Distributed Cognition and exam preparation in higher education: what sources students use before and during the Covid-19 pandemic

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Abstract

What 'sources' of knowledge do higher education students draw on, to prepare for exams? And has the pandemic made any difference? The study presented in this paper addresses these questions, in the belief that gaining awareness of the sources through which students learn is important for the instructional design of the courses and the evaluation methods as well. Framed within the 'Distributed Cognition' theory, the study is based on a questionnaire proposed in July 2021 (summer exam session) to all the students of two schools at Politecnico di Milano (the largest technical university in Italy); 5,369 students responded (16.5% of the total). The results show that students normally resort to a wide range of resources (lectures, lecturer's slides, group work with other students, notes taken by other students, etc.) and that, in the Covid-19 time, recorded lectures and 'exercises' (i.e. practical sessions with a teacher assistant) skyrocket in their perception of relevance, overcoming (almost all) other sources. Academies will need to face the challenge of students advocating for keeping this kind of support even after the Covid-19 era, which has the potential of revolutionising the way universities work, leading towards blended forms of education.

***Keywords:** Distributed Cognition; Higher Education; Examinations.*

Introduction

How do students 'really' get set for exams? What are their sources of knowledge? Do they act as they may be expected, relying mainly on the instructors' lectures, or do they take different paths? And has there been any changes, with the advent of the new situation brought about by the Covid-19 pandemic?

To answer these questions, a questionnaire was proposed in mid-July 2021 (towards the end of the summer exam session) to all the students of bachelor's and master's degrees in the schools of Industrial and Information Engineering and of Civil, Environmental and Land Management Engineering at Politecnico di Milano (the largest technical university in Italy). The questionnaire remained open until September 2021 and collected 5,369 responses (16.5% of the total number of students, i.e. 32,503); it consisted of nine questions, which first of all asked students to 'identify' themselves in terms of year of study and course of study attended and then investigated the methods of preparation for exams in the pre- and post-Covid (in the sense of 'Covid-affected') eras. Space was also given for free comments.

The study is framed within the 'Distributed Cognition' theory, which explains how, in the face of a cognitive task, the various resources available in the environment are used. The underlying belief is that gaining awareness of the sources through which students learn and get set for the exams is important for the instructional design of the courses and the evaluation methods as well.

The paper is organised as follows: the background section introduces the theoretical framework, that is, the Distributed Cognition theory that sparked the research questions. After that, the questionnaire's features and how it was administered are explained. The main outcomes are the object of the 'results' section, where data from the quantitative questions as well as analysis of the free comments are presented, while discussion and conclusions are drawn in the final section.

1. Background: the Distributed Cognition theory

The Distributed Cognition theory was developed in the 1990s by Edwin Hutchins, a professor of cognitive science at the University of California, San Diego (Hutchins, 1995 and 2001). The central thesis is that 'cognition' is not 'central-

ised' in the head of a single individual. In fact, when an individual is carrying out a certain task, he/she is part of a system, with other individuals, artefacts, tools, all cooperating towards the task's completion. A comparison with the steering of a ship clarifies the concept well. The task of getting a ship to navigate properly is spread over a system that is made up of complex tools and a variety of people with different responsibilities. Navigating the ship is achieved if tools and people perform unique tasks, from a cognitive point of view, but which only work if performed in concert. 'Navigating a ship through a narrow passage to the port requires the coordination of many people and devices. People use instruments to take bearings from landmarks and report them to the person plotting the ship's position on a chart. Likewise, someone reports the depth of water beneath the ship, reading from a depth sounder. One person records this information in a log and another uses a variety of plotting instruments to compute the ship's position, current course and projected course from the log. The timing and coordination of all these actions is critical. When asked, or at critical junctures, the navigator recommends changes in the ship's heading or speed to the officer of the deck. These recommendations may or may not be accepted. If they are, they are passed to the helmsperson who steers the ship onto a new heading. In poor visibility, at night, or out of sight from land, radar or other devices are also brought into the equation' (Bell & Winn, 2000, p. 128).

The theory recognises that, 'for certain purposes, it is more appropriate to consider cognition (and intelligence) as a property of the whole system within which the individual functions rather than as something limited by the skin or skull' (Karasavvidis, 2002, p. 14). The elements of a system interact with each other to accomplish a certain task and each of them makes a 'contribution to the cognition of the system' (Kim & Reeves, 2007). The Distributed Cognition theory explains the different ways in which a cognitive problem is approached according to the contextual conditions of the 'system': imagine performing a mathematical operation with or without the availability of a small calculator. Your mind would operate in a different way in the two cases. This means that our mind is not only flexible, but also conditioned by the affordances of the system in which it operates. The activity of the individual's mind is distributed between itself and the possibilities that the surrounding world offers.

But the term 'distributed' in the theory's name should not be misunderstood: 'the term "distributed", in this case, does not mean "divided up" in the sense that candies are distributed to children at a party. Rather it means "spread over", much in the same way that weather systems cover a geographical area. A weather forecaster may point to low pressure cells, high pressure cells, storms, and clear skies on a weather map, but these are not isolated meteorological phenomena. Each of these continuously affects the others. In a similar fashion, the mind, the setting, activity, artifacts, signs, symbols, social processes, and cultural factors comprise a mutually interacting, interdependent and indivisible system of cognition. Thus, from a sociocultural point of view, individual mental processing is better understood as a complex system involving the individual and the whole personal environment. All cognition is fundamentally situated and distributed' (Hewitt & Scardamalia, 1998, p. 77).

The theory of Distributed Cognition has found wide application in what are called 'workplace studies', which deal with studying work contexts seen as organised environments that integrate social aspects, technologies and artefacts (see, e.g. Zucchermaglio & Alby, 2005). Other studies propose to use the theory of Distributed Cognition as a reference model to explain the introduction of technology in the classroom. These studies note how the class-system includes instructors, students, tools and various artefacts with which technology must integrate (Angeli, 2008; Steketee, 2006). This same line is taken by the 'Distributed TPACK' model (Di Blas et al., 2014), where the interplay among various resources, going beyond the 'instructor's head', when educational experiences based on technology are implemented in the class, is acknowledged.

Distributed Cognition is the ideal theoretical framework to investigate the system of cognitive tools used by students in order to get set for the exams: students resort to an ecosystem of resources that influence each other and on which 'it is necessary to work, to optimize coordination between all agents involved in the process' (Bonaiuti, 2013, p. 10, translation by the author), as it will be seen in the following sections.

2. Method

This study takes the Distributed Cognition framework as the starting point and aims at answering three questions:

- Do students actually resort to different sources of knowledge, in getting set for the exams?
- What are these sources and what is their relevance?
- Is there any difference between the pre- and post- (meaning 'affected by') Covid pandemic?

To shed light on these questions, a questionnaire was prepared and administered in mid-July 2021 to all students of two schools of Politecnico di Milano: the School of Industrial and Information Engineering and the School of Civil, Environmental and Land Management Engineering. The questionnaire was deliberately 'agile' to facilitate obtaining the answers. Even so, 5,369 students out of a total of 32,503 responded (about 16.5%). The questionnaire was administered during the summer exam session, when students are particularly stressed out and in which they also required to fill in other, compulsory, questionnaires, like the one about the quality of the courses they have attended. It is known that their patience towards this type of investigation is not much, also because they are sceptical about their feedback having an actual impact on teaching. A student commented: 'Though I am well aware that all these questionnaires are completely useless and none reads them, still I would like to share my opinion¼'. Even with this limitation, which can be explained by the above considerations, the number of 5,369 respondents is quite a high number.

Table 1 shows the questions; the questionnaire was bilingual, to accommodate international students as well. A logic was embedded to steer the respondents towards the proper questions according to their previous answers; more specifically, the question about how students used to get set for the exams before the pandemic was not applicable to first-and second-year students of the bachelor's degree who, sadly, had never had this experience, so they were not offered this question.

Table 1: The questionnaire

Questions	Options
1. Are you enrolled to:	Bachelor's degree Master's degree
2. [*to those who had selected bachelor degree*] What year are you enrolled to?	First Second Third Beyond third year
3. [*to those who had selected bachelor degree*] What degree program are you enrolled in?	[*List of all the degree programs by the two schools*]
4. [*to those who had selected master degree*] What year are you enrolled to?	First Second Beyond second year
5. [*to those who had selected master degree*] What master degree program are you enrolled in?	[*List of all the degree programs by the two schools*]
6. Thinking about the pre-Covid situation, how important were the following "sources" to prepare for the exams? (*scores from 1 to 5, where 1 = "not at all" and 5 = "very much"* + *Not Applicable*)	The lectures The exercises with a teacher's assistant The laboratories The course's decks of slides The study materials provided by the instructor My classmates, with whom I studied in small groups, in pairs Students who had attended the course in previous years and gave me a hand "Experts" whom I asked for clarifications Books, articles, documents found by me Videos on the course topics found by me Notes by students from previous years Other [please specify]
7. To prepare for the exams of this summer session, how important were the following "sources"? (*scores from 1 to 5, where 1 = "not at all" and 5 = "very much"* + *Not Applicable*)	The lectures, attended synchronously The lectures, attended asynchronously (recorded videos) The "exercises", attended synchronously The "exercises", attended asynchronously (recorded videos) The laboratories The course's book of reference Slides and other materials provided by the instructor My classmates, with whom I studied FACE TO FACE My classmates, with whom I studied REMOTELY Students who had attended the course in previous years and gave me a hand "Experts" whom I asked for clarifications Books, articles, documents found by me Videos on the course topics found by me Notes from students from previous years Other [please specify]
8. Do you have any comments you would like to share?	[*blank field*]

The link to the questionnaire was sent via e-mail to the students from an institutional address at the dean's office and they were invited to 'take a few minutes of their time to answer a questionnaire about which "sources" mattered most in their preparation for the exams', promising that their feedback would help better plan courses in the coming years.

3. Results

In this section, the data gathered via the questionnaire (with 5,369 respondents) and the free comments' analysis are presented. First of all, let us take a look at the sample (questions 1–5). The majority of respondents were bachelor's degree students (3,625; 68%). At bachelor's level, the most represented degree programme was Computer Engineering (572), followed by Mechanical Engineering (420) and Management Engineering (414). The most represented course year was the first, with 1,215 respondents out of 3,625.

At master's degree level, the most represented course of study was Biomedical Engineering (212), followed by Management Engineering (173) and Computer Science and Engineering (167). The most represented school year was again the first, with 899 respondents out of 1,744.

Let us now see the two most important questions, starting from the one about the pre-Covid situation. The question was: 'thinking about the pre-Covid university, how important were the following "sources" to get set for the exams? (answer only if you have experienced pre-Covid university)'; 2,990 students responded (i.e. all except the first- and second-year students of the bachelor's degree). The answer was on a scale from 1 to 5, where 1 was the lowest score (meaning 'not at all') and 5 the highest (meaning 'very much'). There was also the option 'not applicable'. In what follows, the positive scores (4 and 5) are summed. In the pre-Covid era, the first three most important sources were, in order: 'exercises', that is, practical sessions with a teacher's assistant (89.3%), instructor's lectures (80.7%) and slides by the instructor (70%). The 'official' study materials indicated by the instructor mattered less (47.6%) than the classmates with whom to study in small groups (54%).

Figure 1 offers an 'at a glance' view of the perceived relevance of the various sources (their ranking can be found in Table 2).
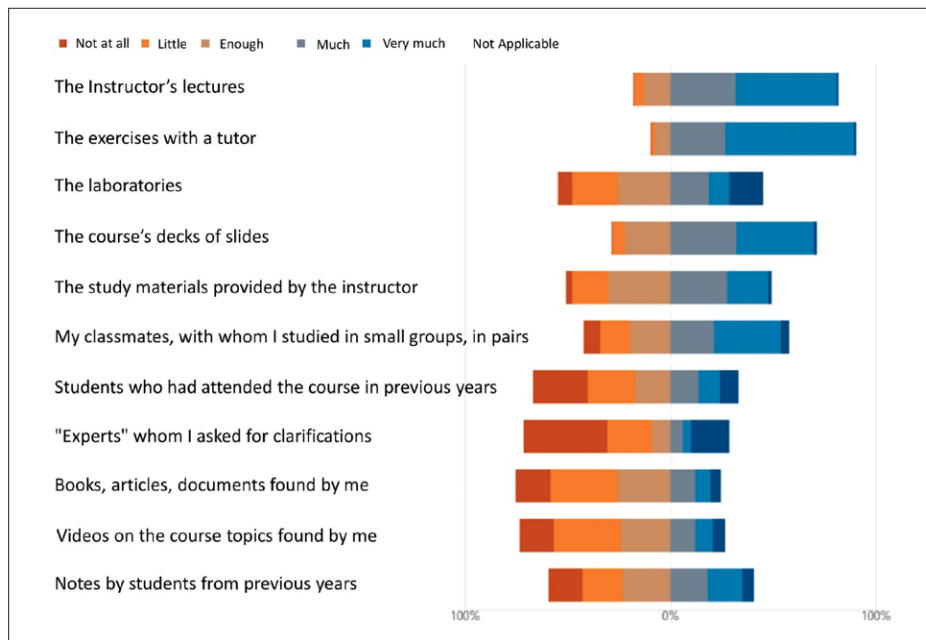

Fig. 1. Perceived relevance of the various sources to get set for the exams before Covid-19

The next question was about the exam session the students were involved in, heavily influenced by the pandemic situation. It was: 'To prepare for the exams of this summer session, how important were the following "sources"?' The results can be seen in Figure 2.
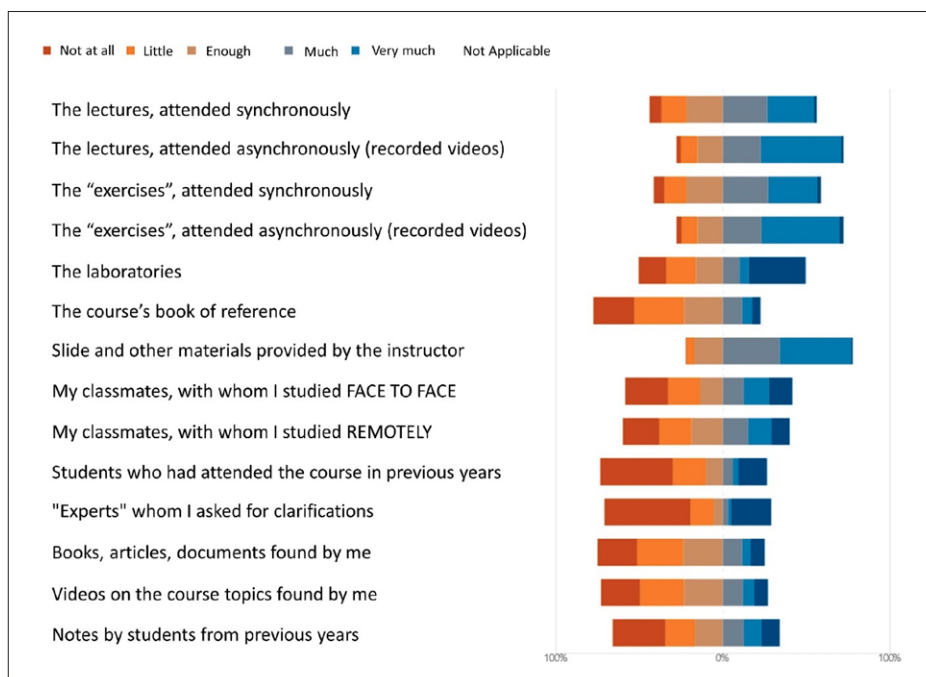

Fig. 2. Perceived relevance of the various sources to get set for the exams 'during' Covid-19

This is the ranking: the instructor's slides (77.1%), the recorded lectures accessed asynchronously (70.6%), the recorded exercises accessed asynchronously (69.7%) are in the first three places. At the fourth place, the 'classmates' (56.4%) can be found, by adding up the scores given to 'Studying with my classmate face to face' and 'Studying with my classmates remotely'. Then follows the synchronous exercises (56.3%) and, in the sixth place, the synchronous lectures (54.6%). In the seventh position, there are the notes by students from previous years (23.3%).

Let us now compare the pre-Covid and the 'Covid-influenced' situations. Table 2 helps by putting against the scores for each item.

Table 2: Comparison between the sources' rankings in the Covid-influenced and pre-Covid situations

During COVID (July 2021)	Pre-Covid
Slides and other materials provided by the instructor – 77.1%	70% (third place)
The lectures, attended asynchronously (recorded videos) – 69.7%	=
The 'exercises', attended asynchronously (recorded videos) – 69.7%	=
Studying with classmates, face to face (27.5%) and remotely (28.9%) – 56.4%	54% (likewise, fourth place)
The 'exercises', attended synchronously – 56.3%	89.3% (first place)
The lectures, attended synchronously – 54.6%	80.7% (second place)
Notes by students from previous years – 23.3%	35.1% (sixth place)
Videos on the course topics found by me – 18.5%	20.8% (ninth place)
The course's book of reference – 17.5%	Study materials referenced by the instructor 47.6% (fifth place)
Books, articles, documents found by me – 16.5%	17.4% (10th place)
The laboratories – 15.9% with 34% 'Not Applicable'	28.4% with 16.5% 'Not Applicable' (seventh place)
Students who had attended the course in previous years – 9.5%	24.3% (eighth place)
'Experts' whom I asked for clarifications – 5%	10% (11th place)

The 'slides and other materials provided by the instructor' skyrockets to the first place; one possible reason is that, due to the new ways of teaching during the pandemic, instructors who had previously relied on the blackboard were pushed/compelled to create slides' decks to be used during the online sessions and this, therefore, became a valuable and reliable source for the students. In the next paragraph, the two new entries in the table, the recorded lectures and the recorded exercises, which cannot be compared to anything in the pre-Covid situation for obvious reasons, will be discussed, in the light of the free comments. Studying with the classmates is confirmed as a powerful way to get set for the exams, sticking to the fourth place in the ranking of perceived relevance. The pandemic does not seem to have affected this kind of cooperation: students were apparently able to work together even from remote. It is only at the fifth and sixth places that we find the lectures and exercise sessions attended synchronously, either face to face or from remote, as the individual situation of the students had allowed. In the academic year 2020–2021, in fact, Politecnico managed to offer lectures and exercises in the campus, but at the same time allowing students to connect from remote, in case of issues (e.g. international students who could not manage to come). The notes taken by other students are still important (seventh place with respect to a sixth place in the 'normal' situation), but the percentage of students considering them quite important is much lower. The reason is that now students have the recordings, and so they can enrich/amend their own notes with no need to ask, as the comments explain. Videos found autonomously in order to clarify doubts are more or less as relevant as they were: it is quite striking to see that they are more relevant than the official textbook of the course, though. The questionnaire has a flow concerning the option about the official textbook, which was isolated in the questions about the 'Covid situation', but not – unfortunately – in the previous one (in the pre-Covid era). The comparison with 'official material provided by the instructor', which is a much broader concept and as such quite 'successful' in the pre-Covid situation, is too weak to be followed. The laboratories occupy quite a low position in the ranking, but they are also considered 'not applicable' by a much higher percentage of students, with respect to the pre-Covid time: no surprise, since the hybrid teaching method caused by the pandemic was definitely hostile to this form of teaching. Eventually, it can be noted that both 'students from previous years lending a hand' and 'experts' are considered much less relevant: again, this is quite likely the effect of having the recordings at disposal.

The free comments (746, after the purge of the 'null' compilations) were classified according to some categories that appeared to emerge as more recurrent, which were:
• request to have the official lectures' notes by the instructor,
• criticism of the official course textbook,

- praise of the value of study groups with other students,
- request to have exam papers from past sessions,
- wish to continue to have recorded lectures at disposal,
- nostalgia for face-to-face teaching,
- complaints, often irrelevant and
- 'other': a mixture of themes and suggestions.

Before plunging into the results of the classification, some premises must be made. The classification was made by a single researcher, with all the limitations that this entails. However, it must be said that the comments were truly unequivocal, also due to their brevity. Again because of brevity, in most cases, comments turned out to be easily attributable to one and only one category; only in very rare cases, the ascription could in principle have been twofold: in these cases, the dominant category was chosen (e.g. a comment like 'in presence lectures were good, but recorded lectures are an extraordinary resource that allows you to go through the most difficult concepts again¼' was classified as 'in favour of recorded lectures'). The category 'other' is a mix of comments of very different nature, ranging from the request to have more exam sessions to the desire by the foreign students to have more opportunities to study with the Italian students. Eventually, under the heading 'complaints' were collected the comments of those who took the opportunity to express their malaise (e.g. 'studying engineering is destroying my life'), in a way that is not entirely relevant for the purposes of study.

Figure 3 displays the results of the classification. As it can be easily seen, what is striking is the large number of comments in favour of the recorded lectures (54.8%), bearing in mind that students were given a space for free comments on whatever topic they wished, in connection to exams, and were not asked specifically 'do you want to keep the recorded lectures?' with a yes/no answer.
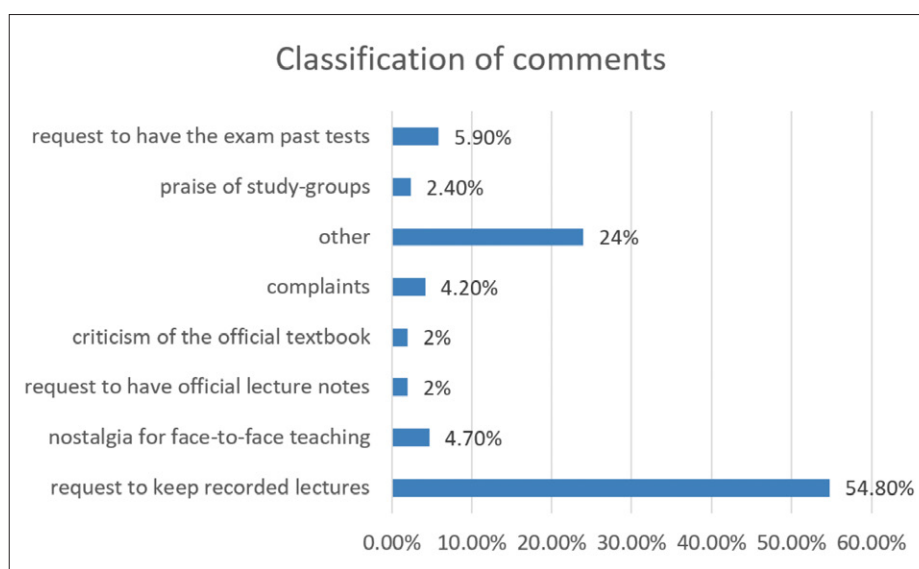

Fig. 3. Classification of the free comments (746)

In what follows, some comments by the students are reported (translation by the author).

On the lectures' recordings

'Recordings saved my life. The amount of information I discovered I had missed during face-to-face classes because I was exhausted by the weird lessons' schedules was too great. I realized this when they introduced the recordings. I think that we, as students, cannot have a period of concentration on everything that is said. In my opinion, the recordings are an incredible help in preparing for the exams. My efficiency has greatly increased thanks to them'.

'The recorded lectures have really helped us students to understand the concepts in a deeper level as we can rewind and review and take the learning process in our own hands. As the grasping power of each student is different it seems logical for students to have the recorded lectures, so even if we miss a point in the live class, we can rewind and get to master the topic'.

'Personally, I find that my level of preparation has improved since the recordings are available, which I have often used, despite having attended most of the lectures and exercises' sessions synchronously. In fact, with them, it was possible to dispel doubts and better understand the issues. In all honesty, since the end of my academic career shouldn't be that far away, I feel I can highly recommend recording lectures/exercises to be used in the coming years as well. In retrospect, in the past years they would have been extremely useful. By this I do not mean to say we should transform Politecnico into a telematic university, but in my opinion, it would be unwise not to exploit the technological tools we have to improve teaching and therefore the preparation of the students themselves'.

On the official textbook versus official lectures notes

'I understand that for many it may be difficult, but the most effective courses are those in which the instructor provides correct, complete and comprehensive lecture notes, where all the passages of all the arguments are reported, the topics are dealt with in a logical and sequential order, the conclusions written clearly and highlighting their importance. This, which is certainly a huge job for the instructor, makes the course much easier and less challenging to follow. Lessons are often too fast; most students lag behind and not only do not understand but have no way of taking notes properly. […] Leaving six texts as a bibliography to a student is counterproductive, there is too much information and written in a too dispersed way, often with different notations. Providing quality handouts should be the priority for every instructor'.

On the wish to have access to past exam's tests

'In most of the eight exams I have taken so far, I have ALWAYS found content that GOES BEYOND what the professors explained or did in the exercises. How did I have to prepare the exams? Practicing on the old exam tests'.

In praise of studying with the classmates

'I have come to understand that the exams I prepared studying together with other classmates, compared to those I had prepared alone, were easier to take'.

Discussion and conclusions

Let us go back to the three research questions this study stems from. Concerning the first, 'Do students actually resort to different sources of knowledge, in getting set for the exams?', it can be said that the answer is yes: data show Distributed Cognition at play, with a wide variety of resources being used. The second question was about the nature of these resources and their relevance. The questionnaire's results show that they are varied, including unexpected ones, like websites gathering previous years students' notes. Moreover, many of these sources seem to be of substantial relevance, in the sense that there is not a specific source largely outperforming the others, but the 'eco-system' is in an equilibrium with a number of sources playing important roles, both before and during the pandemic. In addition, this is confirmed by the result about the 'during pandemic' situation, that is, multimedia sources are preferred over 'traditional' ones. The third and last question on the difference between the pre-pandemic and during pandemic situations ('Is there any difference between the pre- and post-, meaning "affected by", Covid pandemic?') also yielded interesting results. Things do change, with all the new sources (i.e. all the recorded materials – recorded lectures, recorded exercises sessions) getting sudden and high relevance. These results lend to four main considerations.

Recorded lessons are perceived by students as hugely relevant. The most surprising result derives from the classification of the comments, of which 54.8% are dedicated to praising the recordings of the lectures and requesting to keep them in the future. This figure is conspicuous, especially considering that it is the outcome of an open question, potentially concerning a large number of topics (the remaining 46% of the comments, in fact, disperses into various topics, partially merged under the heading 'other').

We are dealing with a 'multimedia' generation. Not only do students appreciate the recorded lectures, but also the videos found independently exceed in relevance the official textbook suggested by the instructor (towards which they are very critical) and books and documents (i.e. textual sources) found alone.

They are also a 'social' generation: the perceived value of studying together is high in the pre-Covid era and remains high after (summing up the remote and face-to-face options), to the point that it surpasses the synchronous lectures and exercises' sessions, that is, the most institutional sources, the ones that might be expected to play the main role.

Students 'calibrate' their preparation on the exam. They would like the lecture notes edited and, so to speak, 'validated' by the instructor; they would want the exam tests of the previous years, they criticise the official textbook because it is disconnected to what the instructor says and asks at the exam, they do little additional research. It is quite clear that their main goal is 'to pass the exam' rather than going deeper into the issues.

All these results must be taken into consideration in planning the future of our universities: keeping the recorded lessons as a resource, 'going multimedia', facilitating students' getting together and group work, and eventually redesigning the way they are evaluated at the end of the courses are all issues that are currently under discussion at Politecnico di Milano. For example, concerning point 3, new spaces are being designed to support the 'watch parties', that is, groups of students watching synchronous or asynchronous lessons/exercises together. On point 4, a commission is working on the redesign of evaluation methods.

The study has an extremely broad focus (all students from the two schools of Politecnico) and this is both an advantage (for having a rough idea) and a limit. Further analysis will, therefore, concern specific subgroups, for example, examining the differences between bachelor's and master's students or specific course of studies. Eventually, it must be noted that it would be quite interesting to run similar studies in other universities to allow for comparisons.

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