Politecnico di Torino

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Supporting academic strategic decisions

Analysis of teaching data during the pandemic to support innovative teaching design

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Introduction

With the onset of the Covid-19 pandemic, the educational system promptly struggled to figure out a viable means of resisting and reinventing itself. What was previously a set-up that had been going on for decades, within a matter of weeks was turned upside down in favor of a landmark change that scarcely suited the passive attitude of educational institutions to embrace change. The Covid-19 pandemic turned out to be a real game changer allowing epoch-making transformations and/or transitions in a remarkably short time frame. The impact on teaching was immediately overwhelming and even now is having a deep-seated impact. An activity that had hitherto relied on face-to-face interaction promptly had to find a way to exist in an age of social distancing in which individuals could only interact virtually. With a health crisis looming in the background, the goal has been to seek the quickest possible solution, without conducting a study or staking a long-term strategy, with the main objective of resuming education immediately through interim arrangements. From the get-go, despite the potential that emerged from distance education, it was considered a mere temporary option pending the gradual return to normalcy. However, precisely due to this sudden shift and times of crisis, students have reconsidered their priorities, and what might have been once taken for granted is no longer so today. Thus, there has been a real reshaping of needs on the part of students that consequently can no longer be left aside.

In addition, it cannot be forgot the transformation of the education system brought by the pandemic occurred in a scenario of an epochal transformation, because for the first time those who Marc Prensky[1] has called "digital natives" are entering university classrooms. This type of student is characterized by peculiar forms of attention and concentration, as they are accustomed to simultaneously handle a multiplicity of information and stimuli through essential, intuitive, extremely rapid modes of interaction with reality. In order to meet these unprecedent abilities and needs, it is necessary to innovate both methodologies and learning content, rethinking even those considered as basic and essential, in a new and different key.

All this represents a major challenge for the university, which must be able to effectively change its skills and knowledge by making them expendable in an increasingly fast-paced, ever-changing world in which attention is distributed and fluctuating among multiple stimuli. To do this, university must have the courage to change and overcome its organizational inertia: in the offering of courses of study, in the layout of curricula, in the forms and modes of teaching, in the classrooms' structure, and in the use of new technologies in various forms and ways (some might be Lims, virtual classrooms, Moocs, the use of video games, digital libraries...)[2].

The transition to a fully online environment happened over night, and most higher education institutions were completely unprepared. However, there are a variety of potential scenarios that might be implemented in the upcoming years.

[1] Prensky M. (2001), *Digital Natives, Digital Immigrants,* in *On the Horizon*, MCB University Press, Bingley, West Yorkshire, vol. 9 n. 5, pp.1-6.

[2] Corbo, Filomena, Marisa Michelini, and Antonio Felice Uricchio. "Innovazione didattica universitaria e strategie degli Atenei italiani." Italian Journal of Management.

As with all higher education institutions, the Politecnico di Torino was a key player in this transition during the pandemic, and to capitalize on the opportunity created, it intends to imprint a strategy that will enable it to be increasingly competitive in the future for the development of an innovative teaching.

In light of this, the Centro Studi of the Politecnico decided to examine the impact that online education had on its teachers and students. Therefore, the research objective of this thesis complements the Teaching and Learning Laboratory's activities (TLLab), which focus more on educational characteristics, and examines teachers and students as participants in a process with values, desires, and behaviors that have been developed as a result of the lived experience. The goal of this work is to examine how online education has influenced the performance of students and lecturers at the Politecnico di Torino in order to create a study that can support the organization's strategic decisions regarding the type of education to be provided in the years to come.

With this in mind, the dissertation is structured into four main chapters, divided as follow:

The first chapter illustrates the concept of digital transformation applied in the field of education, delineating the changes necessary to have technology-enhanced universities which do not limit the teaching and learning process within the classrooms' boundaries. The chapter also explores the concept of MOOCs and its controversial aspects together with a critical analysis of the main advantages and disadvantages of the digital learning. Finally, the exemplar case of H-FARM is presented as an ecosystem where students, corporates and digital start-ups work together contaminating each other.

The second chapter traces a journey along the pandemic, emphasizing how the situation have changed comparing the conditions of higher education institutions pre, during and post the spread of the Covid-19. The aim of the section is to highlight weaknesses and strengths sharpened by the disruptive transformation brought by the pandemic, to point out the lesson learned that could eventually lead to a change in the traditional university business model.

The third chapter focuses more specifically on the Politecnico di Torino and its reaction to the pandemic requirement to digitize education and all the training procedures in record time. This section also proposes some strategical ideas implemented by the atheneum with the purpose of stimulating new forms of didactics and new methodologies.

Finally, the last chapter is methodological in nature and reports the workflow that represents the core of the thesis. After having explained the conceptual approach to the study and the cleaning process of the databases, analyses are then presented distinguishing in three perspectives: the students, the teachings with the related lecturers, and the CPD questionnaires, filled out by teachers and students at the end of every teaching session to assess the quality of its execution.

It is worth saying that this study does not begin and end with this thesis, but rather it is a work that has already been started and will continue in the following months. A constant element among the working groups is the involvement of the professors from the Politecnico di Torino and the Centro Studi as well as the external collaboration with Fondazione Agnelli.

Specifically, previous works have built a solid basis for the research by structuring and editing the databases, as well as started few initial analyses, mainly descriptive in nature. This thesis explores more in depth the already mentioned issues to achieve a concrete understanding of how online education performed during the pandemic. This might provide useful insights for the design of an educational service that could offer a wide range of academic curricula as well as innovative pedagogical methods and various delivery modes.

1. University education among changes, challenges and opportunity

Traditional educational approaches are regularly challenged and innovated in order to match the constantly changing reality. In any area of teaching, it would be required to look at society and consequently adapt means, tools, and methods to what is happening in order to adequately generate innovative teaching.

It is worth highlighting that innovate teaching does not only mean to explore new methodologies or new tools, but rather to make ongoing efforts to develop approaches that are useful to increase the quality of education, encouraging students' active participation in the learning process.

The rapid spread of Information and Communication Technology (ICT) applications has brought drastic transformations, forcing educational institutions, administrators, and teachers to rethink their roles, teaching methods and vision for the future.[3]

The use of ICT in education has become essential for increasing productivity and effectiveness at all levels and in both formal and informal contexts. Even at school stages, computer instruction is required. For the successful citizens of the future, profound technical expertise and a good attitude toward technology are necessary preconditions.

The ability of universities to maximize the use of innovation and provide high quality products, fostering innovation in teaching and learning, will in fact have an impact on their future if they want to persist in a time where this transformation is a key element.

The following paragraphs discuss the role and effects of ICT on education, highlighting how, if proper integrated with the teaching/learning environment, it promotes future growth and development, increasing the productivity and reducing the gap in quality of education between schools in urban and rural areas.

1.1 Digital transformation and the challenge of digital learning

Nowadays, the purpose of educational institutions is to convert their raw input students to technological management-oriented output. This is achievable only with the adoption and integration of ICT with the education system. ICT-enhanced learning environment in fact facilitates active, collaborative, creative, integrative, and evaluative learning as an advantage over the traditional method. It both has made and will make an essential contribution to educational advancement.

In this second decade of the 21st century, higher education institutions (HEIs) have made digital transformation (DT) a priority. This is a natural and required process for organizations who claim to be leaders of change and be highly competitive in their field.

Digital transformation is defined as "the profound transformation of business activities and organizations, processes, competencies and models, for the maximum transformation of the changes and

[3] Amutha, D. "The Role and Impact of ICT in Improving the Quality of Education." Available at SSRN 3585228 (2020)

opportunities of a technology mix and its accelerated impact on society, in a strategic and prioritized way."[4]

In order to capitalize on emerging technology and their quick expansion in human activities, organizations must reinvent themselves and modify all of their operations. Due to this, digital transformation calls for a shift in perspective and entails innovation. When it comes to education, DT is a process that requires an adaptation to the student's evolving educational demands. As a result, the learning experience become more efficient and dynamic. Due to technological advancements, education now takes place in both traditional and virtual settings, connects online and offline, and adopts trends like DIY (Do It Yourself).

The emphasis of the implementation of DT processes within the HEIs has changed over time, with a tendency that evolved first from a technology perspective to an organizational one, and then consolidating into a social one. The teaching dimension is where DT processes has intervened the most, followed by the infrastructure, the curriculum, and finally by the business administration, as it is shown in the radial scheme below.

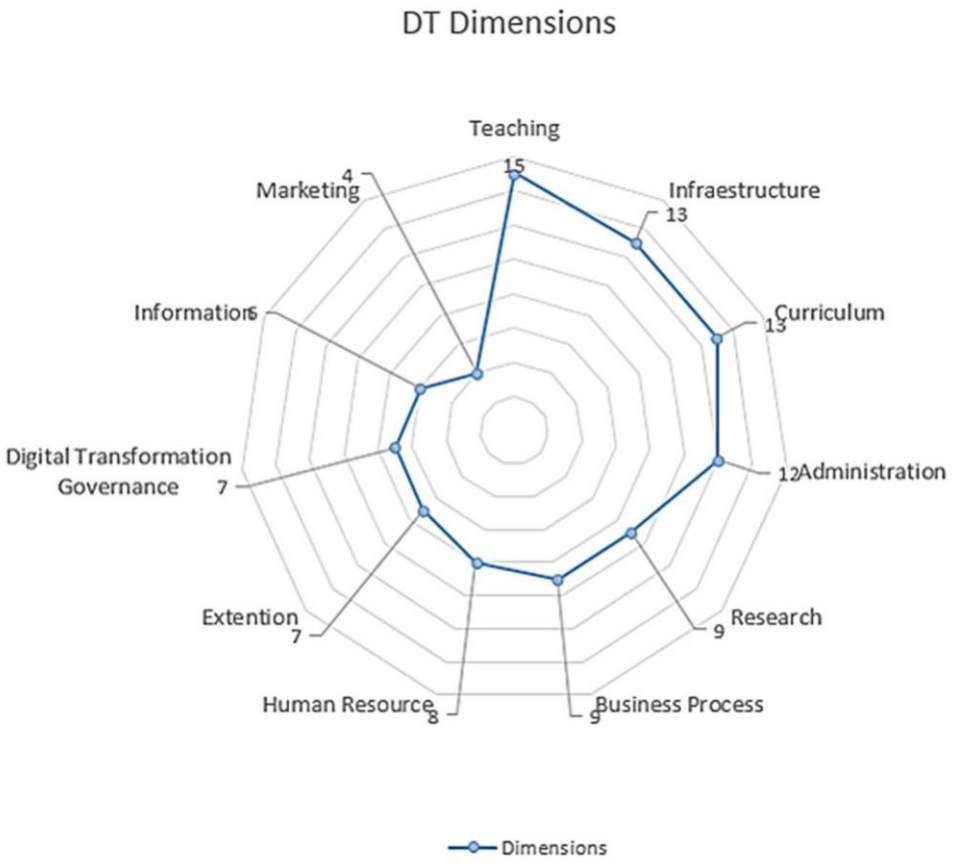


Figure 1. Dimensions impacted by the digital transformation

Regarding the teaching dimensions, innovations encompass academic, curricular, organizational, and structural aspects as well as technical ones. These components enable new roles for teachers and students and foster more autonomous and collaborative learning environments through the

[4] Gobble, M.M. Digital strategy and digital transformation. Res. Manag. 2018, 61, 66–71. [CrossRef]

use of tools that comply with modern educational standards and practices. Digital transformation in fact promotes a practical and innovative approach to education with new pedagogic models that include flipped classrooms, digital cooperative learning (DCL), gamification, augmented reality, virtual reality, and mixed reality. The DT applied to education encourages creating learning techniques based on individualized instruction, content customisation, and the development of individual talents through social learning, betting on creativity and entrepreneurship.

Educational programs have been updated with the goal of guaranteeing a flexible response to the needs of labour market.

Big Data and Artificial Intelligence (AI) are being used as educational resources in the new learning environments, which will benefit difficult HE concerns. These technologies help, among other things, the teacher to track the student's progress or to modify the lesson plan in case they see a knowledge gap.

Moreover, many HEIs are leveraging technology at the administrative level to increase operational efficiency, give learning flexibility, and enhance the quality of education offered. As an example, Artificial Intelligence is being used to tailor the student admissions process and pinpoint the candidates who will succeed in their degrees.

In order for the digital transformation to be successful, HEIs must restructure their model of academic and administrative governance rapidly and precisely, effectively generating new concepts, and enabling a flexible and supportive infrastructure. This all starts with a shift in perspective toward an "entrepreneurial attitude".

All the supporting processes must be completely reengineered. Due to the size of the university and the numerous daily processes it manages, this task requires extreme sensitivity and attention to overcome the different schools' natural resistance to change.
It is a demanding process that calls for an innovative approach, involving the dematerialization of all the processes while maintaining the agility of the technological infrastructures.[5]

As a result of its multi-purpose, multi-process, multi-disciplinary, multi-state, and multi-actorial nature, digital transformation in HEIs necessitates rethinking, restructuring, and reinventing. It is a collaborative effort that centers the individual in the process of growth, change, and its effects on society. In other words, DT needs to be an integral and comprehensive change of the HEI.

1.2 The shift in the teaching and learning paradigm

Information and Communication Technology has changed the governance and the style of functioning of the educational system, increasingly becoming an indispensable part of it.

[5] Faria, J.A.; Nóvoa, H. Digital Transformation at the University of Porto. In Proceedings of the International Conference on Exploring Services Science, Porto, Portugal, 5–7 February 2020.

In this new context, a change in the roles of both teachers and students must occur to generate a more engaged and interesting learning environment for teachers and students, shifting the focus from teaching to learning leads.

The paper "*The concept and application of ICT to teaching/learning process*" explores the implications of ICT in education, with a focus on the drastic change in the teachers approaches and the students' learning methods and defining their new roles in the education journey from traditional instruction to a more virtual learning environment.

Teachers' roles will evolve from transmitter to facilitator, knowledge navigator, and occasionally even co-learner. On the other side, learners will be asked to assume greater responsibility for their own learning, as they seek out, synthesize, and share their knowledge.

The table below contains a description of the key changes and improvement that result from the involvement and adoption of general components of ICT in education.

Changes in Learners' Roles

From	To
Passive Learner	Active Learner
Reproducer of Knowledge	Producer of Knowledge
Dependent Learner	Autonomous Learner
Solitary Learner	Collaborative Learner

Changes in Curricula & Delivery

From	To
Memorizing Facts	Inquiry Based
Rigid Delivery	Open & Flexible Delivery
Fixed Time & Space	Any Time & Anywhere

Figure 2. Changes in the educational paradigm

ICT offers effective tools to support the paradigm shift from one that is teacher-centred to this learner-centred, as well as promoting the definition of new roles for teachers, learners, curriculum, and new media. ICT has the ability to change the way how education is delivered, including when and how learning occurs. It will speed up the transition from a reproductive model of teaching and learning to an independent, autonomous learning model that incentives initiative, creativity, and critical thinking along with independent research.

Students are expected to use ICT in an authentic and active learning paradigm to gather, choose, analyse, organize, extend, transform, and present knowledge. Teachers on their side are expected to develop a brand-new, flexible, and open learning environment with a multimedia-based delivery system that is interactive, exploratory, and creative. ICT, and in particular its application in online programs, enables teachers to incorporate the entire world into classroom activities and at the same

time learners to become more autonomous, facilitating communication and collaboration without borders between them.

When building any innovative teaching and educational environment employing ICT, teachers should constantly keep the learning at the center of all activities and the integration of pedagogy should be the central focus. They are supposed not to follow pre-set rules or structures but rather apply the "servant-leadership" philosophy: the teachers put themselves at the service of their students, with the emphasis being on learning rather than on the lesson.

The main goal of integrating ICT into pedagogy is to enhance learning, inspire and engage students, develop cooperation, encourage inquiry and exploration, and establish a new learner-centred learning culture. Since ICT gives both teachers and students more flexibility to adapt learning and teaching to individual needs, it is vital to improve the integration of ICT concept and application in education.

1.3 MOOCs and the future of university education

Looking at a different future of globalized and technology-enhanced universities, it is worth mentioning the phenomenon of MOOCs (Massive Open Online Courses). The authoritative website *www.moocs.co* defines them as "free non-degree online courses with open unlimited global enrolment to anyone who desires to learn, and regardless of their current educational level."
Since they are open, there are no prerequisites for signing up or attending, and the offered educational materials are copyright-free and can be freely distributed.

The factors that encouraged institutions to adopt MOOCs include a growing understanding of the need to engage more people, entering models for lifelong learning activities, and the chance to promote participation in the knowledge society while also raising their institutional profile.

The curricula that can be potentially delivered by MOOCs significantly broaden the traditional educational offer and the traditional e-learning. Moreover, they need minimal academic support.

With respect to the provider, one can distinguish three main types:

- Distance education university courses with a basic tutorial support
- Blended university courses in which lecturers used MOOCs as multimedia teaching aids, reducing the number of face-to-face classes. This solution requires limited changes to the organization of teaching and could enable personalized learning paths for student workers
- Experimental university courses, in which semester by semester each student can choose (under the guidance of professors) the MOOCs to take in addition to the few courses that are instead delivered by faculty members. This is an innovative solution, that decisively distinguishes between the role of lecturers responsible for a course of study and those who produce the MOOCs. The curricula could be made more flexible year by year, based on the needs of the attending students and the programs that have to be carried out.

Most modern MOOC courses follow a weekly schedule, and students are free to access pertinent resources whenever they prefer. Activities include automated multiple-choice tests, short videos, document sharing, and forums. In addition to asynchronous learning activities, there are synchronous learning opportunities (such as live seminars).

The majority of enrolled students just want to explore a topic, without any interested in completing the course. This results in high non-completion rates, also linked to concerns about the quality of teaching, pedagogy, and sustainability.

MOOCs represent an interesting opportunity for the Italian university as they are an obligatory step to become more efficient and better (in the areas of research, teaching, and the third mission) without demanding an increase in the funds that the State allocates to it. MOOCS represent the idea of promoting openness in education while embracing technological innovation.

As educational products, they are a decisive leap forward being a new family of highly effective teaching aids through which it is intended both to change existing universities and to establish a new generation of high-quality online universities.

1.3.1 Will MOOCS destroy academia?

While online education has a long history, the MOOCs wave began in the fall of 2011 when over 450,000 students enrolled in three computer science courses at Stanford University. Since then, MOOCs have become the most discussed topic in higher education, especially in the U.S.

Even though there is no established business model for MOOC-based education, many prestigious U.S. colleges currently provide MOOCs, either independently or in collaboration with some other companies.

Moshe Y. Vardi, in an article available on the ACM digital library, questions the real significance of the MOOCs, claiming that the rhetoric of the individual tutoring is difficult to reconcile with massiveness as an essential feature of MOOCs. With brief and unsophisticated video interspersed with online quizzes, the absence of serious pedagogy in MOOCs is actually rather noticeable.

Vardi also reports a quite honest comment from one of the first MOOCs pioneers that states: "We were tired of delivering the same lectures year after year, often to a half-empty classroom because our classes were being videotaped."

According to the article's view, the real reason for the MOOCs phenomena has in fact to be found in the tempting possibility of lower costs rather than in the claimed technology's intrinsic educational value. The financial crisis severely impacted higher education in the United States and public institutions saw governmental assistance, which was already dwindling, fall even more quickly.

Although there has been a lot of discussion in recent years about "active learning," "peer learning," "flipping the lecture," and similar concepts, most academic teaching still involves professors lecturing to sizable classes. Undoubtably, there is room for improvement in teaching but given it is well

known that a professorial soliloquy is not effective, maybe MOOCs are not the answer to educational shortcomings.

It is true MOOCs may bring positive elements like autonomy, diversity, openness and interactivity as well as negative sides that may limit the learning potential due to a lack of structure, support, and moderation that is typically associated with an online course.[6] MOOCs have the potential to greatly expand the availability of free university-level education, but significant concerns are also related to them.

To conclude, for sure the concept of a traditional, closed-group, highly organized course where students are dependent on instructors needs to be replaced with a more open network of self-directed learners.[7]

The high technology cannot ensure the success of MOOCs. In order to last, they have to adhere to the primary goal of providing free higher education and be pedagogically driven rather than technologically driven in their design of teaching and learning.

1.4 Online learning from a faculty perspective

Whether a course lends itself to be completely converted to an online version or whether the Web is only be an additional component of the current course format, online teaching is here to stay. Creating an effective, understandable, and interesting online course is challenging and far more complicated than just converting lecture notes into HTML documents. Nevertheless, once teachers have a solid grasp of the process, they will discover more advantages than limitations.

From a faculty perspective, online courses have both positive and negative elements, which are well analysed by Robert W. Taylor in the paper *Pro & Cons of online learning - A faculty perspective* and here shortly presented together with some reflective questions for instructors to stimulate critical thinking towards the development of an effective online learning program.

DOMAIN	PRO	CONS	QUESTIONS
Course's content and program	Online teaching is effective for most academic courses and training programs involving cognitive learning	Programs that aim to change students' attitude and behaviour, as well as courses that requires physical skills, do not work well online.	- Can the objective of the course be measured? - Will the students be able to work alone with simply supervisory direction or will the instruction need them to collaborate in pairs, small groups, or both?

6 Mackness, J., Mak, S.F.J., & Williams, R. The ideals and reality of participating in a MOOC. Proceedings of the 7th International Conference on Networked Learning. Lancaster: 2010; 266–274.

7 Siemens, George. "Continuing attempt to destabilise courses." Recuperado a partir de http://ltc. umanitoba. ca/connectivism (2009).

Technological skills	Instructors can put their methods, competencies, and characteristics to the course pages, freely expressing who they are as people and how they teach.	Teachers have many different levels of creativity and technical knowledge. They are faced with steep learning curves.	- What technical support do I need? Where can I get it? - Do I have an up-to-date hardware? Is my software current?
Asynchronous programs	Students do not have to be in a virtual classroom at any specific time. This is advantageous when students are from different time zones.	Asynchronous programs preclude any immediate discussion and doubt clarification.	- How can I encourage students to communicate among each other, promoting a positive interaction if they are not online at the same time?
Synchronous programs	It is a good opportunity to get a group discussion going. Students who might be reluctant to participate in a regular class, often will engage if they can do so through their keyboard.	Different time zones may be difficult to manage. An instructor must know where students live.	- What are the demographics of my class as a whole? - What time(s) would work best? - What advantages would some synchronous classes provide?
Feedback and communication	Communication is important: thanks to email, feedback is easy. Using a forum, students may pose their questions allowing all the others to see and contribute and encouraging students' inter-communication and integration.	Depending on faculty schedules, instructors may take hours or days before a response could be sent to a student question.	- How can I be certain I am giving sufficient feedback?
Class management	There are many classroom management software programs that instructors can use to set up student's records, store and manipulate data.	Control students' participation may be difficult. Instructors should be aware they are subjected to many distractions.	- How can I know the degree at which my students participate? - Do I expect a regular response from each of them?

Measuring results	Online assessments allow students to receive immediate and meaningful feedback, relieving the teachers from the tedious job of correcting countless examinations.	Multiple choice, true/false, or other "click the answer" tests may not be sufficient to evaluate students' depth knowledge.	- Am I using the most effective testing measure? - How do my students feel about computer-based assessment? - How do my test results compare to the normal academic testing standard?

Table 1. Pro & Cons of online learning: a faculty perspective

According to Garrison & Anderson[8], E-learning offers huge opportunities and risks: a successful e-learning requires a more systematic and centralized approach, as a solid infrastructure and a dedicated technical unit in charge of promoting the use of technology-based teaching and providing the necessary assistance to students and staff.

These specialized entities may play a crucial, fundamental role in the adoption of e-learning; thus, they must be developed as part of a strategic plan that is in line with the institutional mission and vision. These units:

- need to have clear operational standards and management procedures
- regularly check the system's technical requirements
- work together with academic, media development, and administrative staff on the development of strategies and plans that consider the potential of emerging technologies:
  - establish the institutional plan for the delivery of training in the technical aspects of e-learning
  - coordinate access to self-help training materials
  - provide helpdesk service to staff and students
  - create new knowledge about e-learning
- integrate e-learning requirements with the organization's longer-term IT infrastructure plans.

The presence of a dedicated unit ensures that appropriate technological training is provided for staff as well as adequate support and resources, including any affiliated tutors or mentors.

How valuable the use of internet is as a teaching tool varies considerably depending on the topic of the course and depending on the subject: it may be needed to create a new course from scratch or just transform it from a classroom lecture to the online format.

Online teaching will undoubtedly make faculty members' lives more difficult until they master the process, but ultimately it will lead to excellent learning experiences.

[8] Garrison, D. R., & Anderson, T. (2003). E-Learning in the 21st century: A framework for research and practice. London: Routledge/Falmer. doi:10.4324/9780203166093

1.5 The case of H-FARM

H-FARM is a cutting-edge platform that promotes the development of new business models by investing in start-ups, driving the transformation of large corporations from a digital viewpoint, and giving students and professionals access to top-notch digital education.

In order to create value and foster the growth of an innovative ecosystem, H-FARM supports businesses in their digital transformation while also assisting young people in their digital training.

The "H" stands for "Human," emphasizing the initial goal of creating initiatives and making them easier to operate. The idea encompasses everyone involved in the project as well.

The education project is extremely ambitious and one-of-a-kind: traditional educational systems are rapidly losing relevance, and as a result, there is a growing demand for innovative learning techniques. Their educational offering goes from ages 3 to 17 for primary education and continues with bachelors and Master of Science to complete the learning with the university track.

According to the International Baccalaureate model, inclusion is understood as “a continuous process for removing barriers to learning, incorporating the needs of all students." Information accessibility is one of the fundamental principles of inclusion and, as a result, technology is crucial to it. As an Apple Distinguished School, H-FARM International School equips its students with cutting-edge technology with many features to increase everyone's access to knowledge.

H-FARM wants to create an educational pathway that will be able to cultivate the brightest minds in Italy's largest digital ecosystem by integrating best-in-class academic standards with new learning techniques, business, best practices, and start-up opportunities.

The centrality of man and that humanistic thinking that distinguishes Italian culture are inserted into an international baccalaureate model that is becoming the standard of international schooling and that predisposes children to innovation and to the world that is coming, with more adequate tools for reading reality. The key point is the complementarity between some crucial elements of innovation and others from the Italian traditional education model that cannot be overlooked, rather than the substitution of the two. Humanities subjects that distinguish our culture and educational system are valuable but must not be an excuse for not looking to the future.

The education business unit gives students the tools they need to take advantage of and seize all the opportunities created by the digital revolution so they can play an important role in the workplace of the future. Teaching and learning are supported by a people-oriented approach made up of positive relationships, cutting-edge education, and digital innovation.

Education innovates mainly on two areas: on content, to make it relevant and up-to-date, and on teaching methodologies. The distribution of content is indeed reformatted and aligned with the interaction and listening skills of young, which are completely different from those of previous generations. Once the format is redesigned, the content must be conveyed in the most fascinating way, creating an interaction between the student, the content and the teacher that is as fast and as dy-

namic as possible so as to generate stimuli that are always very strong. One example is the implementation of virtual reality: for the past two years, at least once a week a teacher has been conducting a lesson in virtual reality on content he or she has personally developed.

Premising that the freedom of action of private parties is, of course, different from public ones, digital and laboratory facilities are implementations that are in any case feasible and, above all, of top priority in order to make the new generations protagonists of their own time, which is one of the goals of the school system.

2 Towards innovative didactic: the state of the art and the challenges highlighted by the pandemic

The Covid-19 pandemic has sharpened the weakness and lack of resilience to change of the Italian university system. In a context of strong and sudden change, the Italian education system in general has shown itself to be unresponsive and certainly not ready for a transition of this magnitude. Obviously, this was a global event that left almost all institutions - not just educational ones - astonished, but the lack of innovation and the passive use of new technologies adopted during this experience seem to show an attitude of mere observer of change rather than promoter of it.

Crises force society to reinvent itself, and the Covid-19 pandemic is abruptly and radically changing how people live, work, and interact with one another. With academic faculty lacking intrinsic technological talents for online teaching, the traditional university world is witnessing profound modifications as a result of the requirement to digitize education and training procedures in record time. In order to remain competitive and deliver top-notch education in a digital transformation environment marked by disruptive technological advances and accelerated change, the university system must work to overcome this dilemma.

Traditional colleges are at a turning point, according to KPMG International in "The future of higher education in a disruptive environment." They must choose between changing into new types of entities, improving their current operations in search of greater efficiencies and capabilities, doing nothing in the hopes that, if a bailout does not materialize, they will have time to decide what to do next, or doing nothing in the belief that they are impervious to risk.

The aim of this section is therefore to illustrate what strengths and weaknesses the Covid-19 pandemic has highlighted and to analyse the situation pre-, during and post-pandemic to see how this change occurred.

2.1 Pre-pandemic innovations and strategies of Italian and European universities

Italian and European institutions did not have employed digital tools as much as American institutions at first. However, practically all institutions have begun using e-learning as of the end of 2013 according to the European University Association publication "E-learning in European Higher Education Institutions", where the term e-learning refers to any type of learning in which teaching is supported by the use of information and communication technologies.

Instead of a dramatic, disruptive transformation, Europe is seeing a steady unforced transition that is characterized by small improvements to the conventional paradigm. Individual universities of the same type and country have incorporated e-learning in a variety of ways and to varying degrees. Some of the major issues include profile and mission, resources and financial access, an emphasis on particular subject areas, the sort of students they draw, various stages of the e-learning experience, and the rate of technological adoption[9].

However, the absence of national e-learning policies and initiatives appears to be partially verified across all Europe. As evidence of this, in 2014 EUA conducted a survey to find out how different European countries have moved to implement e-learning initiatives interviewing students attending higher education institution.

According to the survey, the majority of respondents said their countries have not created a unified national plan and policy and thus this lack of significance in the agreements of the Bologna Process is another factor contributing to the noticeably diminished interest.

Nevertheless, a number of European universities have made an effort to incorporate novel use and distribution methods. In terms of e-learning initiative the debate over technology-enhanced learning and changes to the teaching profession has included MOOCs as one of its main focal points, but despite widespread interest, just 31 institutions (or 12% of the sample interviewed by EUA) chose to introduce them, according to the survey findings. Their growth was fueled by their international recognition and the admission of fresh students. The data, however, show that the majority of applicants were a mix of domestic and overseas students.

Many institutions' lack of interest was cited as being caused by its questionable utility in terms of educational and pedagogical approach and lack of academic recognition. This was further supported by the information that certain universities were employing them for blended learning, which went against the original idea. For the majority of European MOOCs, the conceptual objective of obtaining widespread international participation was disregarded; in fact, linguistic diversity was a noteworthy aspect in addition to the points already made. In order to meet the demand in particular regions of the world, institutions decided to offer them in Catalan, German, and Italian in addition to English.

What becomes clear from the EUA's results is that, until that point, the motivation for MOOCs was driven by initiatives taken by individual institutions as a form of cautious experimentation on a small number of courses (one to five), not covering a massive involvement in all disciplines. Moreover, the design decisions involved in the delivery of MOOCs have been largely revised from the original concept. As a cooperative online education offering with other schools, 36% of the institutions in the survey investigated the value of online degree programs. This exercise could be pertinent for a significant discussion in the area of higher education in Europe, resulting in a clearer understanding of tools, instructional materials, and best practices that represent the usage of online courses. Other

[9] Michael Gaebel, Veronika Kupriyanova, Rita Morais, Elizabeth Colucci (2014), *E-learning in European Higher Education Institutions*

survey findings revealed that 91% of the assessed institutions used blended learning, combining traditional instruction with e-learning. The pedagogical, financial, and expanding demand for time and location flexibility on the part of students are the key factors contributing to this decision[7]. In addition to these, long-term drivers are most notably the search for flexibility in the educational offer to ensure improved opportunities for resident students and online learners.

2.2 The pandemic emergency and social distancing: the race for university innovation

As has been remarked, over the past few years the sudden spread of the Covid-19 pandemic has accelerated online learning which, along with the ongoing advancement of digital transformation, is leading to a change in the function of digital innovation in higher education.

The pandemic has accelerated innovative processes that previously had marginal roles in traditional universities, even though the digitization of university education was a road that had already begun in the past decade, albeit to varying degrees, throughout Italy and Europe. In fact, the higher education industry had to rebuild itself in the wake of the pandemic, and key changes have taken place in the majority of institutions[10]. First, there was a quick transition to online instruction with the introduction of new working procedures, new initiatives to employ already-existing technologies, and new tools to meet emerging demands. Second, organizations started using remote working methods for their internal, non-teaching tasks. When it became apparent that partial limits would be in place for a considerable amount of time, the third major alteration took place. As a result, mixed mode working became necessary across the board for the university system. The most remarkable development, however, has been that most institutions can now implement the aforementioned stages quickly and effectively. This appears to be in conflict with the higher education industry's delayed adoption of innovative approaches and the conventional conservative mindset[8].

The role of innovation in higher education has clearly changed, moving from the periphery to the center of the organization, which is what underlies these developments. Since radical innovation mostly worked at the periphery of the primary business, there was a lack of managerial focus and less community support[8].

The following details can be used to illustrate the main changes:

1) Effective management and well-defined guidance from above.

The way that institutional leaders employ digital technologies is evolving. Digital investments used to be spread out across the board in a number of minor stakes with little impact. Future-looking leaders are more interested in switching traditional delivery to a dual-mode approach to give students a better educational experience that incorporates the advantages of both worlds now more than ever, especially in light of the pandemic.

2) Bringing innovation into the organization through overcoming organizational inertia.

[10] Pekka Kähkipuro (2021), *A new Digital Innovation Model for Higher Education after the Covid-19 Pandemic*

Digital innovation has typically been an outlier of a limited set of academics. The majority of the organization continued the practice in small, incremental steps. Even after new delivery methods emerged, lectures and "chalk and talk" remained the preferred method. Recent circumstances have compelled professors and researchers to find novel approaches to achieving their career objectives. As a result, digital innovation has begun to spread throughout the entire organization, and the majority of improvement initiatives will take new digital solutions into account. By doing this, the solution will be made future-proof and may even be used in a digital workflow. In this sense, innovation can be categorized as "competence destroying" (for instance, in the potential decline of chalk use and writing) and "competence sustaining" (for example, in the conversion that the university sector is currently undergoing).

3) Eliminating organizational "antibodies".

Change is typically met with natural resistance in most organizations. Since innovation at first focused on unprofitable areas of the company, handling dissent was often handled softly. The adoption of digital technologies and procedures was the only option available during the pandemic in order to work effectively. This opened the door for the traditional organization to improve its backing of innovations and get rid of resistance using more effective methods.

The astonishing thing about these developments is that they happened quickly and effectively, defying the ideas that the education sector lacks the hunger for change and that innovation has historically been slow and centered on secondary activities[8].

Additional elements that came into play and made it possible for this move toward the digitization of education include:

- assistance from organizations. Since 2020, institutional leaders have become more interested in the subject, outlining a clear course to take and encouraging significant investments in this regard, in contrast to the previous decade when innovation in education was carried out by lone entities that experimented out of personal interests or market needs
- the unusual pandemic incident broke a lot of the resistance to change that some teachers had. The method that education is done has changed dramatically as a result of forced modifications that were once tiny, academically driven adjustments. This innovation was "competence destroying" for teachers because it required them to embrace a new paradigm in place of their customary frontal lectures with chalk and whiteboard
- the same inertia to change on the part of teachers existed in the past at the organizational level in the areas dealing with strategic decision-making, and these too have been overcome.

In conclusion, it is interesting to compare and contrast what has happened during the pandemic with what occurred in the Europe ten years ago during the Great Recession. In both situations, the education sector was brought to its knees by a crisis, which caused systemic disruption. At the end of the crisis, the system was even better since it was more resilient and receptive to innovation as a result of this encouraging progress and innovation. In spite of all the problems that the pandemic

has generated with regard to educational institutions, will we have a chance for improvement here too?

2.3 Toward the implementation of an innovative education: the lesson learnt from the pandemic

The Covid-19 pandemic, as we have seen, triggered a process of innovation in universities, which, although it began in the early 2000s, had not been fully undertaken. This event of an exceptional nature forced universities around the world to redesign their didactics and the way they approach their students. Digitization, which was previously seen as a mere support to didactics, has now become an integral part of the latter, influencing its methods, impact and effectiveness. The need to change both their methodology and teaching-learning processes in order to use Information and Communication Technologies (ICTs) to allow students to receive (part or all of their) learning and training through digital resources and devices (aka e-Learning) has presented new challenges to higher education over the past few years, especially after the Covid-19 pandemic. This is meant not only from the standpoint of modernizing higher education but also from the standpoint of facilitating education through technology and teaching students' digital skills (a top priority according to the EU Digital Agenda). It is also significant from the standpoint of inclusivity and accessibility through a learner-centered approach. The potential that technology will create new inequities has been highlighted by this transition rather than being in any way addressed (exploitation by only some of the possibilities offered by the new ICT: winners and losers). Still, inclusion is important. Economic and social inequality was made worse by the pandemic, which was one of its repercussions.

New student groups, particularly those with personal disadvantages, impairments, or disabilities, seek education that is pertinent, timely, on-demand, and tailored to their particular needs. It is possible to notice a change in HEIs from traditional educational providers to more participatory, technologically advanced, and globally focused institutions for all of these reasons and more.

For HEIs to remain effective, they must be able to switch between online and in-person instruction with ease. HEIs were aware of the potential of e-learning as well as the workload and demands placed on the administrative, technical, and instructional staff, as well as the institutional resources and infrastructure, as they moved toward the adoption of e-learning. One aspect of the attempt to integrate e-learning more thoroughly inside the institution is the development of e-learning techniques.

The use of ICT in education should be rooted in the pedagogical-didactic domain, from which it derives a broader sense (educational models and theories) and the potential for ongoing repurposing (didactic aspects). Every educational setting has a "dynamic didactic becoming" that is implicit and never static or defined, but always open to the rich, compelling, but also unpredictability because every subject is undergoing constant flux.

This makes it feasible to situate the accomplishment of this process in a space made up of various dimensions that are intimately and reciprocally interrelate. Trentin[11] tries to pinpoint the unique traits of each dimension in order to present an integrated strategy for the sustainability of e-learning.

- Economic dimension refers to aspects linked to the optimisation of the resources involved, from those of development, to those of operation, to those of subsequent investments
- organisational-managerial dimension of the system refers to the creation of organisational conditions for a real integration of e-learning methodologies in the working practices of the organisation in order to institutionalise them
- professional dimension concerns the identification of the key figures necessary for the management, design, development and delivery of e-learning interventions, as well as the methods for their training
- socio-cultural dimension refers to the social and cultural changes necessary for a wide dissemination of e-learning methods
- content dimension concerns both the quality of the contents conveyed and their implementation, and the aspects linked to transportability, reusability and adaptability to contexts
- technological dimension relates to the aspects linked to the functionality and stability of an adequate technological infrastructure
- informal dimension concerns those processes in which the individual deals autonomously and in real time with his or her own cognitive needs, through the use of e-content, but above all through "networked" interaction within professional online communities of practice aimed at extending the processes of knowledge sharing.

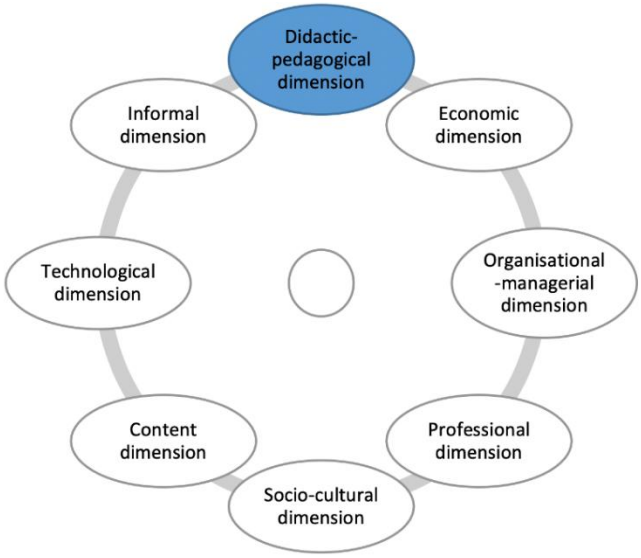


Figure 3. Dimensions of an integrated strategy for the sustainability of e-learning

[11] Trentin G., Un approccio multidimensionale alla sostenibilità dell'e-learning, in TD "Tecnologie Didattiche" N°40, 1, 2007, Ortona, pp.14-20. (2) Trentin G., Towards a real sustainability of e-learning. Proceedings of E-learning & sustainability, Fondazione ENI Enrico Mattei, Giune 2004

E-learning is not a new concept anymore. Before starting any kind of strategic planning, HEIs must develop a vision of the ideal end state. Documents that describe a company's strategy (current practice descriptions combined with ambition and vision statements) are crucial because they provide insight into both the institution's intentions and its deliberations as well as the 'real' strategic processes, developments, and activities that are being addressed (how this would or might be achieved, in a task-oriented style).

The successful strategy is to locate relatively low-risk niche markets where the technology may be comprehended and nurtured and where failures will occur sooner and at a lower cost[12]. As shown in Figure 4, an e-learning strategy must take into account the following institutional roles in terms of their potential for e-learning:

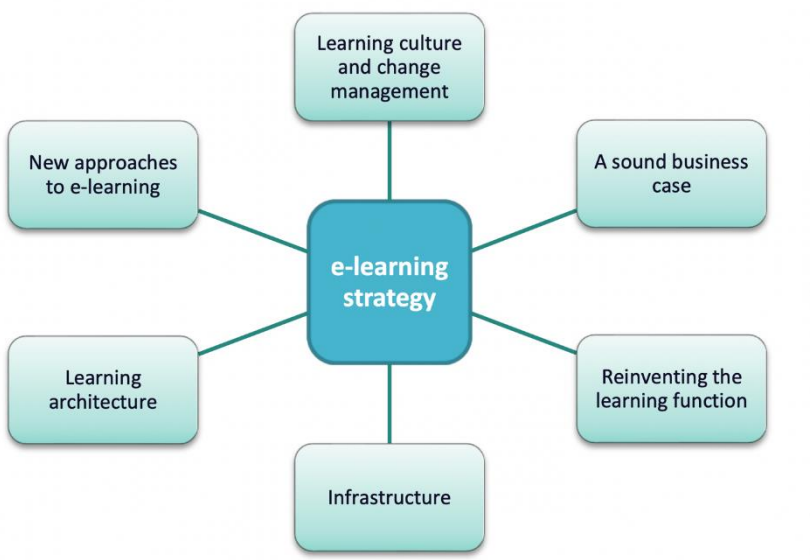


Figure 4. Institutional roles in an e-learning strategy

With the creation of a separate technical unit in charge of e-learning centers and the employment of qualified personnel, it is vital to encourage and support the development and execution of strategies.

The capacity to collaborate in groups is a crucial component of the shift to 21st century skills. The collaborative learning environment challenges students to express and defend their positions and generate their own ideas based on reflection, according to a 2015 report from UNESCO. The organization also makes a clear connection between the emergence of new digital innovations and innovative forms of collaboration, noting that with the development of new ICTs innovative forms of collaboration are also emerging[13]. Recent research demonstrates that using response technology

12 Garrison, D. R., & Anderson, T. (2003). E-Learning in the 21st century: A framework for research and practice. London: Routledge/Falmer. doi:10.4324/9780203166093

13 Scott, Cynthia Luna (2015): The futures of learning 3: What kind of pedagogies for the 21st Century?" UNESCO series Education Research and Foresight. Working papers. http://unesdoc.unesco.org/images/0024/002431/243126e.pdf

encourages greater classroom involvement and communication, adding even greater value for technologies promoting collaborative learning environments.

In this context it is definitely worth mentioning the European project SMARTEL which overarching goal is to enhance instruction at higher education institutions in the so-defined Region 1 (Kosovo, as defined by UN Resolution 1244, Montenegro, and Bosnia and Herzegovina), with a focus on making quality instruction more accessible to students who, for legitimate reasons, are unable to participate in regular HEI teaching activities. The project's objective is to promote equity for students with a) disabilities; b) economic obstacles, such as low income and reliance on the social welfare system; and c) geographical obstacles, such as those from remote or rural areas, small islands, or outlying areas; by utilizing contemporary ICT technology and pedagogical approaches.

Project SMARTEL's anticipated outcomes include:

- the use of contemporary distance learning systems
- e-content development for multimedia platforms
- creating new pedagogical approaches that define the use of ICT in education, educating teaching and technical staff, outfitting distant and central office classrooms with cutting-edge ICT equipment for teaching (smart classroom).

The goal of project SMARTEL is to locate and evaluate the designs of current smart labs and distance learning platforms at higher education institutions in the partner and program countries.

Special consideration is given to applications that assist vulnerable groups (those with disabilities and those who face financial and geographic challenges) in attending lectures in a way that is suitable for them.

Although e-learning options have increased, the adaptation to the educational requirements of children with special needs is still subpar. To suit the needs of both students and teachers for simple access and high-quality engagement with the learning materials, e-learning solutions should be created or chosen.

Despite the instructor gives their relationship meaning, the learner represents the initial categorical element of the educational learning process in the educational setting. Every didactic action is supported on otherness since the instructor and student interact in a relational environment. On the other hand, learning can still occur without a teacher thanks to technology, tools, formal and informal resources, as well as other people's information that has been made sufficiently accessible. These factors can help us put the student at the center of all didactic acts. Additionally, new technologies simply offer different teaching environments and tools.

As was already said, the higher education industry is likewise going through a digital transformation (DT) process that has the potential to fundamentally alter the way that business is done today. Organizational challenges may result from the tensions brought on by the implementation of new technology, the growth of new talents, the optimum use of current resources, the creation of new ones, and the targeting of new consumer segments.

A thorough analysis of the impact of DT on the educational industry business model was addressed by the article 'Digital Transformation for Business Model Innovation in Higher Education: Overcoming the Tensions'. The paper investigates the main tensions arising from the process for each of the model dimensions, the expected solutions and a visualization of how the current model is expected to be innovated. All these considerations will be addressed in the following paragraphs.

2.3.1 Implementation of an innovative education: the need of a new business model

The introduction of digital technology, which has drastically altered how processes and activities are managed, has been the key driver of the change made in university Business Models. In fact, the digital transformation is about more than just the creation and transmission of data—also it is about their analysis to produce knowledge that can be used for the organization's strategic decisions. When digital starts to have an impact on universities' business models, it means that it is no longer only a tool for supporting ancillary operations but rather a source of additional value. It indicates that the potential it offers is now better understood and that it is no longer only a chance to free up time from monotonous analog job.

The adoption of new technologies is inevitable, even in universities. The real problem is effectively implementing the many digital plans and strategies while involving and empowering teachers, staff, and students. For HEIs to continue to be relevant and helpful as an institution, they must take a significant leadership position in assisting in the shaping of new socio-technological realities. Therefore, rather than adopting a technology-driven mentality, higher education institutions should manage the new problems and accompany tensions.

2.3.2 Digital transformation business model innovation's tensions and solutions

As shown in Table 2, the DT-related conflicts and potential solutions can be grouped by the business model dimension.

BMI DIMENSION: Value Creation Innovation	
Tensions	Solutions
• Build new digital capabilities related to new technologies • Process and structure changes: cost and resistance • Lack of clear and standardized processes and protocols regarding the management of digital technologies • A "24-h-accessibility" syndrome (e.g., working from home) • Lack of "doing it all digital mentality" • New partners for new relationship	• Continuous training in new digital capabilities and making participation easy and relevant • Communicate the benefits of digitalization, coaching, and establishing referents • Maintain investments in digital technologies to improve the user experience and facilitate adoption • Develop a technological model to establish guidelines, norms and a concise activities plan

	• Self-impose clear frameworks to manage working and personal areas • Develop a partnership and collaborative mentality
BMI DIMENSION: Value Proposition Innovation	
Tensions	Solutions
• Uncertainty about new offerings, due to evolving students' preferences • Technical and service limitations to expand the offering (e.g., student authentication, scattered database, and so on) • Self-limited regional focus due to traditional offering • User infoxication and spamming • Lack of definition of a clear and global social media strategy due to too much decentralization	• Benchmarking international top referents • Doing pilots to experiment with new offering types to expand the offering (e.g., blended virtual) • Develop a customer- centric mentality to design an attractive offering and experience • Technology investments and new organizational models • Individualized and micro-segmented relevant information and resources • Ask for support from social media experts to develop the centralized strategy establishing clear guidelines and rules, and developing user capabilities to execute the decentralization
BMI DIMENSION: Value Capture Innovation	
Tensions	Solutions
• Reduction of old sources of revenues • Difficult capture of new sources of revenues • Face global competition • "Free" business model • Cost escalation and technological dependence • Reduction of old sources of costs	• Develop new offering types to increase the attractiveness (e.g., virtual) • Develop new promotional strategies to reach international markets • Establish a clear technological model, prioritizing technology decisions, monitoring, and automating as much as possible. • Cost savings through service digitalization

Table 2. BMI dimensions

The primary conflict in the value creation dimension relates to how new tools and equipment, procedures, partnerships, and capabilities that have undergone digital transformation coexist with more established ones. Major tensions like inertia, resistance to change, and frustration are brought on by old organizational dynamics at odds with new ones. The primary means of resolving these

conflicts is ongoing user experience and adoption improvement initiatives, as well as communicating the advantages and benefits of new capabilities.

In terms of the value proposition, the key conflicts are around how to make the new educational offer appealing by focusing on a student who is becoming more globally oriented and who is gradually adjusting his preferences. Being more customer-centric, open to diverse models, and willing to continuously investigate, experiment, and invest in various pilot projects are the major solutions. These actions also help to increase the amount of data used in decision-making processes. The biggest challenges in value proposition are to students and their interest in the academic programs offered by institutions. The speed of change varies greatly between universities and students. Students who are five years apart have grown up in quite different circumstances and have different expectations, prior knowledge, and requirements. According to studies, the younger generations are becoming more globalized, socially conscious, aware of current events, and ambitious.

Third, with relation to the value capture dimension, DT is not now producing any noticeable tensions in income production. Diversifying revenue streams by focusing on new consumer segments is one potential fix. The "make or purchase" choice and its repercussions are the main source of cost-related conflict, and digitization is the answer to make the process more effective.

Due to the necessity of coexisting new technical paradigms and traditional ones, the primary activities of the model are where the biggest tensions arise. Breaking established habits in an organization is a difficult task, therefore it's important to train staff to show them how to use the new tools and, more importantly, why doing so makes sense, such as by highlighting the advantages they have for didactics.

The core management operations of the traditional movement will undergo radical digitization, similar to the instructional activities, at both the administrative and decision-making levels with the introduction of analytical tools to support the organization in strategic decisions.

2.3.3 A hypothetical business model for digital transformation in HEIs

The elements of the company model where the greatest changes are anticipated include new client groups, new capabilities, new customer interactions, and new processes and structures, according to questions regarding the future vision of change brought on by digital. The revenue model, which will continue to be strongly related to tuition fees, research, and technology transfer, is at the other extreme and will be the least affected (an example of an imagined business model canvas is shown in Figure 5).

The most significant innovations in terms of the value proposition relate to the delivery methods for didactics, which call for a hybrid model that combines in-person and online lectures to gradually enter the market. Additionally, it will be feasible to offer new educational models that can satisfy both students who seek to further their knowledge with specific interests as well as the growing demand of businesses for resources that are more in line with the demands of the working world. New digital resources have the ability to reach students all around the world in terms of customer

segmentation. Particular focus will be given to emerging student populations from developing nations, who are increasingly choosing to pursue their education through MOOC-style courses, as noted above, or to working students who have various needs that cannot be satisfied by the current traditional paradigm.

Not to be overlooked are the conventional students, who make up the current core business and require even more care in order to avoid the possibility of cannibalization in the event that new services and offers are introduced. The configuration of important tasks and assets takes into account the new value proposition. To assure both kinds of delivery, the traditional model's basic operations will always shift in accordance with a hybrid model (online and presence). To enhance what will be suggested once more gradually, improved research and data analysis capabilities (big data, AI, IoT) will be used.

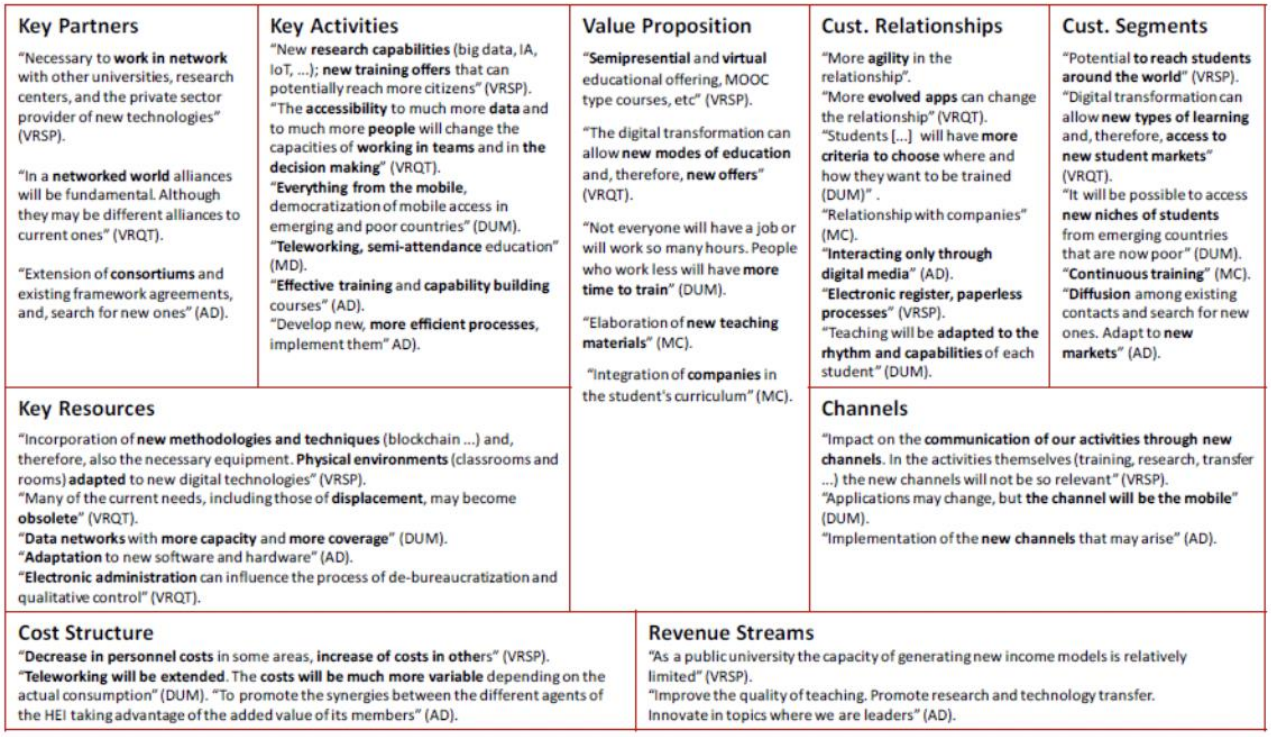


Figure 5. BM canvas for education institutions

3 The case of the Politecnico di Torino: from the choices made during the pandemic towards innovative didactics

Since February 2020, the Politecnico di Torino has required to completely restructure its organizational structure, much as every other university in the globe. It immediately established a virtual infrastructure so that all activities, especially didactics, which could not stop for an extended period of time, could be quickly resumed. A blended form of instruction was implemented after a semester in which all instruction was conducted remotely. Even at the Politecnico, it has evolved the notion that the optimum approach is hybrid didactics, which integrates face-to-face lectures and online learning. Additionally, it should be highlighted that the university was one of the few to

implement distant didactics using tools based on in-house technology competence rather than relying on third-party Cloud providers. Even at the Politecnico di Torino, where tensions and inertia are present in connection to these changes, as in other realities, there are tendencies to give innovation and digitalization the proper amount of attention. Therefore, let's take a look at the most significant strategic choices made by the Politecnico that further the ideas in this thesis.

'Horizon Europe' (HEU), the European Framework Programme for Research and Innovation for the years 2021–2027, defines the Sustainable Development Goals, which the university first works to achieve. By improving the caliber of university technology transfer, a path that has already been taken and will be strengthened, relationships with local reality and particularly with businesses, will be maintained. In this context, the university's licensing and intellectual property activities as well as support for researchers and the I3P incubator will also be boosted.

A Learning Center and the Teaching and Language Laboratory (TLLab) have been established to systematize and disseminate excellent teaching approaches, based on the university's knowledge and prior experience, on the teaching side because it has been recognized how important teachers are. Another goal of the TLLab is to establish a network of professors who can spread innovative teaching techniques. The Politecnico promotes the testing of novel pedagogic techniques, as long as they are properly grounded in the teacher-student connection. This does not include approaches like MOOCs, where group projects, workshops, and visits are preferable supplements to face-to-face lectures. The flipped classroom, or mixed didactics approaches that involve students more with homework and classwork, is one experiment that is now being conducted.

On a financial level, the goals are to raise three times as much venture capital as in the past and to expand the self-financing capacity by at least 50%. The University Research Centre and the Planning, Development, Quality and Life Area (PSQL) have been subsequently established. These two organizations have the responsibility of analyzing the volume of data gathered internally at the Politecnico to track the effectiveness of lecturers and students.

Furthermore, on the occasion of the launch of the 'Second Didactics Week', the TLlab - Teaching and Language Lab building was inaugurated; this is a physical space designed to allow those involved in didactics to meet, exchange ideas, experiment and learn. The spaces and fittings of the two-storey building are designed to allow the simulation of new forms of didactics and new methodologies to be transferred to the classroom and, according to the rector Guido Saracco, "The project aims to grow the idea of an academic community open to experimentation and pathways that increasingly place the student at the center of teaching, ensuring equity, inclusion, interculturality, and the development of critical thinking and creativity".

According to the "Mid-term evaluation and updating of strategic directions" document created by the rectoral mid-term review in 2021, one strategy that needs to be implemented right away is to look analytically back at the pandemic period that was experienced and determine which of the many changes that were made were forced experiments that will be abandoned, and instead which changes introduced proved to be effective, perhaps even more so than the previous ones. The

second section of this work is a first step in this direction. The educational programs offered by the university are in fact continually reviewed and changed to achieve the best results.
To comprehend how the didactics provided during total lockdown and the mixed didactics introduced later worked, data from the pre- and post-pandemic years on students, lecturers, degree courses, CPD questionnaires, and more are crucial. The following section includes all the statistical analyses and evidence uncovered over the course of months of research in partnership with the Politecnico di Torino, with the goal to provide support for these claims.

4 Data analysis

This chapter will analyse the workflow that led to this thesis: first an introduction of the databases used for the analysis, presenting all the variables and the considerations made; and then an in-depth focus on the conducted study with its resulting evidence. The first analyses carried out are related to the *students database*, while subsequently two strands of analysis were tackled on the *courses, teachers and CPD database*, one focused on teachings while the other on data collected from CPD questionnaires.

4.1 Methodological approach

The main idea behind this work is the conceptual analogy between the university model and a manufacturing process. According to this reasoning, the student is thus seen as a raw input who, after undergoing some processing (i.e., attending certain courses taught by as many lecturers), comes out with new skills learned.

This process is naturally influenced by external factors, resulting in changes not only in students but also in teachers. The pandemic that broke out in the early 2020s is one such example. The objective of this part of the work is therefore to investigate how students and teachers have reacted to this pandemic and what changes have occurred with respect to traditional teaching, trying to identify possible correlations and causes. The ultimate goal would be to develop a new model of teaching that considers the evidence found.

It is worth highlighting that the methodology adopted in this work has involved the analysis of data from the entire population of Politecnico di Torino, regarding both students and lecturers, and not just a sample. The whole analysis has been carried out from three different but related perspectives, which correspond to the three raw databases obtained from the data collected internally within the Politecnico di Torino: students, teachers, and courses.

The considered timeframe goes from the A.Y. 2015/2016 to the A.Y. 2020/2021.

4.2 Data gathered

4.2.1 Students database

The first database considered for the analyses is the one with students' variables, where every row represents a student in a given academic year. The database fields consist of both descriptive (i.e.,

age, gender, etc.) and educational performance variables (i.e., average of exam grades, credits exceeded, etc.). The same student may appear repeatedly, keeping the same descriptive variables but having variations in the academic year and the related performance variables.

For clarity, all the variables of the databases are listed below.

VARIABLE NAME
matricola
anno accademico
coorte
CONTA ANNI
Genere
data di nascita
età
regione residenza
stato residenza
stato cittadinanza
fuori sede
straniero
tipo corso
NOME_CDS
cds_EN
ing-archi
anni di carriera
ISPE
ISEE
ISEEU
ASP
tipo mobilità
challenge
media esami
cred superati
indicatore performance

Table 3. Variables of the students database

To have comparable data in the analyses, the original database was cleaned in order to ignore outside prescribed time students, thus considering only those who attended the Politecnico for the three whole years or less. Moreover, only records with an average of exam grades other than 0 and a number of exceeded credits between 6 and 80 (respectively the minimum and the maximum number possibly included when compiling the student career plan) were used, so as to eliminate outliers that could litter the analysis.

The study considers two cohorts - the term refers to the year of enrolment- of students who did not experience the pandemic (2015 and 2016) and one whose students instead saw their academic

career half impacted by distance learning, in order to compare them and investigate eventual differences. The cohort 2017 was not included because it does not present a homogenous partition of academic periods characterized by traditional face-to-face teaching and remote or blended delivery mode (for the 2018 cohort there are three teaching periods each).

Finally, the focus of the analyses was in all cases limited to the bachelor-level degree paths in engineering, therefore excluding master's degrees and the architecture major. As a matter of fact, there are no master's degree pathway that present a cohort impacted by the pandemic (i.e., the 2018 cohort) that has a homogeneous breakdown of academic periods characterized by classical and remote or blended teaching.

The cleaned database counts 32647 records (10863 for 2015 cohort, 10589 for 2016 cohort, 11058 for 2018 cohort).

It is worth noting that there is an inconsistency in the database for the data recorded under the *cohort* heading since each actually corresponds to the previous year. In clearer terms, the value 2017 refers to students matriculated in the academic year 2016/2017, a year corresponding instead to the 2016 cohort as matriculations occurred in September/October 2016. This incongruence had been corrected in all the figures and tables reported, hence all the results are written correctly.

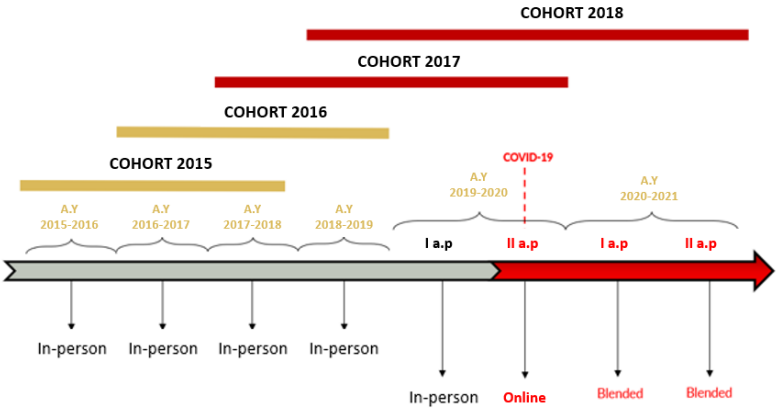


Figure 6 – Time framework and cohorts considered for the analysis

4.2.2 Teachers and courses database

Looking to the other side of the coin, there are other two databases, one for the lecturers and another for the courses. In the former every record represents a faculty member of the Politecnico di Torino with a set of descriptive variables, while in the latter each rows represents a course taught by a specific faculty member in a given academic year. The fields in this database are variables that uniquely distinguish a teaching, such as the degree program of belonging or the number of CFU to which it corresponds.

A single database has been then constructed that cross-references the last two so that all the necessary information is in one source, the *courses and lecturers database.* In this DB, every row represents a teaching in a given academic year, unambiguously identified by the pair of variables

"COD_INS" and "ID_DOC_TITOLARE," which are respectively the code that denoted the course and the identification code of the teacher who owns it. Regarding the columns, on the other hand, the variables related to the course are presented in the first part of the DB, while all those related to the teacher are in the second part.

For clarity, all the variables included in the final structured database are listed below.

VARIABLE NAME
COD_INS
ID_INCARICO
A.A.
ing-archi
TIPO CORSO
CDS
NOME INCARICO
CFU
Voto medio
Numerosità classe
Anno incarico
Periodo didattico
Scelta
LINGUA
Lingua straniera
NUM_BLOCCHI_SETTIMANALI_DA_1,5_ORE
NUM_BLOCCHI_SETTIMANALI_DA_3_ORE
NUM_BLOCCHI_SETTIMANALI_DA_4,5_ORE
NUM_BLOCCHI_SETTIMANALI_DA_6_ORE
AL
EA
EL
ES
LRV
VC
VE
VG
VL
%E
ID_DOC_TITOLARE
Docente Dipartimento
DATA_NASCITA
Età
DESC_QUALIFICA
Genere
TipologiaDocTitolare
ORE_INCARICO_TOT2

ORE_INCARICO_DOCENTE_TIT
PERC_ORE
DESC_TIPO_ATTRIBUZIONE
N° lezioni online
Presenza media studenti
lezioni preregistrate

Table 4. Variables in the courses and teachers database

With the aim of seeking some trends in the variables characterizing the analysed teaching, the original database was cleaned in order to consider exclusively the courses that have been held every year (form a.y. 2015/2016 to a.y.2020/2021) and that always keep the same teacher. This results only in courses with six records all with the same teacher ID or a total of 297 teaching-teacher pairs (1782 records).

4.2.3 Data from CPD questionnaire

In addition to the three, there is one more data collection that has been requested to the IT Department and it gathers information on the CPD questionnaires submitted from A.Y. 2015/2016 to A.Y. 2020/2021. CPD stands for *Comitato Peripatetico per la Didattica,* and it is a joint faculty-student committee that aims to cooperate in improving the services provided to students. Among its main activities there are monitoring initiatives on teaching, such as deliver a questionnaire to students and faculty on the quality of teaching at the end of the course. Surveys to students are anonymous and questions are grouped in different sections: organization of the teaching period, organization of teaching, teacher effectiveness, infrastructure, interest and satisfaction, employee effectiveness. There are four possible answers: "definitely No," "more No than Yes," "more Yes than No," and "definitely Yes". Faculty member questionnaires are delivered with similar structure.

However, the questionnaires differed in the various academic years because of the changed conditions of teaching due to the spread of Covid-19. Specific questions designed to assess mode, organization and other aspects were in fact included to be coherent with the new teaching experience occurred during the emergency period.

From the answers to those questionnaires, two main metrics were extracted: the satisfaction rate and the satisfaction index, both calculated for courses and lecturers. These indicators are useful to diagnose the quality of teaching and teacher effectiveness and their calculation differs as it is showed in Table 5.

SATISFACTION RATE	SATISFACTION INDEX
Course rate= $\frac{\sum_{i=D(1)}^{n} satisfaction\ rate_i}{n}$ where $satisfation\ rate_i = \frac{R(3)+R(4)}{R(1)+R(2)+R(3)+R(4)}$	Course Index = $\frac{\sum_{i=D(1)}^{n} Index_i}{n}$ where $Index_i = \frac{1*R(1)+2*R(2)+3*R(3)+4*R(4)}{R(1)+R(2)+R(3)+R(4)}$
Where R(i) = *#Answer*$_i$ where i = D(1), D(2), … , D(n) where n = *#questions*	
Teacher rate= $\frac{\sum_{i=D(9)}^{n} satisfaction\ rate_i}{n}$ where $satisfation\ rate_i = \frac{R(3)+R(4)}{R(1)+R(2)+R(3)+R(4)}$	Teacher Index = $\frac{\sum_{i=D(1)}^{n} Index_i}{n}$ where $Index_i = \frac{1*R(1)+2*R(2)+3*R(3)+4*R(4)}{R(1)+R(2)+R(3)+R(4)}$
where i = D(9), D(10), D(11), D(12), D(13) where n = 5	

Table 5. Satisfaction rate and index

In words, the satisfaction rate shown in the table above represents the impact of positive responses ("definitely Yes," "more Yes than No") on the total answers received to a given question. The satisfaction rate for the course is the average of the rates calculated to all responses in the questionnaire, while the one for the teacher is the average of rates calculated only for those responses reflecting the lecturer's effectiveness (D9, D10, D11, D12 and D13). The satisfaction rates, instead, express a weighted average on a scale of 1 to 4.
These indicators will have to be observed carefully as they allow to codify the qualitative data taken from the CPD questions.

The datasets containing the answers to the student and faculty questionnaires were processed in order to enter the information into the *courses and lecturer database* and join the data in one source. Here each row contains descriptive information about a given teaching, the associated teacher, and all statistics that were extracted from the CPD Student and Lecturer questionnaires.

Ultimately, there are two main databases: the *students database* and the *courses, teachers and CPD database.*

4.3 The students' point of view: analysis of grades and credits

The students' perspective allows to best discern the effects derived from the pandemic and the subsequent shift to online teaching, analysing the implications on their educational performance.

In the first meaningful analyses conducted, it was examined the average exam grades and the average number of credits exceeded by the students in each of the three academic years (a.y.) and for every cohort, with the aim of identifying, albeit in aggregate, whether there were any changes at the macro level between the cohort impacted by the Covid-19 pandemic and the two that were not.

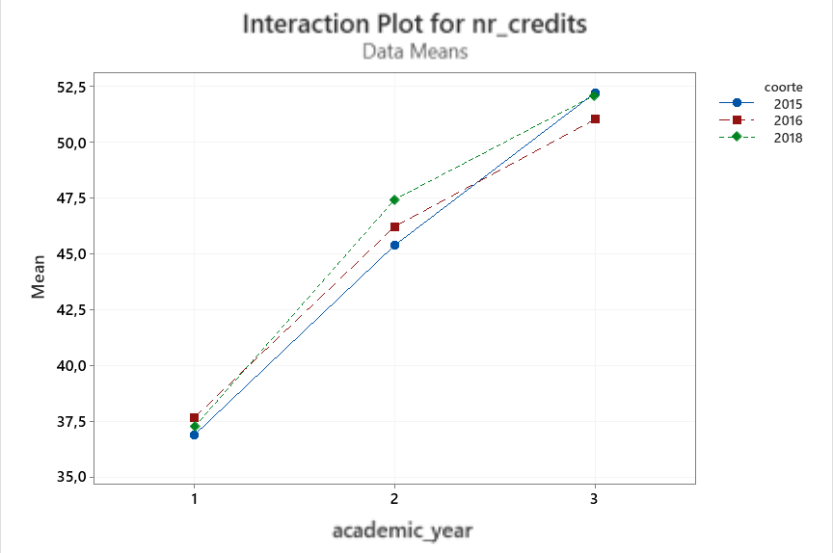


Figure 7. Credits exceeded by students over the three a.y.

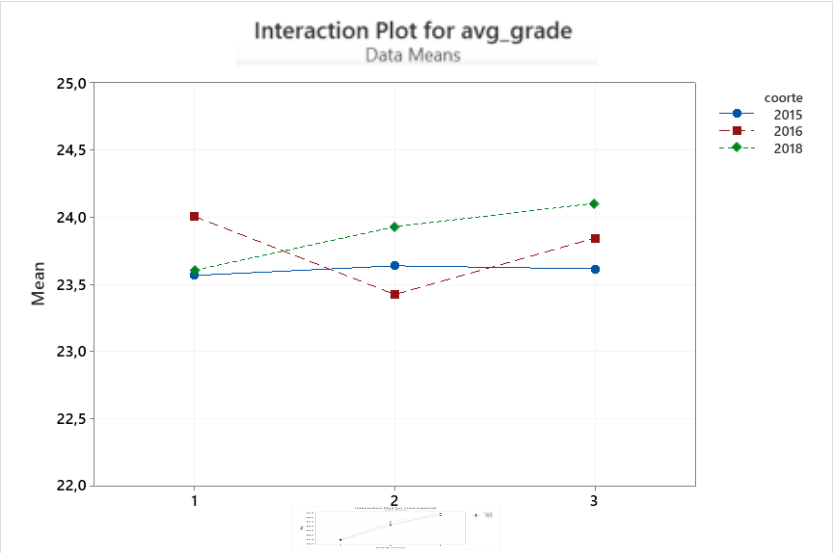


Figure 8 . Average grades of students over the three a.y.

The figures depicting the trends mentioned above demonstrate that, in the first year, the cohorts did have comparable grade point averages and credits earned. It is not a coincidence that in that year the pandemic did not had spread yet.

On the other hand, in the second and third years, it is clear that students in cohort 2018 obtained on average greater grades and exceeded more credits than their colleagues in the other two cohorts. The graphs show this evidence holds true especially when comparing cohort 2018 with cohort 2015.

Cohorts 2016 presents an anomalous trend in the students' average grades. Further investigations in the data revealed that cohort 2016 have been impacted by a change in educational offerings in

the second academic year, which could be a potential explanation for the sharp decline in that very year.

More considerations can be done by looking at the graphs, in order to explain the reasoning behind the analyses that follow.

Trends in the average grades and credits are usually linked. Generalizing, basing on which type of students – if well or low performing – increase the number of credits they passed, it can be expected his or her average grade will respectively rise or drop. The graphs showing the exceeded credits depict curves that shared an increasing trend. On the other hand, the average grades present great differences and the reasons could be numerous.

To go deeper and investigate this consideration, further analyses have been conducted, firstly differentiating Italian and English students and then considering the percentiles. The aim is in fact to understand what influences those trends, whether is the students' own characteristics or other external factors, such as the variation in the educational syllabus, which had probably changed the distribution of credits among subjects, and the online teaching due to the pandemic.

4.3.1 Comparison between students from Italian and English teachings

As said, for the first block of analysis, the data have been divided in two groups with the goal of separating students of Italian courses from the ones who instead attended courses taught in English. The study considered students only from degree Programs with teaching exclusively in Italian or English, without including paths with courses in both languages.

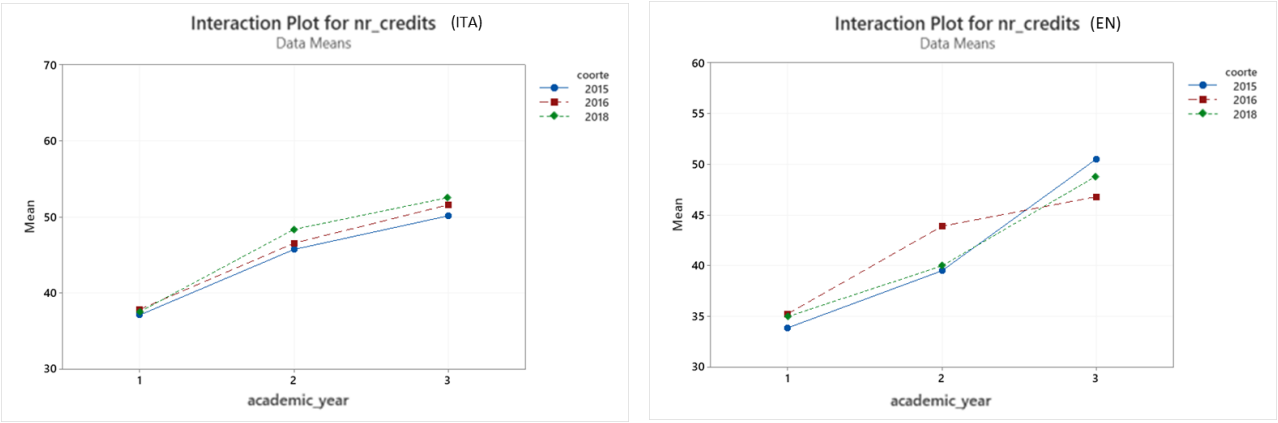


Figure 9. Credits exceeded by students over the three a.y.: ITA VS EN

Starting from a focus on the credits exceed by students, both Figures 9 and 10 confirm the unusual trend of 2018 cohort, which means are higher than the others over the entire three academic years. This result is more evident for the students of Italian teachings and in particular for the second year.

English courses appear to be the cause of the trend showed in the comprehensive graphs by the curves of cohorts 2015 and 2016 in third year. On the other hand, in fact, credits of 2018 cohort from the Italian group is constantly greater than the others.

As seen before at an aggregate level, for both Italian and English students, it is important to stress how the three cohorts showed similar means of credits in the first year, in which no one had experienced the Covid-19.

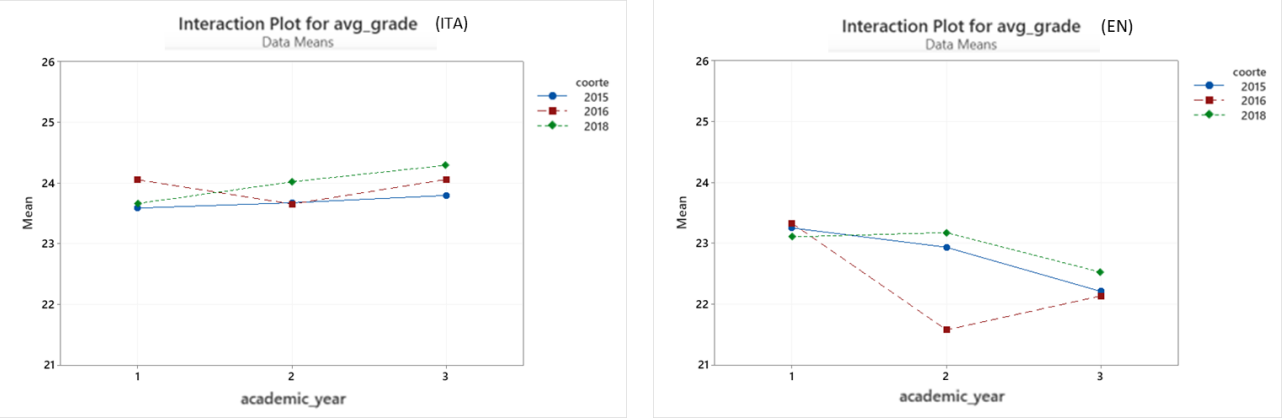


Figure 10. Average grades of students over the three a.y.: ITA VS EN

Regarding the average grade, the separation between Italian and English reveals how the anomalous behaviour of the 2016 cohort persists in both groups, indicating the change in the educational offer had impacted all the degree programs and more evidently the ones held in English.

Moreover, the increasing trend in the average grades is confirmed and evident in both groups.

In general, the effect in the performance appears to be greater for students from Italian courses. This result shown in the graph can be verified mathematically calculating the deltas between the years and distinguishing for the two languages, as it is reported in the table below comparing 2018 and 2015 cohorts.

	AVG GRADES		**CREDITS**	
	ITA	**EN**	**ITA**	**EN**
DELTA II ANNO	0,35	0,25	6,98	0,49
DELTA III ANNO	0,5	0,32	2,4	-1,6

Table 6. 2015 and 2018 cohorts' deltas of grades between the academic years

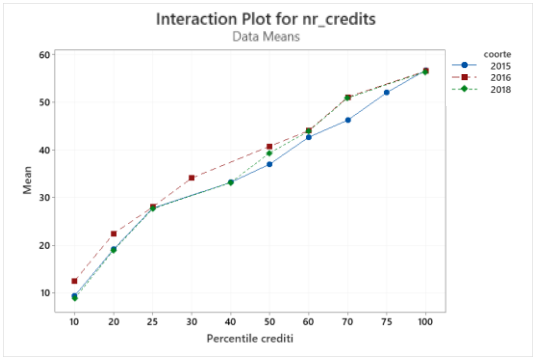
After having established the non-negligible change in the cohort 2018 students' performance, it is interesting to investigate whether students with different characteristics experienced various performance distortions. In this regard, it is essential to look at the percentiles and plot the distribution of students along the performance axis. The graphs that follow report the percentiles along the x-axis and the values of grade point average and number of credits passed along the y-axis. They are presented year by year in a sort of matrix that shows the average credits and the grades as columns, and the two distinct groups of Italian and English students as rows. The graphs should be interpreted as cumulative frequencies.

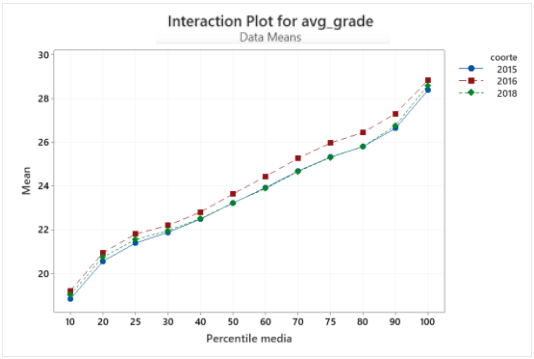
1ST YEAR

STUDENTS AVERAGE EXCEEDED CREDITS

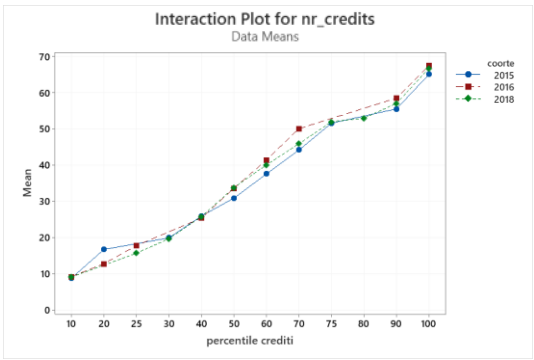
STUDENTS AVERAGE GRADES

ITALIAN





ENGLISH



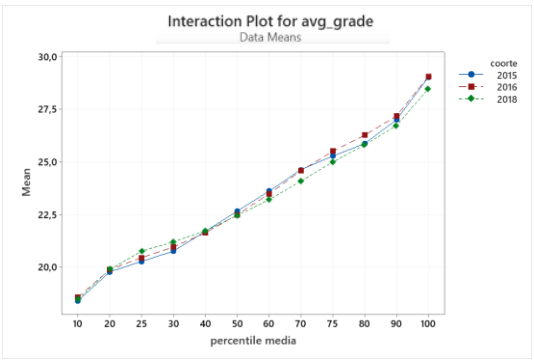


Figure 11 - credits and grades percentiles, 1st year

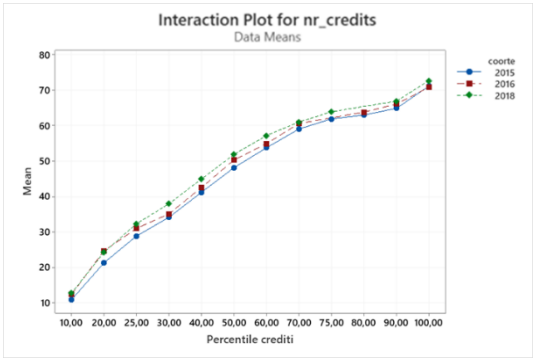
From the graphs of percentiles of first-year averages and credits, distinguishing between courses in English and in Italian, it remains well-established that prior to Covid-19 there are no trends with observable patterns when comparing the three cohorts.

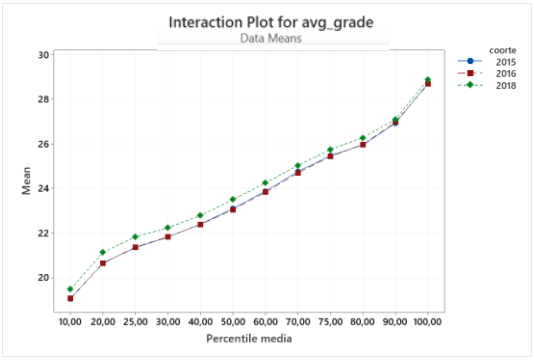
2ND YEAR

STUDENTS AVERAGE EXCEEDED CREDITS

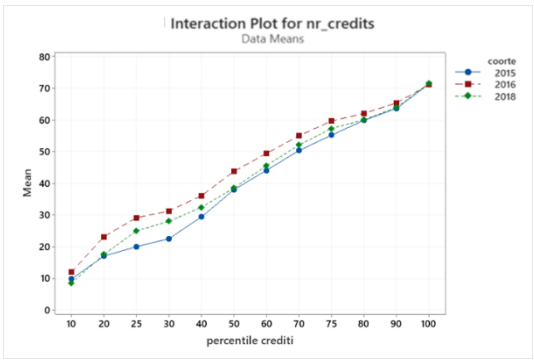
STUDENTS AVERAGE GRADES

ITALIAN





ENGLISH



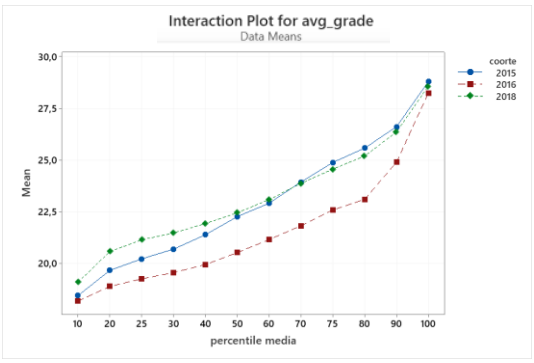


Figure 12. Credits and grades percentiles, 2nd year

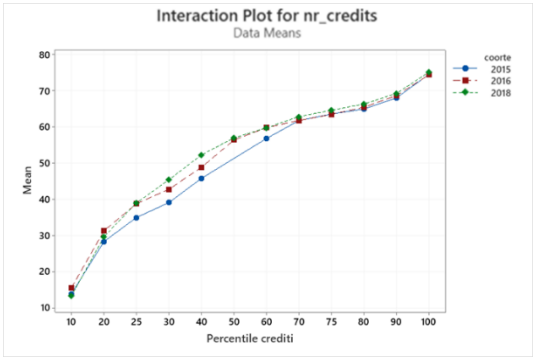
In the second year, looking at the credits percentiles, students who generally used to take a low number of credits had passed a higher number of exams in cohort 2018 compared to those in cohort 2015. This result is valid both for Italian and English teachings but is more evident for the latter.

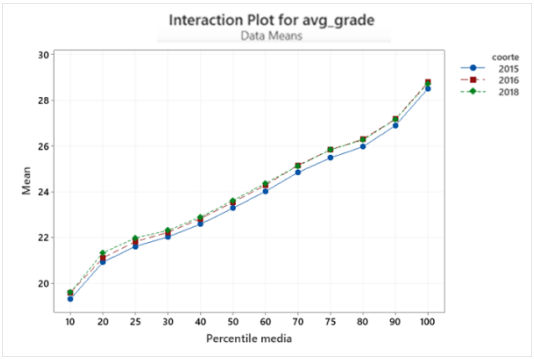
The grades percentiles instead show a different behaviour between the two groups. All the Italian students of the cohort 2018 received on average higher grades than their colleagues from the other cohorts. On the other hand, students of 2018 cohort from the English group present greater grades only in the first percentiles: at the 60th percentiles in fact, the curve intersects the 2015 cohort line.

3RD YEAR

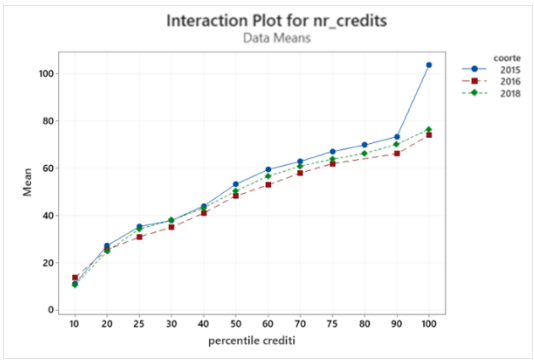
STUDENTS AVERAGE EXCEEDED CREDITS | STUDENTS AVERAGE GRADES

ITALIAN





ENGLISH



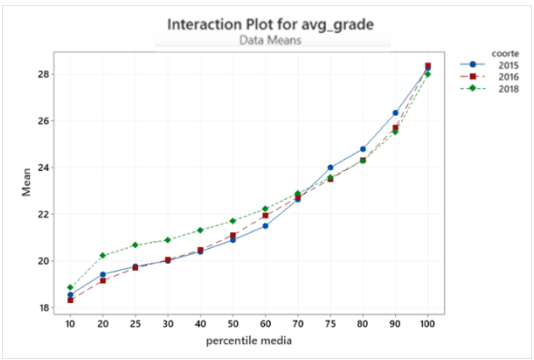


Figure 13. Credits and grades percentiles, 3rd year

Finally, looking at the third-year credits percentiles, Italian students confirm the previous results for the cohort 2018 while, in English group, students who usually get the most credits had decreased this performance.

Regarding the average grades, the means of 2018 cohort students from Italian teachings experienced a trend that is uniformly higher than the other cohorts. In contrast, English pupils have better averages grades only in the first percentiles, as occurred for the credits exceeded in the second year.

Combining all the results obtained and explained above, it is possible to state that the English group presented two different behaviours along the percentiles, indicating the presence of two possible populations of students who had reacted differently to distance learning: one of lower-performing students who passed more exams with higher grades, and a population of higher-performing students who instead during the third year passed fewer exams with lower grades.

To explain this distinction, a first assumption can be made observing that English courses are generally taken by Italian students who have great skills and high ambitions, and by international students who does not know Italian. The first group might in fact represents the well performing students in the last percentiles while a portion of the international students might be included in the first percentiles, possibly due to the different learning styles and methods they are used to.

On one hand, with distance learning, teaching methodologies have gained flexibility and a more universal language, generating benefits for foreign students. On the other, evaluation through online tests may have penalised the well-prepared students.

Up to now, the cohort 2016 have not been included in any consideration due to the variations in the educational syllabus that altered its results. However, if now we consider the 2015 cohort as a fixed reference in the graphs, it is interesting to look at how the other two curves move with respect to it, with a focus on the first percentiles. It is in fact possible to notice that when the lower-performing students from the cohort 2016 had passed more exams, this increase in the number of credits exceeded is translated into a decrease in the average grade, as it is usually expected. On the contrary, in 2018 cohort, more credits in the lower percentiles are followed by an increment in the average grade, suggesting that distance learning have had a significant impact.

This effect is more pronounced in English teachings where, in fact, the lowest-performing students have significantly improved both the credits passed and the obtained average grade.

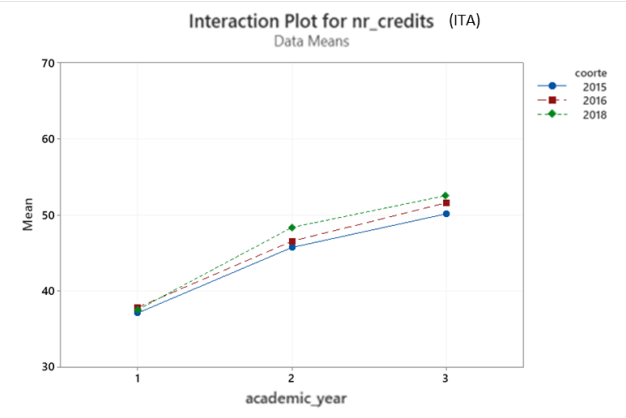
4.3.2 Analyses with the admission test (TIL) score

Each cohort is naturally composed of a heterogeneous set of students, and it is not certain that a group enrolled in a given year has on average the same characteristics as another from a different matriculation cohort. This reasoning led to consider each student TIL score and conduct further analyses.

TIL stands for *Test d'Ingresso onLine* and is the placement test prior to matriculation. From now the acronym will refer directly to the score obtained by the student and will be a parameter used to rank students and their attitudes to performance.

TIL data were not available for all the matricula, therefore, before to proceed it was necessary to check whether and how previous results change by removing all the students for which the corresponding TIL was not found. With this in mind, using the smaller data set mentioned, analyses were relaunched: results were not significantly altered, and the patterns and evidence previously found remained valid.

Filtering the database in order to keep only those students the TIL was available for, a considerable reduction has impacted the English group. This translates in analogous graphs for the average grades and credits of students from Italian teachings, while the results for English teachings show some differences, especially for credits in the third academic year where the mean for the cohort 2018 seems to be the lowest of the three.



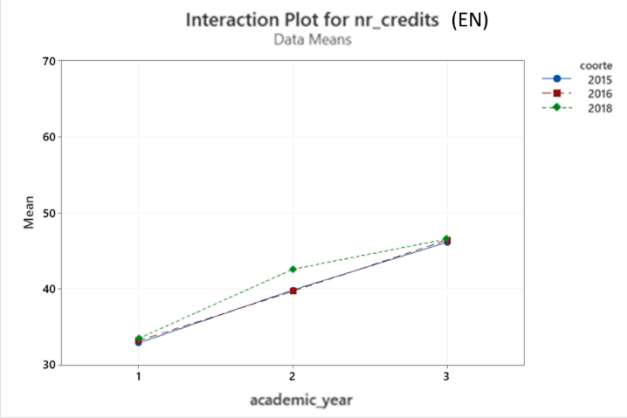
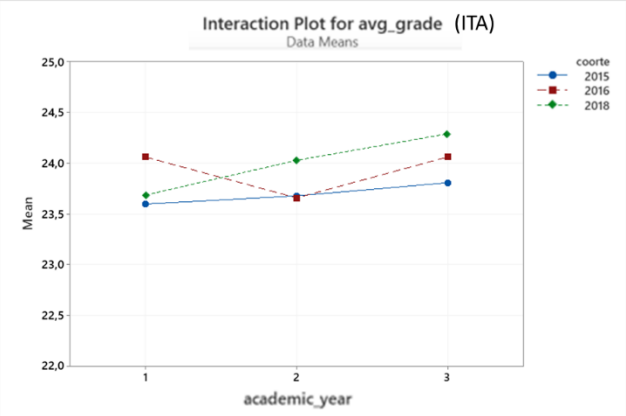


Figure 14. Credits exceeded by students with TIL over the three a.y.: ITA VS EN



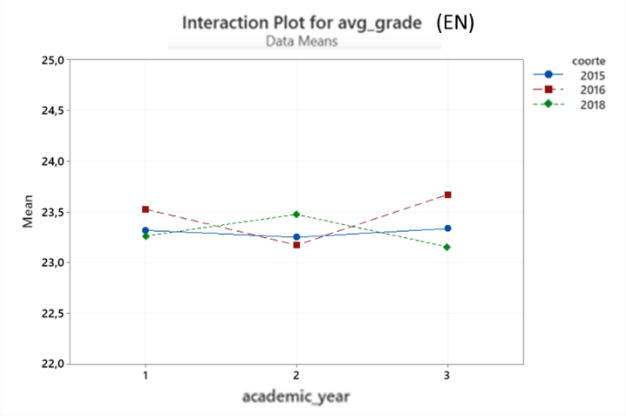


Figure 15. Average grade of students with TIL over the three a.y: ITA VS EN

In order to continue investigating the effect of students TIL over the average grades and credits, it is interesting to compute the average TIL for each cohort over the three academic years to see potential intrinsic differences between students from distinct years. A graphical representation of TIL trends over the academic periods is shown in figure 16, distinguishing between the three cohorts.

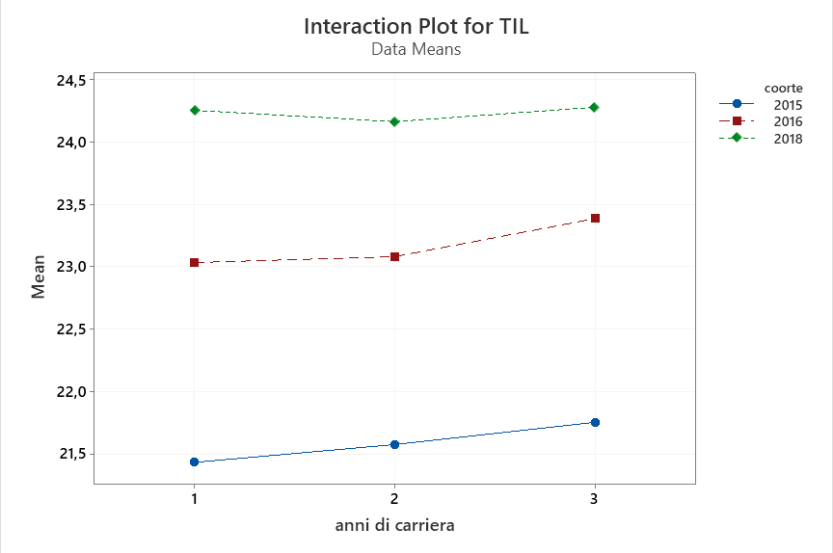


Figure 16. Average TIL of all the cohorts over the three a.y

It is noticeable that within the same cohort the average TIL slightly changes and in particular it increases. This trend is clear in all cohorts as it is a consequence of the "natural selection" process that characterizes all university courses. As the years pass in fact, some students drop out and on average they do not have a very high TIL score.

Apart from this consideration, what emerges from the graph is that every cohort show a higher average TIL compared to the previous one. The explanation is not to find in the difficulty of the test, which is comparable over all the years, but instead in the increasing selectivity of the enrolment process of the Politecnico di Torino. The limited number of accepted students has been in fact decreased over the recent years and this resulted in the need of the students to obtain a greater TIL in order to be able to join the Politecnico community.

It is worth mentioning that, given the great difference found between the average TIL of every cohort, means of grades and credits have been cleaned from the variance explained by the TIL. Using in fact the inverse of the regression equation, new values for average grades and credits have been computed and again subjected to descriptive analyses analogous to the ones conducted before. Although the TIL is significantly correlated with both grades and credits, it did not alter the results previously obtained using the more complete database.

Deeper investigating the TIL and its implications on students, it has been found out its influence on the performance decreases over the career. This result might be explained by the topics covered by the entrance test (mathematics and logic, chemistry, etc.): all connected with the subjects provided for the first academic year. As year pass, performances increase their dependency on technical skills acquired and experienced gained and the impact of TIL is reduced.

The decrease of TIL's impact on the students performance is particularly evident for the cohort 2018, as it is noticeable from the graphs presented in figures 17 and 18. Both figures depict the results from a generalized equation model, assuming within-student average grades across years are

equally correlated. Covariates for the models include student age, gender, nationality, admission test score and degree program language.

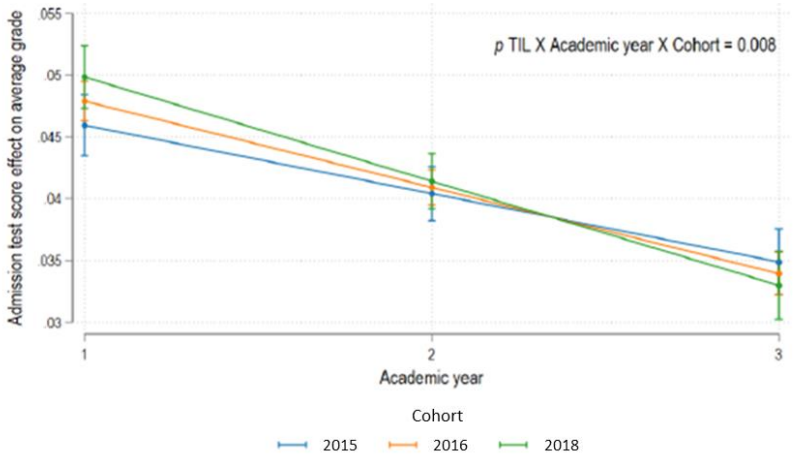


Figure 17. TIL effect on average grades linear prediction

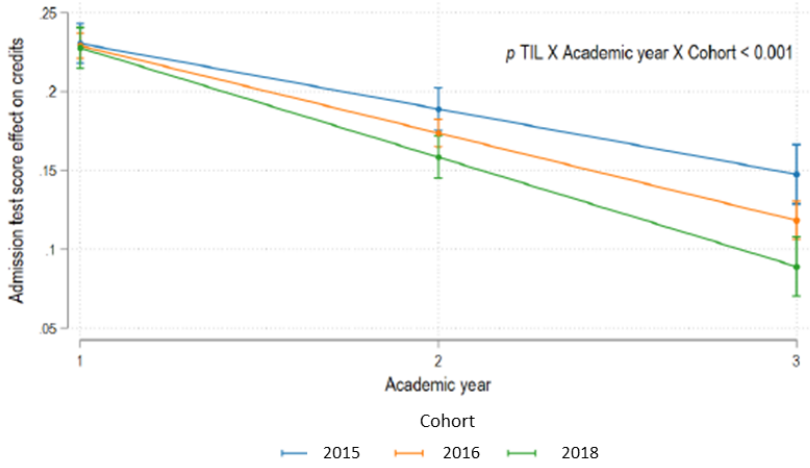


Figure 18. TIL effect on credits linear prediction

All the results reported so far as comment to the graphs have been confirmed with several linear regressions performed on Minitab. Response variables for the analyses were the average grades and the exceeded credits, and both final models were robust, presenting a R-square respectively of 97,53% and 96,65%. The differences observed between cohorts and over the academic years resulted in fact statistically significant, as well as the difference between average grades and credits of students from the Italian and English groups.

Regressions also showed evidence not in the regard of the pandemic but still interesting. Firs of all, students who attend teachings delivered in English receive on average lower grades than their colleagues from Italian programs. This result is also valid for the number of exceeded credits.

Going deeper in this consideration, the analyses revealed that foreign students on average show lower performances. In particular students from China are the ones who passed the lowest number

of credits with inferior grades, followed by the ones with American and Asian citizenship in terms of credits and grades respectively.

Term	Coef	P-value
Constant	18,8908	0,000
TIL	1,188	0,059
Interaction TIL-cohort	-0,000586	0,060
Cohort		
2016	0,22738	0,000
2018	0,3028	0,000
Language		
EN	-0,4684	0,000
Academic year		
2	0,00696	0,000
3	0,25364	0,000
Grades percentiles		
20	1,6382	0,000
25	2,3376	0,000
30	2,7648	0,000
40	3,3595	0,000
50	4,0848	0,000
60	4,8317	0,000
70	5,6595	0,000
75	6,3507	0,000
80	6,8394	0,000
90	7,7376	0,000
100	9,4000	0,000
Citizenship		
African	-0,0579	0,000
American	-0,1743	0,000
Asian	-0,1825	0,000
Chinese	-0,1029	0,000
European	-0,0760	0,000

R-sq	R-sq (adj)
97,53%	97,53%

Term	Coef	P-value
Constant	4,860	0,000
TIL	1,37	0,776
Interaction TIL-cohort	-0,00068	0,775
Cohort		
2016	1,8923	0,000
2018	2,091	0,000
Language		
EN	-5,0065	0,000
Academic year		
2	8,1781	0,000
3	12,3940	0,000
Credits percentiles		
20	11,8635	0,000
25	20,2294	0,000
30	24,384	0,000
40	28,9701	0,000
50	35,1102	0,000
60	40,0659	0,000
70	44,5617	0,000
75	47,8023	0,000
80	48,051	0,000
90	51,352	0,000
100	54,8576	0,000
Citizenship		
African	-0,743	0,017
American	-0,893	0,159
Asian	-0,071	0,739
Chinese	-1,087	0,000
European	0,160	0,595

R-sq	R-sq (adj)
96,66%	96,65%

Table 7. Linear regressions for students' grades and credits

The analyses then proceeded with the division of students according to their TIL score quartile. The first thing to say is that students' average grade is significantly and positively correlated with each quartile, meaning that no matter the cohort of belonging, students who obtained a higher score at the application test received later in their career higher grades as well as exceeded more credits. This is especially valid for the average grades of students that entered with a great TIL and are thus grouped in the fourth quartile. Moreover, those students are the only ones who have decreasing performance in terms of received grades over the three academic years.

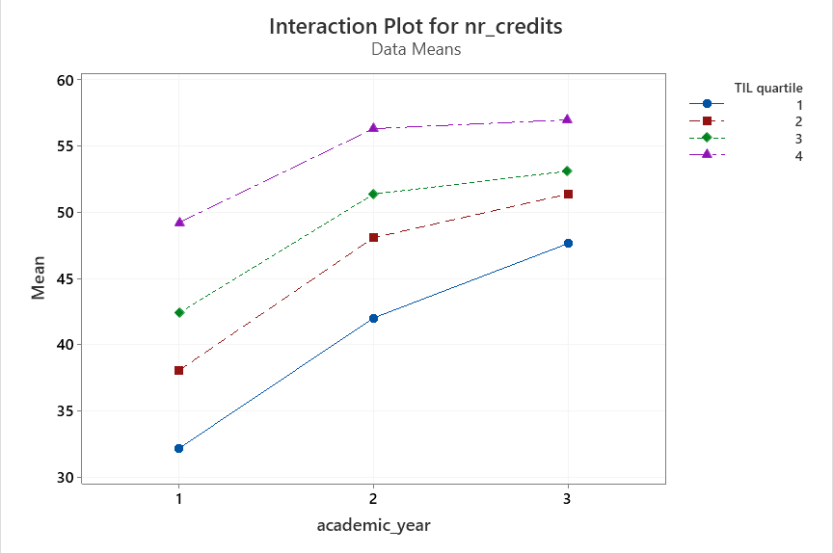


Figure 19. Credits exceeded by students over the three a.y.: comparison between TIL quartiles

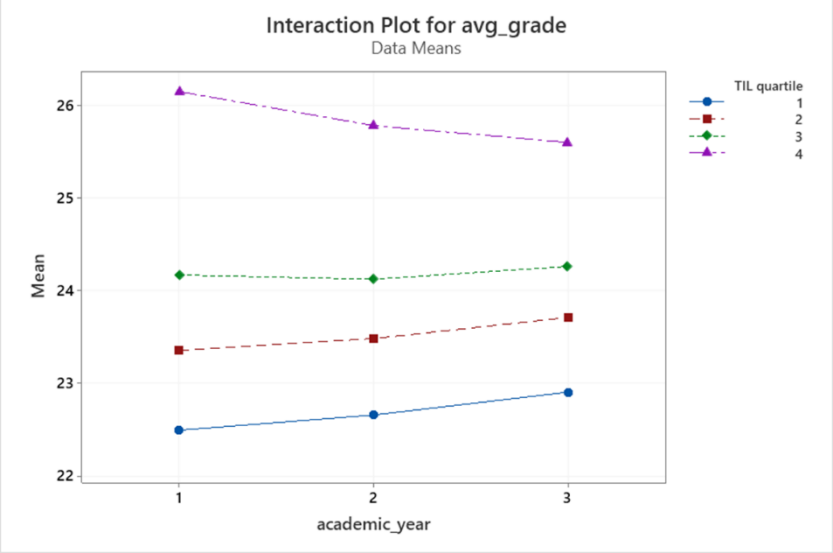


Figure 20. Average grades of students over the three a.y.: comparison between TIL quartiles

This last consideration about students characterized by a great TIL score, might suggests that the test correctly tags those who will have low and/or mediocre average grades while it "overrates" the well-performing students.

In relation to the pandemic, what this investigation highlighted is that students with lower TIL (1st quartile) benefited the most. This result is perfectly coherent with the previous finding if we consider those students are generally the same ones who do not achieve very high performances. This consideration is evident for both the average grades and credits, and it can be graphically observed in Figure 21 and 22.

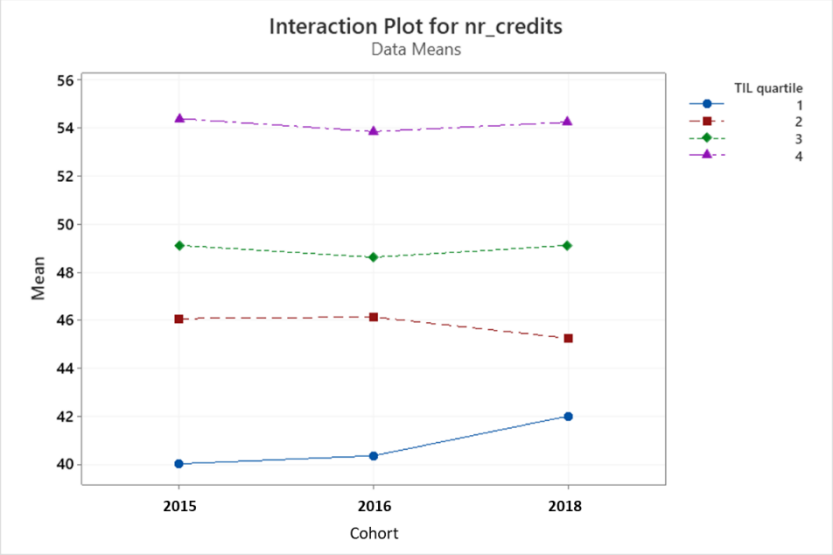


Figure 21. Credits exceeded by students over the three cohorts: comparison between TIL quartiles

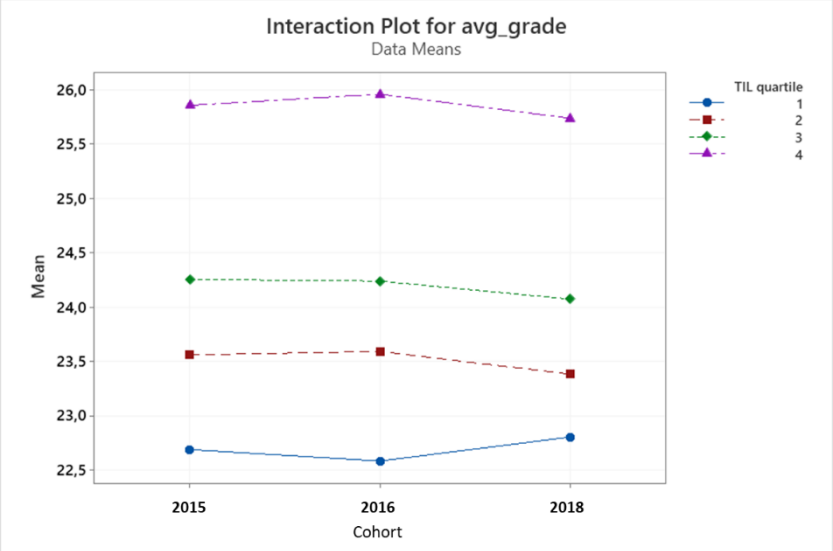


Figure 22. Average grades of students over the three cohorts: comparison between TIL quartiles

4.4 The teachers' point of view: analysis of students' evaluations

So far, the attention has been on how students' performance has changed in the recent years and how they are influenced by students' own descriptive variables. Now it is time to focus on the same output but looking from the lecturers' side. With the *courses, teachers and CPD database* -where each row corresponds to a teaching- is in fact possible to analyse the average evaluation a teacher gave to the students of his/her course in a given year, obtaining the dual variable of the one observed in the previous section.

The analyses considered exclusively courses that have been held every year (from a.y. 2015/2016 to a.y.2020/2021) and always have kept constant teacher. Moreover, for consistency with the

previous analyses and to present the other side of it, the focus was at first limited to the bachelor-level degree paths in engineering.

The graph in Figure 23 presents the trend of the grade students received on average in each course. The year shown refers to the whole academic year (i.e., 2016 stands for the a.y. 2015/2016).

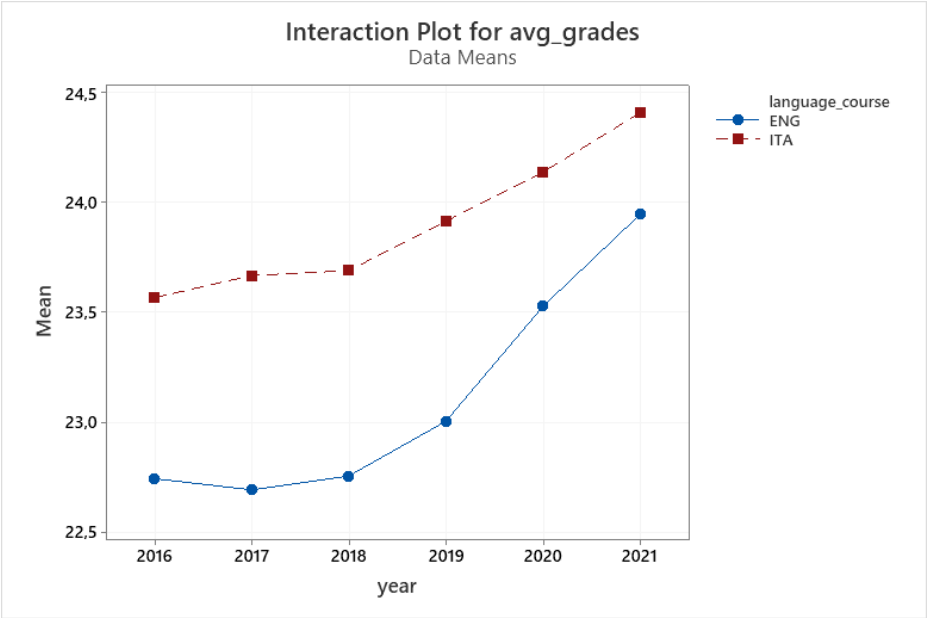


Figure 23. Bachelor students' average evaluation over the years: ITA VS EN

Coherently with the results of the study on students' performances, the graph clearly shows an increasing trend in the last years, and this has of course been confirmed by the statistical analysis performed. With a linear regression, the average evaluation of students has been studied in relation to variables that are proper both to the course and the lecturer, in order to understand what could have influenced such trend.

Two of the regressors used are the percentage of hours dedicated to practice exercises during the course and the percentage of hours taught directly by the main teacher. The trend of these variables during the considered timeframe is presented in Figure 24 and, as beforementioned, they exclusively consider bachelor-level teachings.

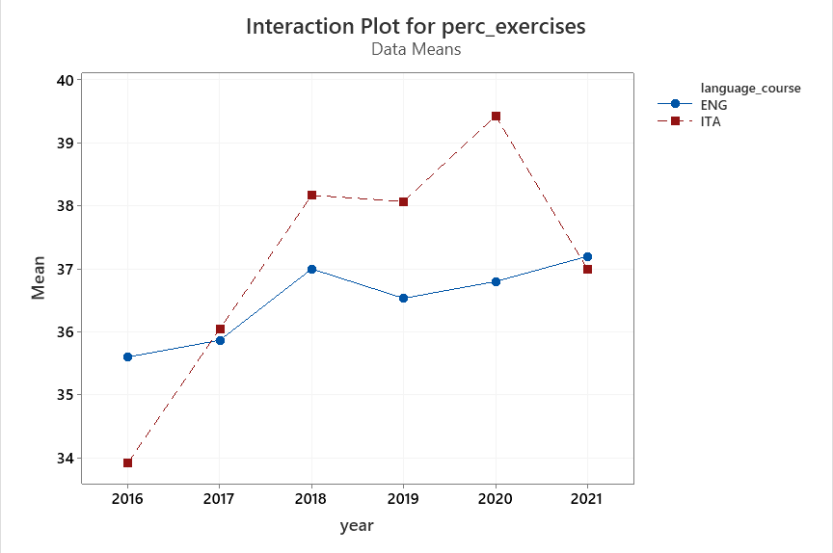


Figure 24. Percentage of practice exercises over the years: ITA VS EN

The percentage of practice exercises carried out by the teacher includes the ones conducted in normal classroom, the ones in the laboratory as well as in the so-called *Decentralized Student Support Facilities* (SDSS), the video streaming exercises and the reviews with students.

The trend appears to be increasing in the years before the pandemic. Dividing by teaching periods, the teachings in the first academic periods are found to have a higher number of practical hours. With the spread of the pandemic, teachings in Italian experienced a reduction in both academic periods while the ones taught in English maintained a stable trend.

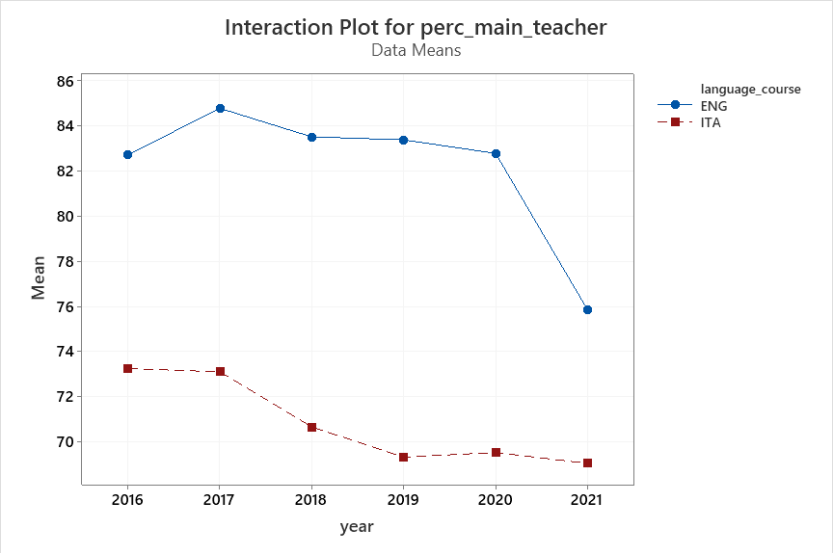


Figure 25. Percentage of main teacher lessons over the years: ITA VS EN

The trend in the percentage of hours directly carried out by the main teacher from the academic year 2015/2016 to 2020/2021 is more or less stable for English teachings, while decreasing for Italian teachings. In courses taught in English, tenured lecturers appear to be more present.

With the spread of the pandemic, a reduction occurred also for English teachings and in a more evident manner.

Other than the confirmed growing trend, the results obtained from the analysis are the following:

- in classes with a high number of students, evaluations are on average lower (a possible explanation could be that generally in large classes is more difficult for the teacher to pay attention to individual students' needs)
- similarly, in teachings with a high number of practical classes, teachers generally assign lower grades (usually the teachings that involve many practical exercises are the most difficult ones). The only practice exercises that are significant for the students' performance appear to be the ones conducted in common classrooms during normal lectures. This type of exercises is also the more carried out by teachers thus representing the major component of the analysed variable.
- in courses conducted in Italian, students receive on average higher evaluation compared to their colleagues of the English path (confirmed results of the previous analyses)
- the age and the gender of the lecturer have not a significant impact on students' evaluation. Nevertheless, in the considered sample, older teachers appear to be stricter, as well as male professors
- the percentage of hours directly taught by the main teacher of the course is not relevant for the evaluation the students received.

Term	Coef	p-value
Constant	25,341	0,000
% of practical hours	-0,01135	0,001
% of main teacher hours	0,00262	0,322
Teacher age	-0,00632	0,447
Number of students	-0,007821	0,000
Year		
2017	0,050	0,805
2018	0,060	0,765
2019	0,264	0,195
2020	0,507	0,014
2021	0,802	0,000
Teacher gender		
Female	0,308	0,021
Teaching language		
EN	-1,087	0,000

Table 8. Linear regression for students' average evaluation

The average valuation of students has increased over all the years and in particular the rise of the years 2021 is significant. This confirms what has been already said and how this increase may be due to the pandemic, which occurred during that very academic year.

All these considerations are most representative for the degree programs of Aerospace engineering, Mechanical engineering, Energy engineering and Biomedical engineering, in order.

Moving to a more general level, a more comprehensive analysis has been conducted, also considering the master-level degree programmes. Even in this case the study was limited to the engineering path and involved exclusively the courses that has kept the same teacher over the entire six years.

Focus of this analysis was investigating eventual differences between bachelor-level and master-level degree students' evaluations. The increasing trend is visible in both cases, but it is more evident in the bachelor-level courses.

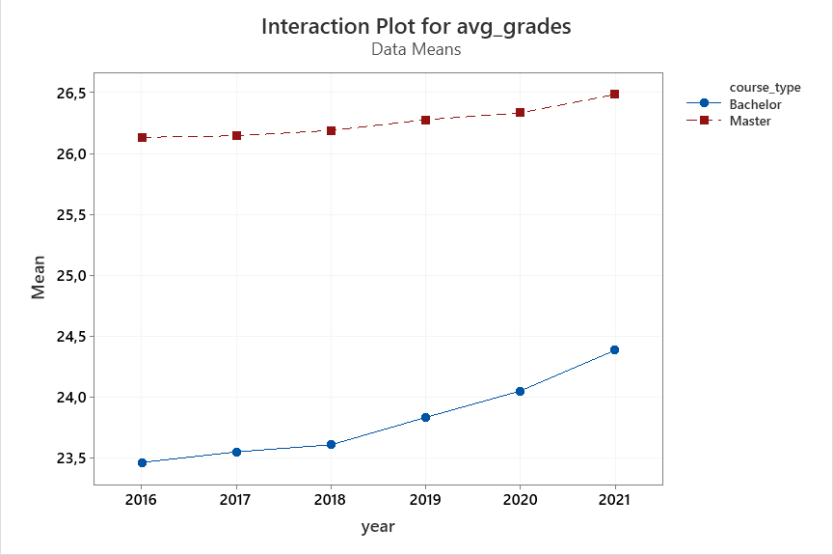


Figure 26. Average evaluation over the years: bachelor VS master

Performing a regression analysis with the aforementioned bigger sample, students of master-level degree courses received significantly higher grades. A potential explanation for this could be the overall greater experience and skills students have reached after the achievement of the first-level degree.

The other results obtained from this study are coherent with the ones derived from the bachelor-only analyses. The sole difference that has been pointed out is about the language in which the teaching is held. The presence of courses taught in English is in fact way more considerable in the master-level degree programmes. This translates into a switch between the two curves of Italian and English when plotting the average evaluation over the years, as it is presented in Figure 27.

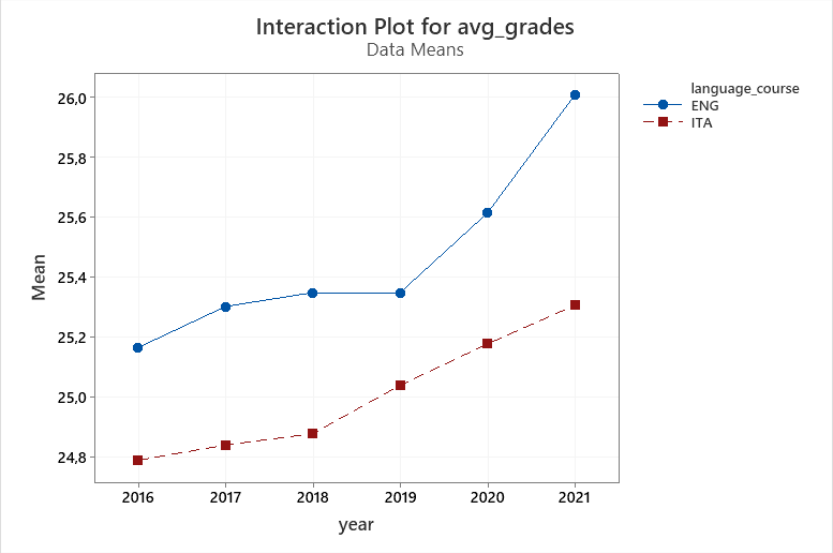


Figure 27. Students' average evaluation over the years: ITA VS EN

With the goal of going deeper in the study of the differences between pre and post pandemic, an analysis was conducted only considering teachings of the first semester held in the academic years 2018/2019 and 2020/2021. This approach enabled to directly compare the same courses, once taught through face-to-face lectures (in 2018) and once through online classes (in 2020). It was not considered the first semester of the a.y. 2019/2020 because, even if lessons were conducted in presence, the exams were online thus the evaluations would have been already impacted by the pandemic.

The database was therefore filtered in order to have two rows for each course, one with records related to 2018/2019 and another to 2020/2021.

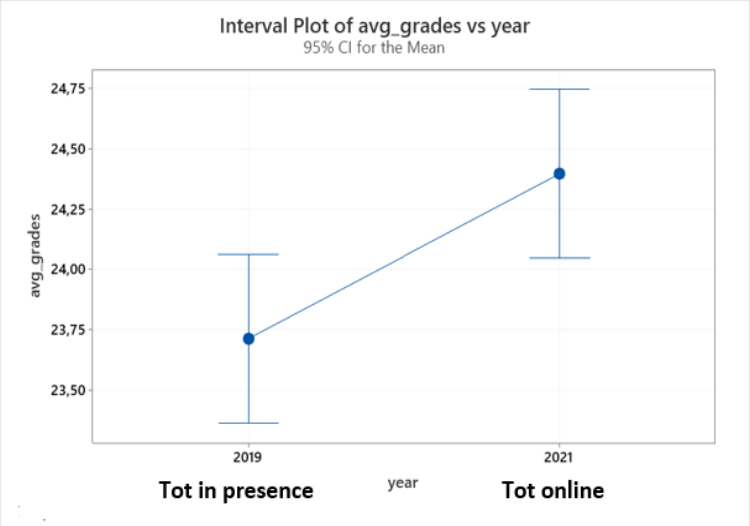


Figure 28. ANOVA: average students evaluation VS years

The difference clearly shown in the graph resulted to be statistically significance at a 10% alpha level.

Students who attended the course in 2021 received higher grades, and this difference is greater for bachelor-level teaching compared to the master-level ones, and for courses taught in English, as it is shown in the graphs presented in Figure 29.

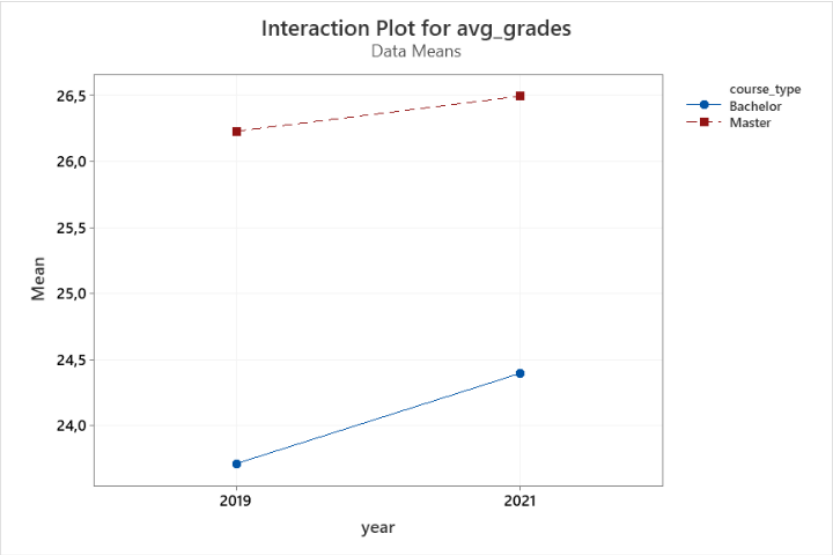


Figure 29. Students' evaluation in 2019 and 2021: bachelor VS master

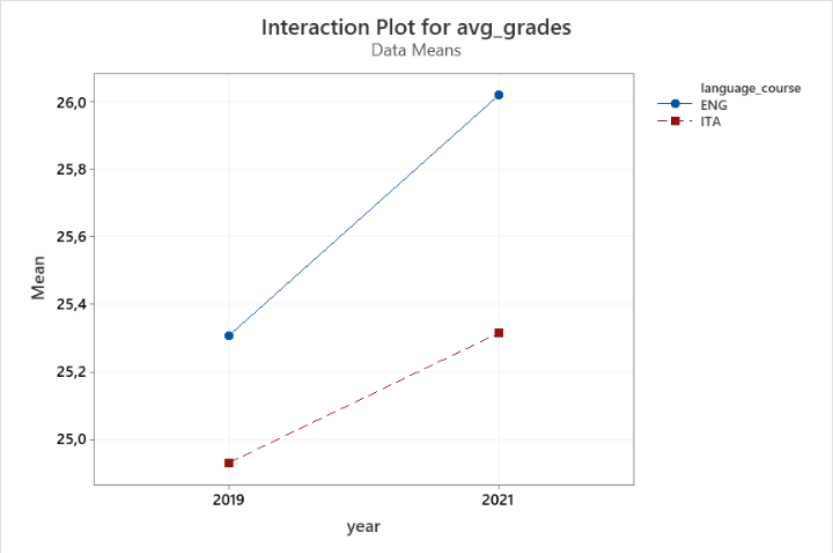


Figure 30. Students' evaluation in 2019 and 2021: ITA VS EN

Given that what differs the courses in the two years is only the teaching delivery mode (in presence vs online) and consequently the exam modality, it is not a hazard to say this is another confirmation of the pandemic-related increase of students' grades, obviously linked with the use of e-learning technologies.

4.5 Cluster analysis: differences between degree programs

A distinct level of analyses includes the investigation of how the different Degree Programmes react to the Covid-19 comparing their behaviour before and after the pandemic.

This study included 18 Degree Programmes (DPs), which together were sufficient to represent the whole educational offerings proposed by the Politecnico di Torino. Given that every English DP has its mirror in Italian that covers the exact same topics and since the goal was to understand the reaction of DPs of different nature, from the analyses were excluded the DPs taught in English.

Aerospace engineering
Biomedical engineering
Chemical and Food engineering
Civil engineering
Material engineering
Cinema and Media engineering
Industrial Production engineering
Automotive engineering
Building engineering
Electrical engineering
Electronic engineering
Energy engineering
Physical engineering
Engineering and Management
Computer engineering
Mechanical engineering
Environmental and land engineering
Mathematics for engineering

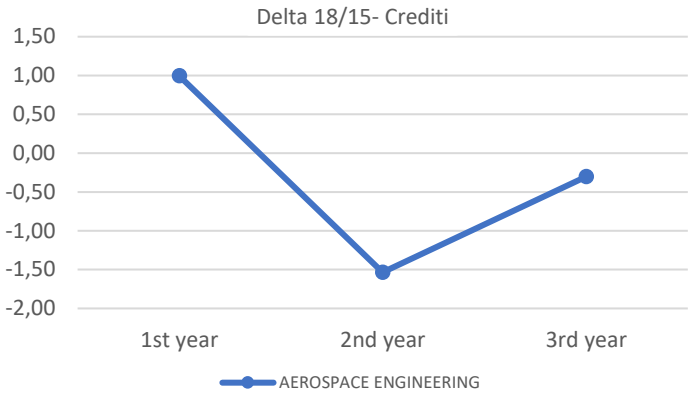
Table 9. List of the analysed degree programmes

The average of students grades and credits for each Degree Programme in the 2015, 2016 and 2018 cohorts and along the three academic years was calculated but instead of analysing their absolute values, deltas were determined between the 2018 cohort values and the 201X cohort values, with the goal of partially eliminate the cohort's own effect. The cohort impacted by the Covid-19 was therefore held fixed. In this way any eventual natural differences in performance between cohorts are cleaned up as they are quantified by the 2018/201X delta of the first year, a year in which Covid-19 also did not yet affect cohort 2018.

To better explain the method, the figures below show as an example the calculation of the delta credits between cohort 2018 and 2015 for the Aerospace Engineering degree program. The same process was then repeated for the other 17 Degree Programmes.

Aerospace engineering – exceeded credits			
	1st year	2nd year	3rd year
2018 cohort	43,97	51,68	53,88
2015 cohort	42,97	53,21	54,18
Delta 2018-2015	0,99	-1,53	-0,30

Table 10. Example of delta calculation



Repeating for all the Degree Programmes:

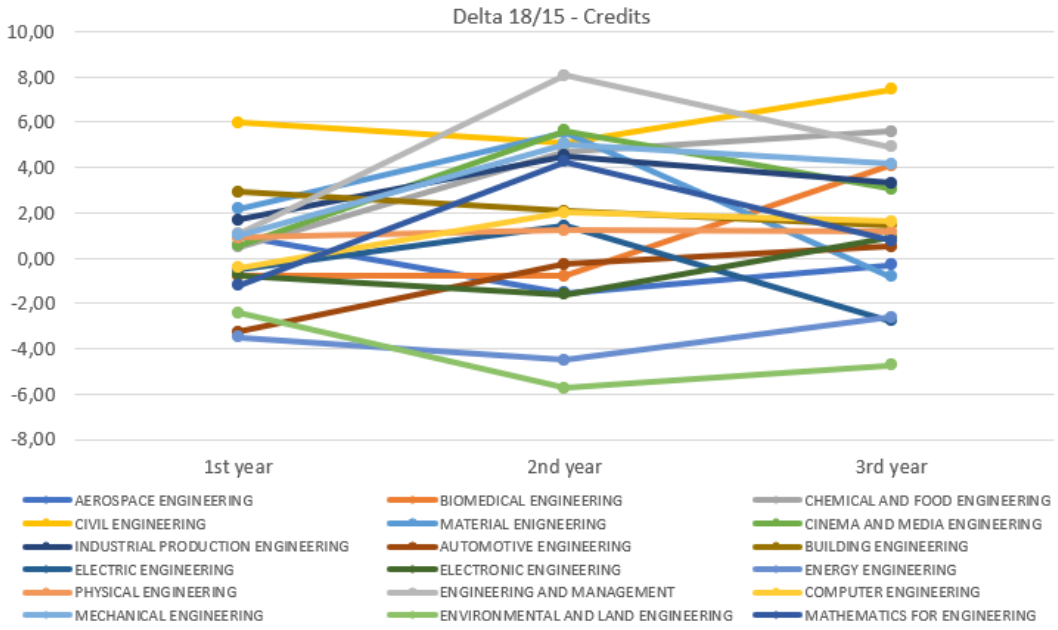


Table 11. Graphical representation of the delta credits between 2018 and 2015 cohorts

Combining credits and grades average with the different cohorts, the procedure has been repeated until obtaining four graphs in total representing:

- Delta credits between 2018 and 2015 cohorts
- Delta credits between 2018 and 2016 cohorts
- Delta average grades between 2018 and 2015 cohorts
- Delta average grades between 2018 and 2016 cohorts

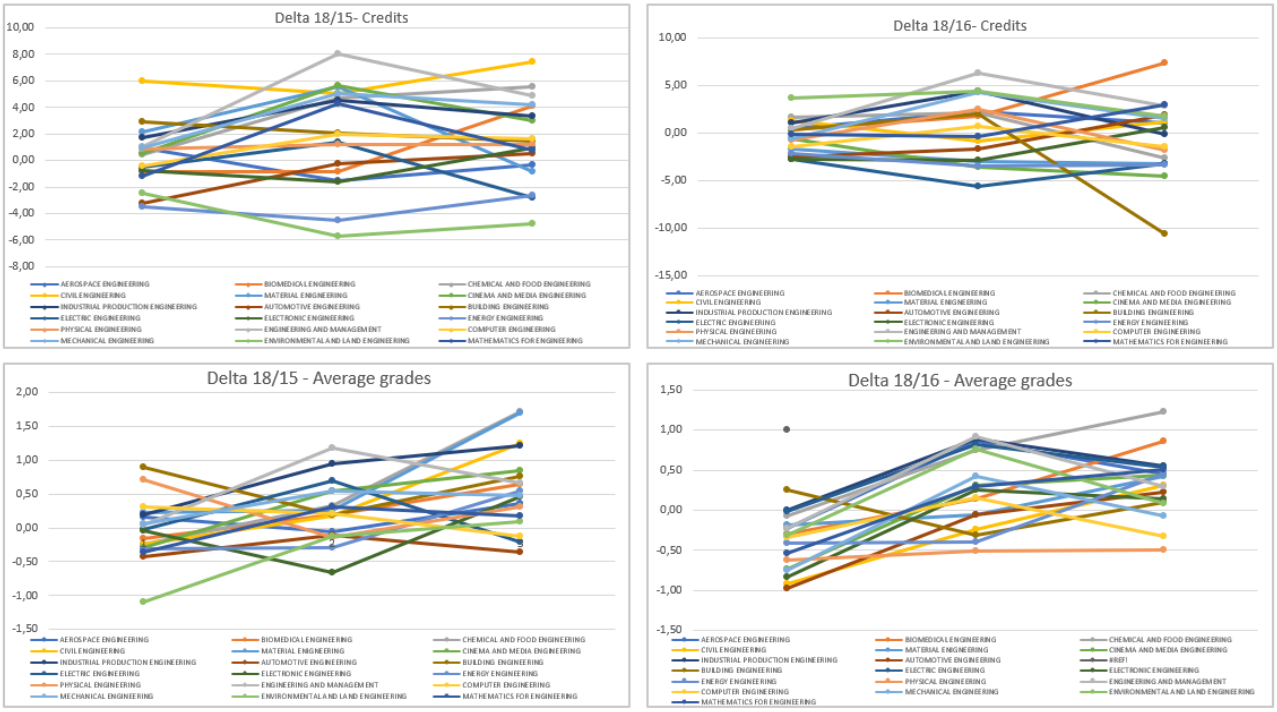


Figure 31. Graphical representations of all the deltas used for the cluster analysis

From the graphs it is already possible to notice some patterns between the curves, meaning some degree programmes react similarly to the pandemic. This suggested a deeper investigation of the phenomenon with a cluster analyses.

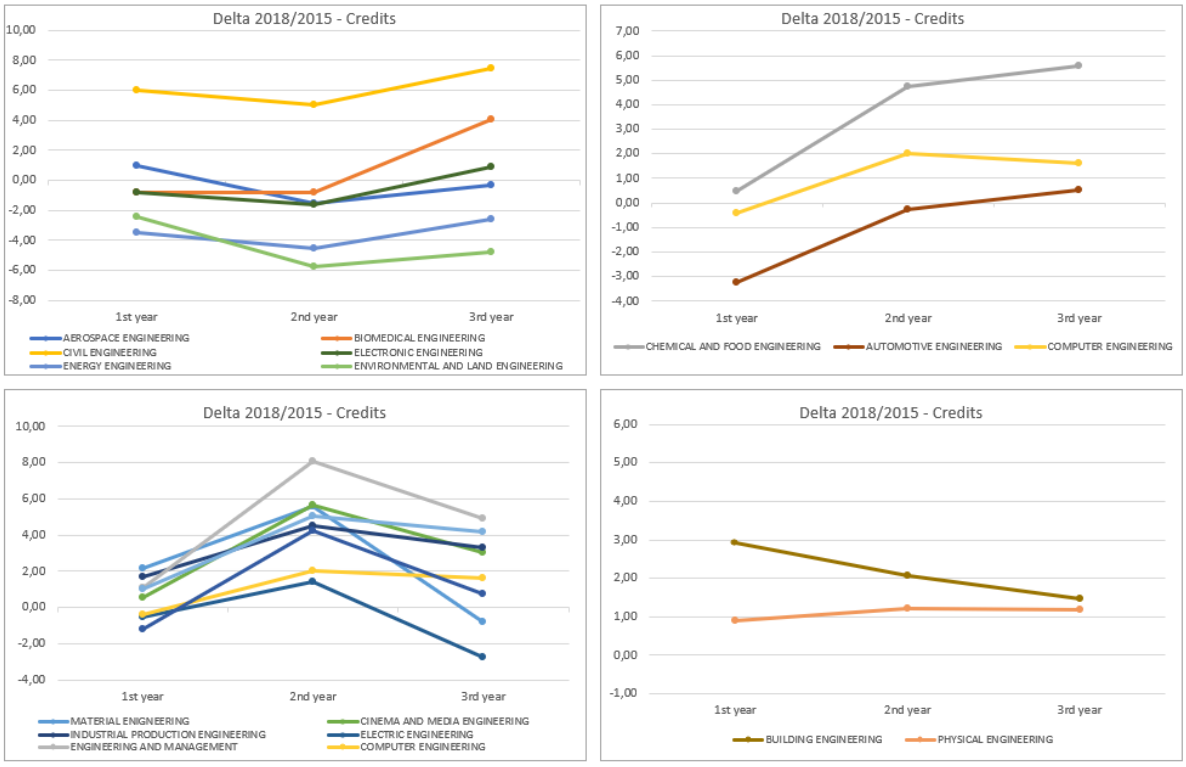


Figure 32. Example of DPs clustering according to the trend in delta credits

The type of cluster analysis chosen is a two-step, which uses the likelihood method as a technique of data comparison and involves two stages: the input data, after being standardized, are firstly compressed into a manageable set of secondary clusters (1st step) and then into larger clusters using the method of the hierarchical cluster (2nd step).

The database used in the analysis consists of 18 records (one for each DP) and the eight slopes obtained from the four graphs above were the predictor variables that, each with its relative importance, will go to determine the belonging of a DP to one cluster rather than another.

An alternative analysis was conducted using as predictor variables the four second derivatives (one per graph) that identify the convexity or concavity of the curves. However, it was preferred to use the previous outputs because the first derivatives describe the curves with a greater level of detail.

Three analyses were launched by setting the parameter "number of clusters in output" to 4, 5 and 6, respectively. The 5-cluster output will be from now on ignored since it does not add any information compared to the 6-cluster output.

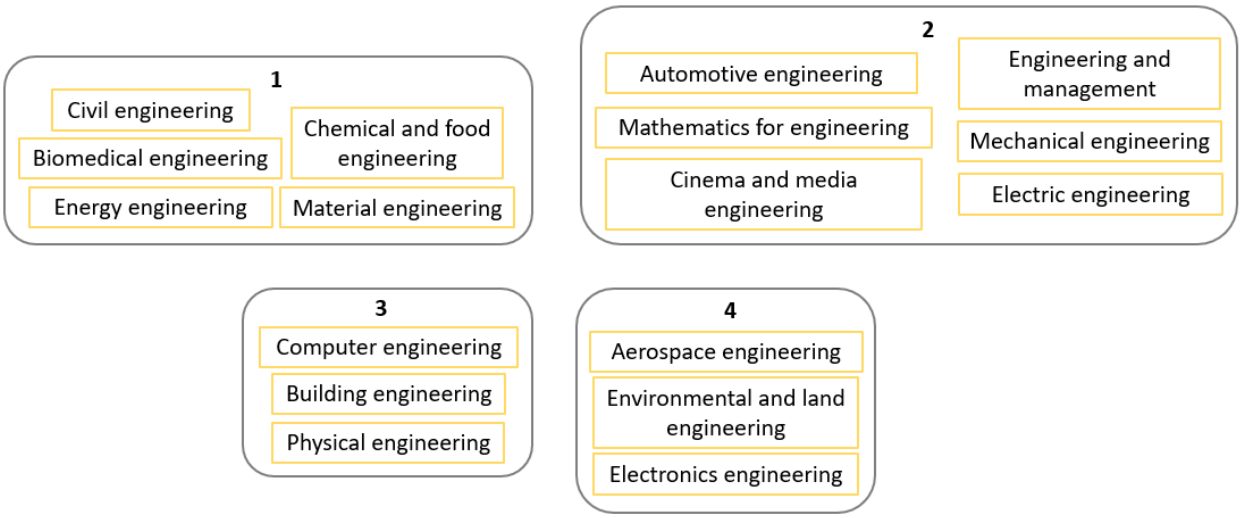


Figure 33. Output with 4 clusters

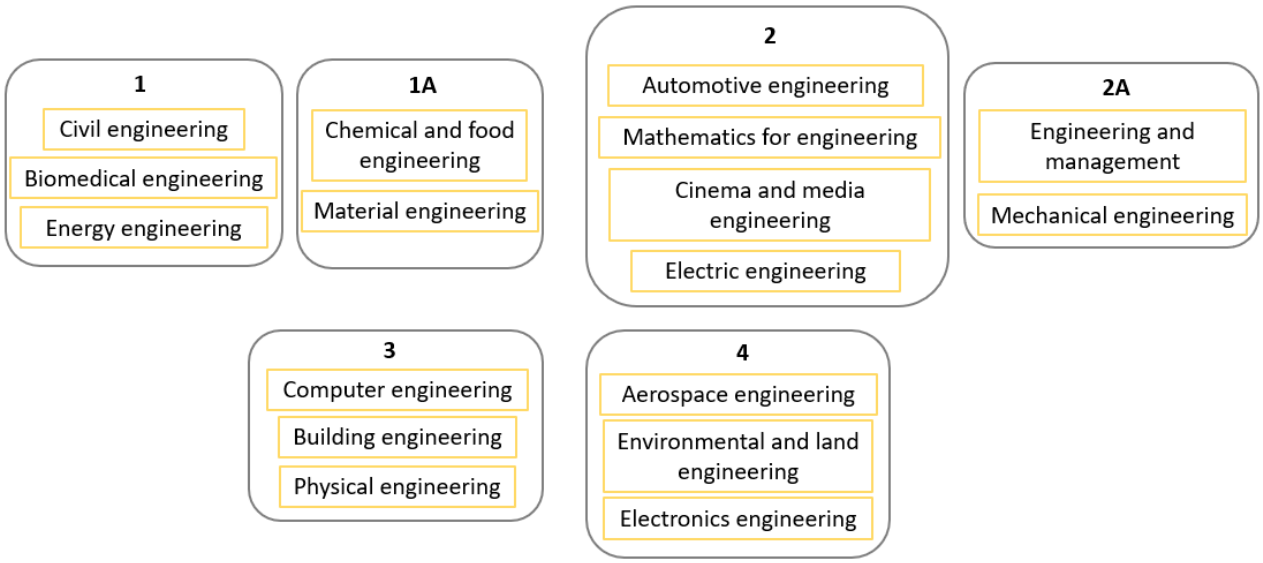


Figure 34. Output with 6 clusters

In clearer terms, students of degree programmes grouped in the same cluster have showed a similar change in the average of grades and credits exceed between after and before the pandemic. The obtained clusters were plotted with respect to their mean values of average grade and credits exceed deltas, which are nothing more than the student performance variables entered as inputs to launch the cluster analyses.

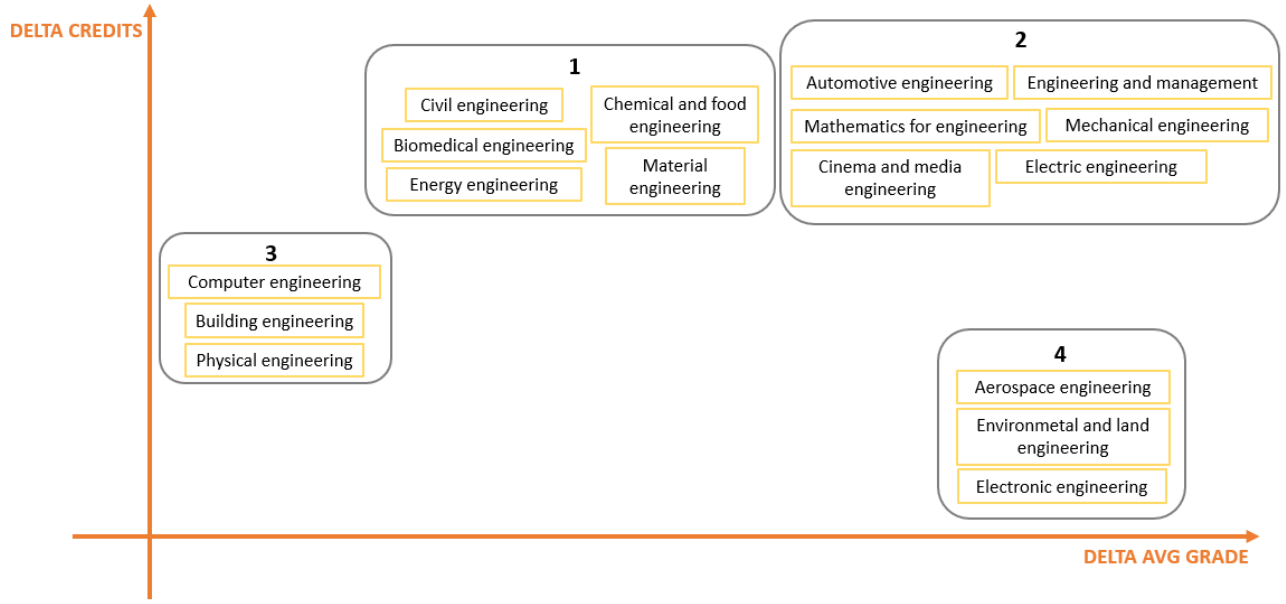


Figure 35. Clusters' plot with respect to the deltas

Having obtained these two preliminary outputs, a new objective consequently arises: identify the determinants in the creation of clusters and thus, in practical terms, what have influenced the behaviour of the various degree programmes during the pandemic.

With this goal in mind, the analysis moved from the *students database* to the *courses, teachers and CPD database* using the "Degree Programme" field present in both databases as a key. In this last

database there are in fact numerous descriptive variables related to teachings that may explain why a course, and consequently a degree programme, has generated certain student-side performance and the subsequent cluster.

This study included several multinomials logistic regressions, a model chosen because the response variable (clusters of belonging) had more than two outcomes that do not have an order. The regressors were selected after a brainstorming session that attempted to formulate several hypotheses about the possible characteristics common to those DPs that were showing to respond similarly to the pandemic. The analyses were conducted considering the outputs of both 6 and 4 clusters analyses and saw as input both aggregate data related to the DPs and those for individual teachings.

All the results obtained are graphically summarized in Figure 36 and then briefly explained.

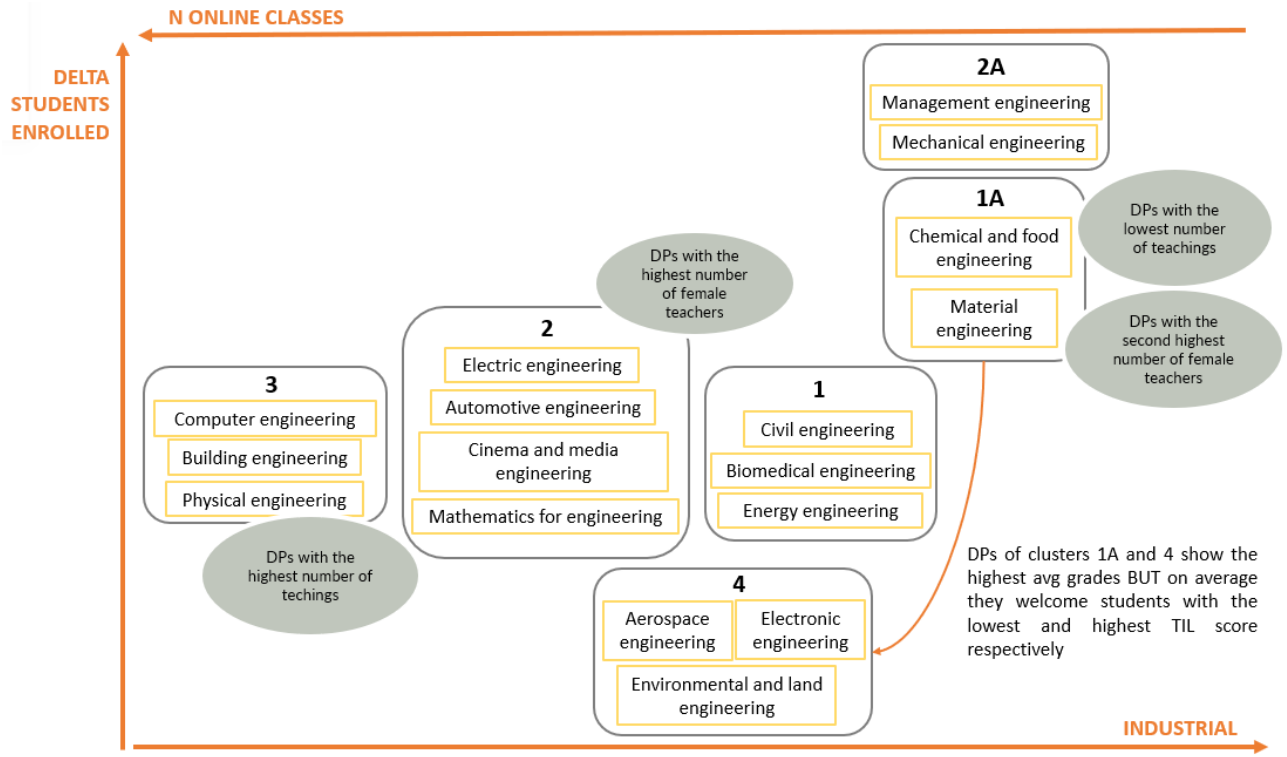


Figure 36. Clusters' plot with respect to teaching descriptive variables

- The degree programmes of management engineering, mechanical engineering, chemical engineering, and material engineering all belong to the degree class L-9 (industrial group). All exhibit an increasing enrolment rate in the last two years and have shown in pairs similar behaviour during the pandemic, dividing into clusters 2A and 1A respectively
- The degree programmes of physical engineering, building engineering and computer engineering do not belong to the L-9 degree class. They recorded the lowest number of online classes and showed a similar behaviour during the pandemic (cluster 3)
- The degree programmes in which students on average received the highest grades are grouped in the two clusters characterized by lowest and highest average TIL among others

(respectively cluster 1A -chemical and material engineering- and cluster 4 - aerospace engineering, electronics engineering, and environmental and land engineering-).

Despite these detected patterns, there are no relevant conclusions to be drawn: there are probably too many socio-psychological factors that do not allow for the identification of any specific variables that could justify the similar behaviour between degree programmes. It was therefore decided to abandon this approach and maybe proceed in the future with more qualitative methods and analysis, such as conducting interviews or questionnaires. Alternatively, this analysis could be conducted with the support of other departments, specifically designed for this kind of studies, such as the one for data analysis and artificial intelligence.

4.6 Analysis of teachers' and lecturers' performance: students' satisfaction towards lecturers and courses in the CPD questionnaires

A further tranche of analysis was conducted on the data obtained from the administration of the CPD questionnaires. This is a tool used by the Politecnico to provide students with important information on lecturers and teachings and to understand the level of student satisfaction with the didactics offered. The CPD questionnaires are given out at the conclusion of each course and students are asked to respond to general inquiries about how the course has been run as well to evaluate the lecturer based on various criteria, such as availability and capacity to pique interest in the topics covered. Answering the survey is not mandatory.

On the basis of the scores and answers given by each student to both the teacher and the teaching, it is possible to obtain two satisfaction rates concerning the lecturer and the course respectively. Then, by combining the CPD data with the lecturers DB, it is possible to obtain a database in which each record corresponds to a teachings, showing also the two satisfaction rates aforementioned. Starting from these two indexes, various analyses were carried out with a view to highlight the factors that impacted more or less significantly on lecturer and teaching satisfaction, obviously taking into account the different academic years as well as the pandemic period.

A premise must be made, however, that the response rates to the CPD questionnaires, not being compulsory, are subjected to fluctuations over the years. In particular, with the spread of the pandemic, there was a considerable slump in the response rate to the questionnaires (from 70% to around 40%). For this reason, the initial data were non-homogeneous, thus only those courses that have maintained the same lecturer for all years and always had response rates greater than or equal to 40% were considered in the study. The bias in the low response rates led to the final selection of only one-third of the initial teachings (for a total of 864 records).

Moreover, one limitation of the model may be the fact that the students who fill out the CPD questionnaire are generally the most diligent ones, following that the results are mainly representative of the most rigorous students of the population.

Furthermore, analyses exclusively included degree programs delivered either completely in Italian or completely in English.

After making the necessary adjustments, it was then possible to plot the data of both the teacher and teaching satisfaction rates over the entire time horizon considered, as can be seen in Figures 37 and 38 respectively.

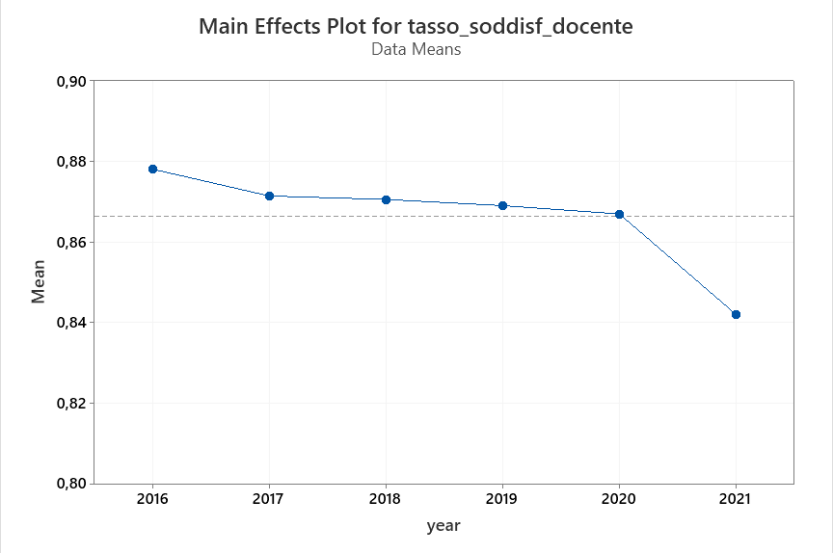


Figure 37. Teacher satisfaction rate over the academic years

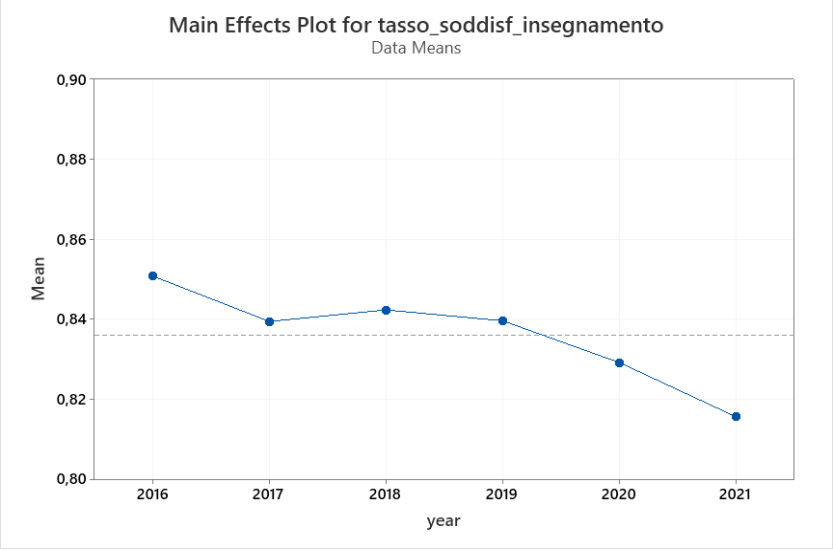


Figure 38. Teaching satisfaction rate over the academic years

The years indicated in the plots refer to the academic years, so for example the year 2019 refers to the academic year 2018-2019 and therefore the impact of the pandemic is only appreciable in the years 2020 and 2021.

Students' satisfaction shows a decreasing trend over time and, especially in the case of the teaching-related index, this behaviour appears to have been only accelerated, and not due, by the pandemic.

With the help of several linear regressions to identify which variables might have had an impact on both the teacher and teaching satisfaction rate, several analyses have been conducted.

Starting from the lecturer index, the following outcomes were found:

- the impact of the students' attendance rate is positive and statistically significant, which means that on average students who attend classes assiduously are likely to evaluate them positively
- the percentage of hours carried out by the lecturer in charge of the course and the ones dedicated to carry out practical exercises do not have a significant impact on the satisfaction rate
- Italian and English courses do not have meaningful differences in the evaluation given by the students, meaning the language in which the teaching is held is not relevant *per se*
- the use of an appropriate platform (e.g., the choice between Zoom, Google Meet or BBB) has a positive and significant impact, being on average more appreciated by students
- younger teachers are on average evaluated more positively
- there is no significant difference between the received evaluations of teachers with different gender.

However, it must be said that the model does not appear to be appropriately robust, showing a R-squared value of almost 30%. This does not imply the findings are not true or invalid, but just that the model is not adequate to predict future trend.

In an endeavor to better appreciate how these variables have had different influence before and after the pandemic, two parallel analyses were conducted by first considering the academic years exempted to the impact of the pandemic (i.e., from academic years 2016 to 2019) and then only academic years 2020 and 2021. The analysis showed that before the pandemic, in the years from 2016 to 2019, the teachings in English were slightly preferred by students in the sample. This result, however, is not confirmed for the pandemic period, during which the Italian teachings of the analyzed sample are evaluated slightly more positively. Comparing the two models, analogous but for the considered timeframe, the R-squared jump from 20 to 46 percent, leading to the consideration of having a more robust model for the pandemic period.

A final analysis was conducted on the teacher satisfaction rate to assess the impact of the teaching delivery mode, i.e., whether it was conducted in-person or remotely. However, given that this difference can only be appreciated in the pandemic period, the analysis considered exclusively the academic years of 2019/2020 and 2020/2021, thus also seeing how this impact changed in the two years under analysis. The evidence obtained is that the delivery mode does not appear to be significant in students' appreciation of the teacher. However, in the analyzed sample there is a slight preference for lectures conducted in presence.

In addition, in the last year (2021) there has been a decrease in the teacher satisfaction rate, even though it is not attributable to the fact that the questionnaires were delivered during the pandemic period. This result suggests that probably it would have happened anyway.

Similar to the analysis conducted for the lecturer satisfaction rate, the teaching satisfaction rate has also been investigated to identify the factors that most influenced it. A preliminary analysis has showed the variable that most affects the teaching satisfaction rate is the students' contentment about the main lecturer. This result appears to be predictable and quite obvious, but it allows us to extend the evidence previously found for teachers also to teachings.

Accordingly with the intent to investigate this dense interaction between the two rates, an analysis based on structured equation modeling was conducted and the subsequent results are shown in Figure 39 and Table 10.

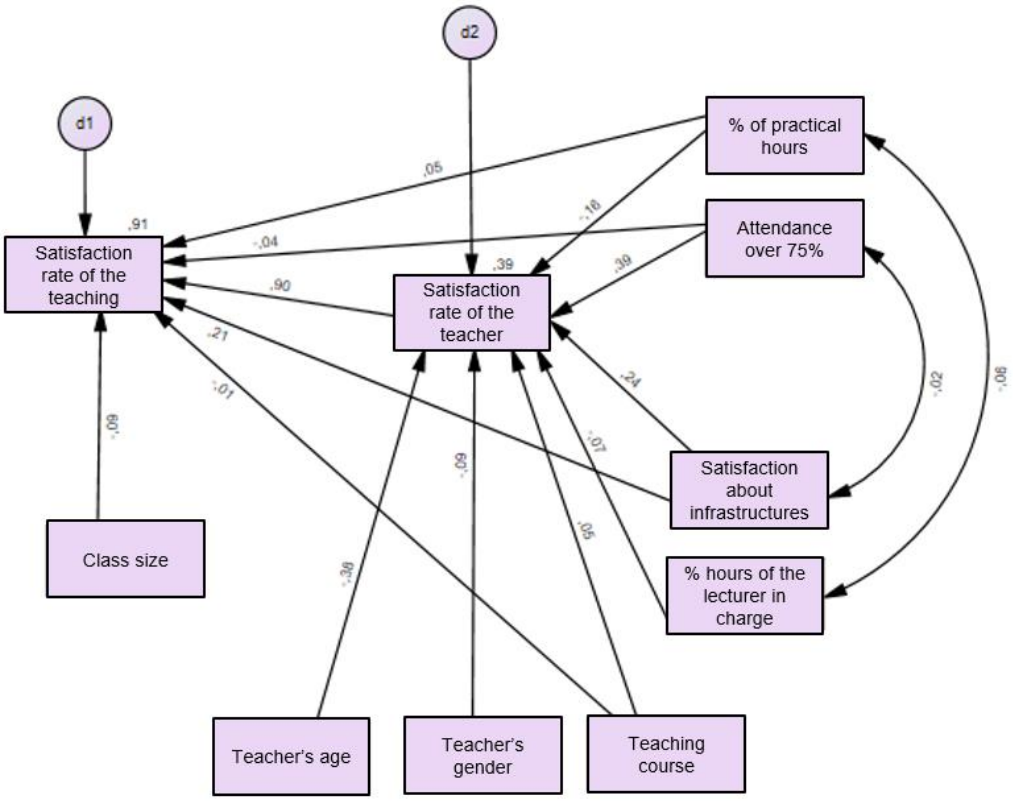


Figure 39. Structured Equation Modelling for teacher and teaching satisfaction rate

Response variable		Regressor	Standardized regression weights - estimates-
Teacher satisfaction rate	←	Frequency of attendance	0.390
Teacher satisfaction rate.	←	Teacher's age	-0.378
Teacher satisfaction rate.	←	Satisfaction about the infrastructure	0.236
Teacher satisfaction rate.	←	Percentage of practical hours	-0.161
Teacher satisfaction rate.	←	Teacher's gender	-0.090
Teacher satisfaction rate.	←	Percentage of hours of the lecturer in charge	-0.071
Teacher satisfaction rate.	←	Teaching language	0.053
Teaching satisfaction rate.	←	Teacher satisfaction rate	0.901
Teaching satisfaction rate.	←	Satisfaction about the infrastructure	0.211
Teaching satisfaction rate.	←	Numerousness of the class	-0.085
Teaching satisfaction rate.	←	Percentage of practical hours	0.049
Teaching satisfaction rate.	←	Frequency of attendance	0.043
Teaching satisfaction rate.	←	Teaching language	-0.011

Table 12. Standardized regression weights' estimates for teacher and teaching satisfaction rates

The results that arise from the model regard both satisfaction rates and can be summarized as follow:

- the age of the lecturer is the major influence in lecturer satisfaction rate, second only to the frequency of student attendance in classes
- the infrastructure is significant for both lecturer satisfaction rate and teaching, especially for the latter it appears as the second most important variable of influence
- the percentage of exercises conducted are significant for both indexes but show a higher influence for the lecturer satisfaction rate
- teacher satisfaction rate is confirmed as the variable with the greatest impact on the teaching satisfaction rate

As previously mentioned, the teacher satisfaction rate has a strong influence on the teacher satisfaction rate, and in this regard, an analysis, similar to the one carried out for the teacher rate, was conducted to see how this influence changed before and after the pandemic.

The obtained result is that the teacher satisfaction rate appears to have a greater influence on the teaching satisfaction rate during the pandemic period than in previous years. Speculating on this observation, the following evidence could be explained by the shift to online teaching in that timeframe. While following classes remotely, in fact, the ability of the teacher of conducting an interesting and engaging lecture is way more valued by students with respect to face-to-face class, since there are fewer external factors to be considered.

In the final analysis, the impact of delivery mode on the teaching satisfaction rate was investigated, taking into account the time window impacted by the pandemic and the year before. This filtration of data was needed in order to eliminate the noise of having much more data related to the period

prior to the Covid-19 that could have altered the results, thereby preventing the effect of traditional face-to-face teaching from prevailing. In this way, three distinct academic years straddling the pandemic were considered, the 2018-2019 academic year held totally in-person, the 2019-2020 academic year spent straddling the beginning of the pandemic, and finally the 2020-2021 academic year totally under the Covid-19 pandemic. What emerged is that the teaching delivery mode is not significant in students' appreciation of the course, although the analyzed sample showed a slight preference for face-to-face education. This evidence is in line with the one found when analyzing the teacher satisfaction rate.

In order to extract as much knowledge as possible from the CPD questionnaires, more analyses were conducted but from another point of view, thus considering as response variable the percentage of the respondents whose attendance of the teaching was higher than 75%.

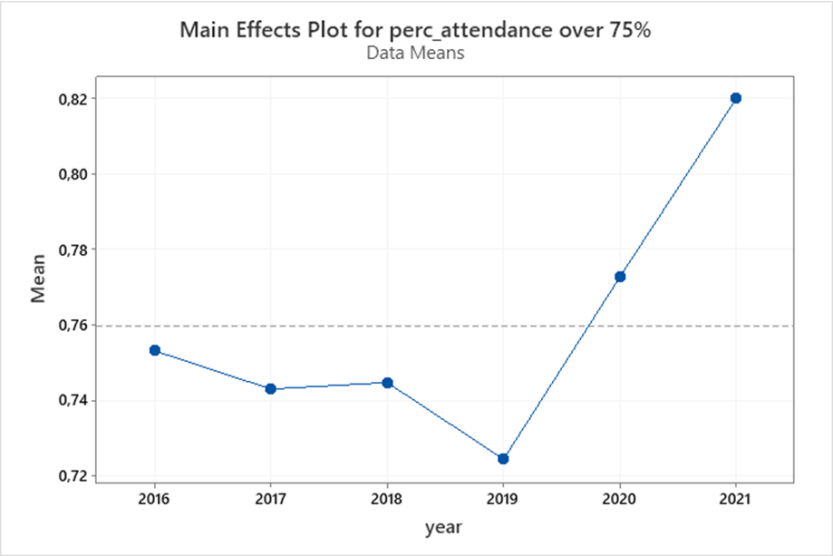


Figure 40. Trend of the percentage of students who attend more than the 75% of the teaching

The increasing trend clearly visible in Figure 40, has of course resulted also in the linear regressions performed but with a significance level lower than the alpha 5% only in the academic year mostly impacted by the Covid-19 (2020/2021). Without the pandemic (all the years prior to the a.y. 2019/2020) show a decreasing trend even though it is not statistically significant.

It has been noticed the direction followed by the curve is in contrast with the trend of the CPD response rate along the years. This means that the part of the population who answers the questionnaires is mostly the one which include those students who attend over the 75% of the teaching. The decrease in the response rate is thus due to students with lower attendance habit, maybe for a scarce interest in the teachings and in communicating their feedback.

Moreover, the more the students are pleased by the lecturer the higher will be their attendance rate, meaning the teacher satisfaction rate is positively and significantly correlated with the percentage of attendance over the 75% of the teaching.

The linear regression also showed how in teachings held in English the percentage of students who attended almost the entire course is lower with respect to the Italian ones.

Term	Coef	p-value
Constant	0,4198	0,000
Teaching satisfaction rate	0,251	0,043
Teacher satisfaction rate	0,2602	0,005
Infrastructure satisfaction rate	-0,1041	0,014
Teaching language		
EN	-0,0744	0,000
Year		
2017	-0,0095	0,548
2018	-0,0070	0,657
2019	-0,0253	0,110
2020	0,0233	0,142
2021	0,0800	0,000

R-sq	R-sq (adj)
21,64%	20,81%

Table 13. Linear regression for the percentage of students with attendance over 75%

Filtering only for bachelor-level courses the results remain valid, and the model increase its robustness, presenting a R-sq of 27,85%.

With the further aim to investigate on the impact of the teaching delivery mode on the students attendance, the variable was included in the regression but reducing the dataset and considering only the academic years from 2018/2019 to 2020/2021, in order to have an amount of data related to the period prior to the pandemic that is comparable to the one instead impacted by the Covid-19. This analysis presented results perfectly coherent with the more comprehensive study, highlighting the positive relation between the online teaching delivery and the percentage of students who attend over the 75% of the course. This is coherent with the increase of attendance in the last two years. Distance education has in fact the great potential of reaching way more people than traditional lectures.

It should be noted, however, that the evidence presented in this section may be subject to a bias caused by the large amount of data foregone due to filtering of response rates.

4.1 Limits and next steps

The major limits of the analyses presented up to now regard the final part on the CPD questionnaires. Those data are in fact subject to a bias due to the appreciable drop of the response rate in the years of the pandemic (from 70% to around 40%). For this reason, the study exclusively

examined those teachings that have maintained the same lecturer for all the years considered, thus from 2015 to 2021, and always had a response rate greater than or equal to 40%. This selection finally led to consider only one-third of the initial teachings.

Moreover, one more limitation of the model may be the fact that the students who fill out the CPD questionnaires are usually only the most diligent ones. What follows is that the responses that have been analyzed refer to a sample that possibly is not representative of the entire students' population but only the expression of its most diligent side.

Another limit is related to the cluster analysis conducted on the degree programs. Analyses showed there are differences in the performance deltas of students from different paths but, delving deeper, the statistical models built to find the factors that could explain such phenomenon were not robust and therefore cause-and-effect relationships cannot be stated.

Downstream of this work, some thoughts can be made on how the study may evolve. The data used as input for the analyses have been adequately exploited and the main analyses that were intended to be done have been carried out.

The impact of Covid-19 on the Politecnico has been assessed to be non-negligible, however some difficulties have been encountered when figuring out what specific factors had caused the identified phenomenon. This led to the proposal to find new data collection methods and to the idea of trying a more qualitative approach, submitting questionnaires and interviews to the actors of the atheneum which have been directly involved, namely students and faculty members.

5. Discussion and conclusions

The digital transformation brought about by the Covid-19 pandemic has been a journey filled with obstacles, but also with successful innovations and breakthrough concepts, as well as opportunities for even more developments in the years ahead.

It is undeniable that the university teaching has been profoundly affected by the pandemic and having realized the potential of this unique phenomenon, the Politecnico di Torino has decided to capitalize on the experience by analytically processing what occurred to figure out what paths the future of teaching ought to take.

Such idea has been embodied in this work and in those that preceded it, with the aim to design a future educational offering that could meet recent students' needs as well as illustrate the phenomenon to teachers in order to incentive their behavior in the intended direction.

Thanks to the previous meticulous selection of variables involving teachings, students, faculty, as well as to the careful review and cleaning of the databases, it was possible to depart from an already structured model of the issue, which enabled to work on homogeneous data sets and to directly focus on more concrete analyses related to the likely impact of the pandemic.

The three different strands followed in the study suggest there have been several changes within the Politecnico, in terms of students as well as in terms of assignments and faculty; nevertheless, it is neither trivial nor even automatic to identify the online educational delivery mode as the trigger of this identified phenomenon.

The first part of the analysis looked at the performances of students from bachelor-level degree paths in engineering from two perspectives, examining firstly the students records and then dual data collected from the teachings. Both point of view showed that the evaluation process has been influenced by the pandemic, with the cohort 2018 positively impacted by the period. Regarding both the exceeded credits and the obtained grades, during the years when Covid-19 has spread, it is noticeable an increase, more evidently for students who have attended teachings held in Italian.

In particular, by exploiting the analyses conducted on the percentiles, it could be observed that the students who benefited the most from the remote or blended teaching delivery mode were those with the lowest performance. If, in fact, grades and credits are generally negatively correlated, during the pandemic passing more exams resulted in an increase in the average grades, no matter the student distribution percentile under analysis. This consideration is always valid for the students from Italian courses, while the English degree programs have showed the existence of two populations who differently reacted to the online learning: students who generally achieve lower performances have improved their results while the best-performing students experienced some difficulties.

Apart from this observation, the general findings suggest several possible keys to explain the noted phenomenon: remote and/or blended teaching is more effective than traditional lectures, less stricter evaluation criteria, less challenging exams due to the online modality or tests more easily eluded by students.

Investigating on students' performance pointed out also some results that are not strictly related with the pandemic, but still interesting and worth mentioning.

First of all, in teachings with a high number of attending students, the average received evaluation is lower, meaning smaller classes are auspicial in the future.

Moreover, students' evaluation is influenced by the time the teacher spends in carrying out practice exercises during lectures and, more specifically, in teachings with a high number of hours allocated to these, students obtained on average inferior grades. This could be explained by the usually appreciable difficulty of those courses involving many practice exercises. The spread of the pandemic caused a reduction in the percentage of hours dedicated to practice in the Italian teachings, probably because of the complexity in arranging such works with the distance learning going on.

When the lead professor of a teaching conducts most of the lecturing, students tend to get higher grades on the final exam, demonstrating the effectiveness of a larger presence over the entire span of teaching. Along the years the percentage of hours directly taught by the professors who owns the teaching is decreasing in Italian degree programs, while it shows a quite stable trend for the

English ones. With the spread of the Covid-19 though the percentage decreased also in teachings held in English, indicating, perhaps, the need of an additional technological support provided by assistants.

The analyses also pointed out that when a student passes the mandatory placement test to enroll at the Politecnico di Torino, he/she obtained a score which is a good predictor for his/her performances in the following academic years. To be more specific, this effect is more evident in the first year compared to the rest of the career because of the matching between the topics covered in the test questions and the planned academical subjects. In relation to the pandemic, the decreasing influence of the admission test score on the student performance along the years is reducing with the spread of the Covid-19, suggesting a possible exogenous effect.

Focusing still on the entrance test, the students who enroll in cohort 2018 with the lowest score (thus belonging to the first quartile of the distribution) are the only ones who succeeded in obtaining higher grades as well as passing more exams. This result is coherent with the aforementioned consideration about the lower performing students as the ones who beneficiated the most from the distance education.

The other part of the study focused on the CPD questionnaires always submitted to both students and professors at the end of every teaching. Collecting these answers, the satisfaction for the professors and the teachings have been investigated, highlighting an overall decreasing trend that started even before the spread of Covid-19.

CPD showed limited outcomes regarding the impact of the pandemic. Even the teaching delivery mode does not appear as a significant factor in influencing the satisfaction of the students, although the analyzing sample showed a slight preference for traditional face-to-face lecturers.

In general, the satisfaction of the teaching is mainly explained by the contentment for the professor and more evidently during the period of distance education. It is in fact quite straightforward to think that, when attending lectures remotely, students actually give more weight on the teacher's ability to deliver an interesting and engaging lecture since there are far fewer other influences to take into account.

These results, albeit not finals, can be considered satisfactory in terms of quantifying the effects that there have been on the performance of students, faculty, and teachings. As a matter of fact, thanks to the studies carried out, a more conscious insight into the effect the pandemic actually exerted on the Politecnico di Torino was gained, thereby laying the groundwork for a new didactic, a goal that has been the aim behind this study from the very beginning.

At this stage, it is indisputable that after the radical change occurred in both cultural and professional environment, the academic educational model cannot remain unchanged. Transmissive teaching, traditionally adopted, seems in fact to be no longer adequate for the cross-curricular skills required by today's society. What have been and still is a period of crisis might also represent a time of great opportunities when new horizons are rising. Hence, it becomes necessary

to reflect broadly, collegially and in a more structured way on the issue, declaring innovation as a clear objective on a strategical level.

This is where this dissertation ends, leaving behind a set of significant analyses that aim to be the basis for further studies in support of the university, faculty and the entire student community.

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