they were not speaking, and by respecting the speech of other
198 classmates. The main drawback was that exchanges between students were limited.

199 Moreover, a large number of students reported an increase of the time needed to work
200 on the classes after the videoconferences, which slightly increased the work load.
201 61.9% thought they were less effective than learning with the educator in presence.
202 Regarding the content of the courses, 43.5% of the students thought they covered an
203 amount of knowledge that was equivalent to that in the face-to-face sessions, but
204 44.7% thought it was smaller (11.8% bigger).

205 Tutorials had a similar duration to lessons, were classically more interactive and
 206 specific than a lecture, and sought to teach by example/application. They were firstly
 207 organized in autonomy without any synchronous input from educators (Fig 1.b – Q5).
 208 This approach was massively rejected by the students: 94.4% of the panel judged it
 209 ineffective. The second approach tested was the diffusion of a correct version of the
 210 answers to exercises by mail or on a web platform (such as Moodle – Fig 1.b – Q6).
 211 This approach was considered useful by almost 29.1% of the student panel and
 212 useless by 45.3%. As an alternative, some educators proposed to answer the
 213 students' questions in online forums or using chatting apps like WhatsApp (Fig 1.b –
 214 Q7) as a support.



215

216 **Figure 1.** Student responses relating to the pedagogy attempted for distance learning for
 217 classes (a) and tutorials (b) in time of COVID19. Total number of respondents = 88 (academic
 218 years 2019/2020).
 219

220 Unfortunately, due to the long response time needed to type the answer and the lack
 221 of readability, this approach was ultimately widely rejected by students (83.1%). The
 222 use of videoconference software was much better received by the users (Fig 1.b – Q8),
 223 with an 80% satisfaction rate. The students emphasized the dynamics during the

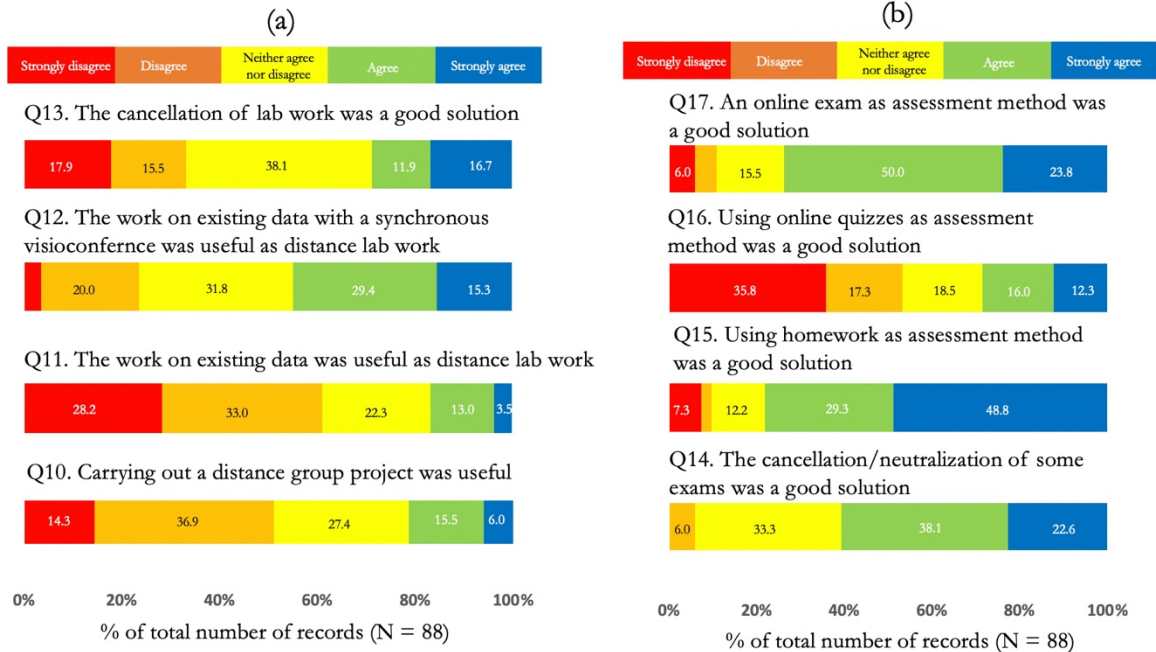
224 tutorials and that the exchanges with the teacher helped them not to drop out of the
225 session. Nevertheless, some students pointed out that, during distance tutorials, the
226 rhythm was often imposed by the best students and they therefore suggested
227 organizing small groups and even randomly dividing the group into sub-rooms to
228 favor collaboration between students' (more than face-to-face tutorials). As the
229 videoconference software was equipped with a whiteboard option where all
230 annotations could be displayed to all the users (Fig 1.b – Q9), this option was tested
231 first by educators equipped with tablets/pencils but then rapidly extended to other
232 possibilities. In the absence of specific equipment, various alternatives were
233 implemented with similar degrees of effectiveness: (i) sharing a correct version
234 prepared before the session and showing the elements of correction as and when
235 appropriate, (ii) sharing the video stream of a smartphone filming the hand writing in
236 real time, (iii) using a Microsoft Excel spreadsheet that was displayed step by step and
237 sent to the students after the session. These interactive approaches were the most
238 useful according to our student panel (92.9%) and also according to educators
239 (100%), as this allowed the educator to advance at the same pace as the students. It
240 also provided the possibility to refine the explanation with more details for students
241 that were experiencing difficulty. For all these tutorial approaches, 49.4% of the
242 student panel perceived a decrease in the effectiveness of the tutorials relative to a
243 face-to-face one and 22.4% thought they were more effective. Regarding the content
244 of the courses, 48.8% of the student panel thought they covered an equivalent or
245 greater amount of knowledge but 51.2% thought they covered a smaller amount than
246 the face-to-face sessions. Another aspect was the adaptability of the taught content
247 to the communication tools and vice versa. Content that needed deeper explanations
248 and argumentation, for example the logical development of a theory in physical-
249 chemical science, were better perceived in face-to-face or videoconference sessions
250 than in autonomy. The possibility to interact with the educator until they achieved
251 full comprehension reassured the students. Autonomous documentation and

252 commented slideshow methods performed better than face-to-face for story-like
253 contents, as, for example, in the lecture on “waste management strategies”. These
254 (partially) self-taught methods were more attractive and prevented students from
255 dropping out.

256 ■ LAB WORK, PROJECTS AND ASSESSMENTS

257 Group projects were organized in parallel with the lectures and tutorials in several
258 domains (bibliographic research, initiation to research, experimental project, etc.) in
259 groups of 3 to 6 students for a duration of 2-4 months (Fig 2.a – Q10).

260 According to the results of the survey, 51.2% of students found it difficult to participate
261 in group projects with distant project members, i.e. without the possibility of face-to-face
262 with each other. The shared result can be explained in two ways. First, it can be hard to
263 work remotely within a group especially when it is necessary to collectively use and work
264 on software related to the subject of their project. In addition, the absence or lack of active
265 participation of certain members can degrade all teamwork. The students also
266 encountered difficulties in distributing tasks and in interacting. It was observed that
267 groups of more than 3 students made these tasks impossible to carry out. It should also
268 be noted that the students' participation and motivation in the group work were more
269 unequal than in pre-lockdown projects. The absence of synergy due to the distance can
270 partly explain this lack of motivation. In contrast, other students thought that using the
271 videoconference application made it easier to work in a group. The students notably
272 pointed out the need to allow extra time in the timetable that was reserved for the
273 projects, so as to help the organization of supplementary meetings.



274

275 **Figure 2.** Student responses relating to the attempts in pedagogy concerning distance learning
 276 for project and lab work (a) and assessments (b) in time of COVID19. Total number of
 277 respondents = 88 (academic years 2019/2020).
 278

279 In the end, 51.3% of the students did not see an increase in the effectiveness of the
 280 projects and only 15.9% thought they were more effective than a face-to-face project.
 281 Regarding the interest of working in a group, 52.9% of the students thought that
 282 maintaining group projects at distance was useful. It is worth noting this remark was
 283 valid for long-term projects, as working in small group for tutorials was much more
 284 appreciated.

285 Practical lab works (laboratories) are considered as an application (and a measure
 286 made by the students) of scientific methodology, based on proposing an initial hypothesis,
 287 designing an experimental protocol from it, performing the experiments, interpreting the
 288 results and possibly refining the initial hypotheses. At the time of distance learning, this
 289 pedagogical method was one of the most difficult to maintain. Firstly, educators proposed
 290 replacing the lab work by an analysis of data provided by them (Fig 2.b – Q11). This
 291 approach, which consisted solely of the numerical application of the lab work in
 292 autonomy, was rejected by the students (61.2%). The same approach using the presence
 293 of the educator with videoconference in small groups (Fig 2.a Q12) was appreciated by

294 the students (44.7%). Some students appeared frustrated to lose the practical aspect of
295 the lab work, which was probably exacerbated because the student panel questioned was
296 composed of students of disciplines relating to Engineering Science where the "hands-
297 on" dimension is particularly important. In contrast, some others underlined the fact that
298 the theoretical aspect was treated in much greater depth and this helped them to
299 understand the courses. Because of the circumstances, some of the practical lab work
300 was cancelled (Fig 2.a – Q13). This solution divided the student panel: 33.3% found it a
301 good solution, 28.6% disagreed, and 38.1% were neutral on the question. The students
302 stated that attempts at maintaining the lab work was more time consuming for them and
303 more exhausting (even without experiments). These results should be put into
304 perspective. The practical work proposed for distance learning was not fully appropriate
305 to replace laboratory sessions. The restricted access to the experiments, due to the
306 lockdown, did not permit this type of teaching to be adapted in good conditions. Pictures
307 and videos would have enabled a better understanding of the experimental work and
308 allowed the operation of the devices in real conditions to be visualized. As for the distance
309 project, students encountered many issues in terms of organization and interactions
310 (planning, connection, sharing data, motivation of some members, etc.) and pointed out
311 that writing a report on each session was a strong constraint, requiring more time and
312 several visual resources (videos, 360° photography, AR, VR) that were not designed before
313 the lockdown and could not be produced in time. Finally, 72.0% of the student panel
314 observed a decrease in the effectiveness of the lab work at distance and only 6.1% thought
315 it was more effective than learning in presence. Regarding the content of the lab work
316 session, 81.9% of the student panel thought they had done less than in presence sessions
317 and a small majority (53.7%) of the student panel thought the distance did not alter the
318 work in groups.

319 Concerning assessment, various forms were tried out. As for the lab work, first, some
320 intermediate exams or project presentations were cancelled or neutralized in order to
321 release time for students and to give time for educators to find a solution (Fig 2.b –

322 Q14). This approach was appreciated by 60.7% of the panel but some students
323 pointed out the risks of cancelling intermediate exams as (i) they would have helped
324 them to evaluate gaps in their knowledge or difficulties in a topic and (ii) such
325 cancellations dangerously reinforced the need to succeed in the final exam. Some
326 other exams were replaced by homework over a long period (Fig 2.b – Q15). This
327 system was much appreciated by students, with 78 % expressing satisfaction and
328 appreciating having time to reflect on a given problem. Online quizzes (multiple choice
329 or open choice) were implemented (Fig 2.b – Q16) but a large majority (53.1%) did not
330 find them satisfactory. This was because the quizzes, as proposed, did not allow the
331 method of thinking, the analysis, the writing or the understanding of a problem to be
332 evaluated and this created considerable stress for the students. Many students were
333 worried about not completing the test in time. Finally, the last system to be tested
334 was for the student to download the exam question(s) online and upload his/her
335 answers to a server (Fig 2.b - Q17). This system was the most appreciated, with 73.8%
336 of approval from the students, because it was the one that came closest to the usual
337 exam conditions. However, some students pointed out the stress caused by
338 downloading/uploading files in the event of technical problems, and concentration
339 problems that would not have occurred in the exam room. They asked for clear rules
340 to be defined before the exam and more time than usual to complete the exam. This
341 last request may seem contradictory to the feelings of some of the students who
342 denounced illicit communication between learners during the assessments.

343 The online assessments introduced strong biases between the students, as some
344 worked online with others (several teachers have observed identical answers to exam)
345 and especially for calculation exams, as it worked fine in writing/redaction exams,
346 and some students try to save time by pretexting connection problems. Some
347 solutions to avoid cheating have been considered in France, such as monitoring
348 exams via videoconferencing, or by installing software on the student's computer,

349 which allows monitoring through facial recognition but also prevents access to other
350 documents on the computer (TestWe⁵³). However, these solutions are perceived by
351 students as an intrusion into their privacy. In addition, this system is a source of
352 discrimination for students who do not have a computer or a high-performance
353 Internet connection. And, finally, these software are expensive and complicated to set
354 up. In some disciplines, solutions to avoid cheating have been considered. For
355 example, students did not have to answer the same questions. Also, sometimes, the
356 content or the order of the exams has been modified and, to avoid the student going
357 on the Internet, the questions have required more reflection from the candidate⁵⁴. The
358 methods of testing have changed in some disciplines, giving priority to homework on
359 subjects for reflection and oral examinations, allowing exchanges and a better
360 understanding of the student's personal work and achievements. Skills assessments
361 in "project" have made it possible to carry out distance learning support and allow
362 for personalized contact with the students. These online exam sessions may be an
363 opportunity to put cooperation and mutual aid above the excessive individualism that
364 universities normally display. The time of collective intelligence is perhaps the future
365 of a post-coronavirus.

366 Globally, and despite some failures in our attempts, the panel of students voiced a
367 good percentage (60.0%) of satisfaction with the implementation of full distance
368 learning and 65.8% appreciated all the measures taken to adapt the planning of
369 learning. 76.7% also appreciated the technical tools provided during the semester
370 and a large majority of 87.2% appreciated the involvement of educators during the
371 distance semester. Nevertheless, only 38.5% of the panel were satisfied with their
372 work. It is important to note that, in our study, the students already knew their
373 teachers and the working methods of the institute. It must have been less easy for
374 1st year students who are less used to working independently. Teachers observed an
375 increase in students' marks in exams (1 to 2 points more out of 20) but it is still too
376 early to know the real effectiveness / success of this teaching method.

377 Concerning the teachers' feedback, we would like to point out that a large majority of
378 them had not prepared supports for distance teaching before the crisis. However,
379 they quickly managed to organize and implement sharing sessions for (i) their
380 corrections via platforms such as Moodle, (ii) good practices using collective
381 videoconferencing or, (iii) mutual aid in learning these massive videoconferencing
382 software packages. This solidarity permitted many teachers to progress collectively
383 in facing the rapid adaptation of distance education. 19% of the teacher panel
384 encountered some issues in using the distance learning tools and 21% faced
385 problems to adapt their teaching. 85% of the educators spent more time preparing
386 what was to be learned (64% - a much longer time) and 85% encountered issues for
387 distance assessments. Nevertheless, 67% of the panel was convinced of the need to
388 maintain individual assessment for distance learning. 100% of the panel thought the
389 distance learning changed the relationship between educators and students. 50% of
390 the panel recognize they have acquired a new vision of distance learning, 65% think
391 it will impact their way of teaching and 53% will conserve some approaches when
392 presence learning is restored. Several educators reported some health consequences
393 of spending most of the daytime focusing on screens during videoconferences, such
394 as headaches, which may also be experienced by students. This may affect
395 concentration and the ability to react promptly during distance classes. Overall, 75%
396 of the panel was satisfied by the distance learning provided. These results should
397 nevertheless be balanced with respect to the audience and students' profiles. They
398 are not transposable to all levels or domains of higher education.

399 ■ DISCUSSION

400 The COVID-19 pandemic has created significant challenges for the global Higher
401 Education community. The first was to adapt distance learning tools⁵⁵ to the current
402 generation of students. Initially, the distance learning tools were developed for motivated
403 students with strong time constraints who had chosen this method but, in the current

404 situation, it has been imposed on the Y/Z generation who have fewer time constraints
405 but many sources of distraction and stress. Many existing approaches were therefore not
406 suitable and new ones had to be adapted to the context. In the event that the pandemic
407 continues to disrupt traditional teaching platforms, the lessons learned from this
408 experience might help us prepare. Special attention should be paid to:

- 409 (i) working on the ethics of student assessment and its real purpose;
- 410 (ii) remaining flexible towards students, whose social life has been disrupted to a
411 large extent, in order to regain a certain balance. Particular attention must be
412 paid to the well-being of students, for example by setting up a support system
413 for students with psychological difficulties;
- 414 (iii) breaking the monotony of distance learning by bringing back
415 motivation/conviviality,⁵⁶ establishing distance gamification^{19,34,56-58}, and
416 restoring the pleasure of learning⁵⁹;
- 417 (iv) assisting students who do not have reliable Internet access and/or who are
418 struggling with technology; the digital fracture between students must be
419 narrowed. According to UNESCO,⁶⁰ 826 million students in the world do not
420 have a computer and 706 million do not have Internet access at home (around
421 1% in our institution);
- 422 (v) working with international students, who were more isolated⁶¹ and less
423 equipped⁶² than most other students;
- 424 (vi) paying more attention to the working conditions of teachers at home, with
425 regard to their equipment and tools, but also the ergonomics of their working
426 environment (health safeguards), their connection time and respect of
427 disconnection between private life and working time, and
- 428 (vii) favoring a variety of supports, whether for teachers, who must be free to select
429 the tools suited to the subject and their technicality, or for students, in order
430 to avoid weariness when using single format supports.

431

432

433 The COVID-19 crisis has changed our world, and it has also taught us that the education
434 system must be renewed to better prepare the current student generation for an
435 unexpected future. This includes:

- 436 • preparing our students to become citizens of a sustainable world ^{63,64}, to work
437 collaboratively on a global level, to be prepared for a change in the economic
438 markets⁶⁵⁻⁷¹ (although energy, water and environmental sectors seem to have been
439 little impacted by the crisis - placement rate of students in last years of 50% before
440 graduation in our department),
- 441 • redefining the role of educators⁷², who should no longer be the sole owners of
442 knowledge but become mentors or facilitators, in particular to encourage students
443 to find sustainable solutions to complex problems, based on a critical analysis of
444 existing data and their own knowledge, which they need to develop,
- 445 • teaching life skills^{73,74} necessary for the post-crisis world, such as creativity⁷⁵,
446 innovation, autonomy, resilience, adaptability, communication and collaboration,
447 empathy and emotional intelligence, and
- 448 • unlocking new technologies to offer engaging and motivating education programs.

449 This last aspect was targeted during this semester, but more interactions are necessary.
450 Examples worthy of mention are the development of quizzes during videoconferences to
451 motivate students, the establishment of regular question/answer sessions to guide
452 students or give and receive feedback, the implementation of more support materials
453 such as video, AR, VR, filmed visual experiments⁷⁶⁻⁸⁴ or 360° laboratory visits^{85,86}, and
454 more distant measurements.^{87,88} It is also important to vary the media for access to
455 learning, and to hybridize the teaching methods, so that each student can find his or her
456 way in access to knowledge. During a learning session, it is essential to give students the
457 opportunity to apply their knowledge before the final assessment. This allows the teacher
458 and the student to verify that the concepts learned are well understood. This experience
459 opens up many perspectives, based on the experience acquired during the COVID-19
460 pandemic, such as the possibility of removing large classes in lecture halls by offering
461 distance learning courses and by promoting remedial work in small groups of students.

462 The University will have to invest sustainably in distance equipment (tablets/pencils) for
463 teachers or virtual laboratories to provide the students with the most pleasant and
464 engaging experiences. Hybrid education requires time and investment: teacher training,
465 recruitment of pedagogical advisers, studio design, information material, etc. Contact
466 with teachers remains central and cannot be removed, so certain means of
467 communication, such as meetings by videoconference or the use of distance whiteboards,
468 should be preserved even after the crisis. Face-to-face communication helps to motivate
469 students, better capture their attention, and set the right pace for those who go too fast
470 (partially acquired skills), so as to help reduce school dropout while not frustrating the
471 engaged and proactive students. Distance learning involves a profound change in the role
472 of the teacher and in the teacher-student relationship.

473

474 Overall, this experience was generally beneficial, pushing our students to work on their
475 flexibility and benevolence but, more importantly, it is our hope that, for the Z/Y
476 generation,^{48,50} these experiences of isolation and distance learning away from the
477 campus or their peers /educators will serve as a reminder of our strong human need for
478 face-to-face social interaction. The President of the Sorbonne University confirmed this⁸⁹:
479 "Distance learning alone is useless, it is not the solution. It must be a complementary
480 element to face-to-face teaching. You never learn better than in a group. We need contact
481 and exchanges with students. Teaching must be hybrid".

482

483 ■ CONCLUSION

484

485 The COVID-19 crisis has resulted in the closure of schools and universities across
486 the world. Globally, over 1.7 billion students were out of school. As a result, higher
487 education had to adapt quickly and to change radically, with a massive rise of e-
488 learning, with teaching being provided on digital platforms or in live classes online.
489 The teachers at INSA Toulouse have accomplished so much in such a short time with
490 impressive commitment. This unexpected, rapid shift to online learning has led to a
491 multiplication of teachers' strategies for distance learning, tutorials, project groups,

492 lab work and assessments in a dozen teaching units concerning chemistry, chemical
493 engineering and environment at INSA Toulouse, France. The purpose of this paper
494 was to collect the experience of these challenging days, with feedback from students.
495 The analysis showed great successes and some failures in the solutions proposed.
496 Some guidelines have been put forward and remaining challenges addressed in order
497 to learn from such a singular experience, and to face the future with more knowledge
498 about distance learning. The main outcome has clearly been to trust human creativity
499 and to allow teachers the flexibility to creatively develop their own pedagogy,
500 especially with the support provided by their institutions. While some believed that
501 the unexpected, rapid transition to online learning – without training, with
502 insufficient bandwidth, and with little preparation – would result in poor
503 transmission, our analyses showed a blend of success and failure when the
504 experience was reviewed. Teachers recognize that they have learned more about
505 distance education in these two months than in the past ten years, and this was the
506 result of their constant commitment and dedication to education during this crisis.
507 As one university head claimed⁹⁰, "The coronavirus will have done more for e-learning
508 and online training than all the plans and strategies of states and institutions of
509 higher education!" .

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