

**EMERGENCY REMOTE TEACHING AND HYBRID  
TEACHING DURING COVID-19 PANDEMIC**

Academic Performance Measurement using Data Mining  
and Statistics

Yan Guan

Dissertation presented as partial requirement for obtaining the  
Master's degree in Information Management

**NOVA Information Management School**  
**Instituto Superior de Estatística e Gestão de Informação**  
Universidade Nova de Lisboa

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**Advisor:** Professor Roberto Henriques

**Co-advisor:** Prof. Leonor Fernandes

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## **ABSTRACT**

The COVID-19 pandemic caught us by surprise, bringing disruption in all spheres. The traditional higher education institutions' face-to-face teaching method has become unfeasible. Universities witnessed the need to temporarily shift from traditional face-to-face teaching to remote or hybrid instruction. When facing an uncertain crisis circumstance, as we are facing now, it is fundamental to secure that the hybrid teaching approach delivers the same or better level of effectiveness when compared with the traditional teaching approach. This study focuses on the emergency remote teaching and hybrid teaching adopted at NOVA Information Management School (NOVA IMS) as emergency solutions to face the limitations triggered by the pandemic. This study analyzes the performance of emergency remote teaching and hybrid teaching methods by comparing them with the traditional teaching approach based on the quantitative data of academic records across 2nd-semester courses of the Information Management bachelor's degree from the past three academic years (2018/19, 2019/20, 2020/21). To analyze the data, data mining techniques and statistical tests (ANOVA and Kruskal-Wallis tests) were applied to determine the similarities/differences between the student's academic performance across different teaching modes. The results show that the shift in teaching mode did not result in poorer academic performance, instead, no statistically significant differences were found.

## **KEYWORDS**

Learning analytics; Emergency remote teaching; Hybrid teaching; Academic performance; COVID-19 pandemic; Statistical tests

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## LIST OF ABBREVIATIONS AND ACRONYMS

|                 |                                                  |
|-----------------|--------------------------------------------------|
| <b>ANOVA</b>    | Analysis of Variance                             |
| <b>COVID-19</b> | Coronavirus Disease 2019                         |
| <b>ECTS</b>     | European Credit Transfer and Accumulation System |
| <b>EDA</b>      | Exploratory Data Analysis                        |
| <b>ERT</b>      | Emergency Remote Teaching                        |
| <b>F2F</b>      | Face-to-Face                                     |
| <b>GPA</b>      | Grade Point Average                              |
| <b>HT</b>       | Hybrid Teaching                                  |
| <b>LA</b>       | Learning Analytics                               |
| <b>MANOVA</b>   | Multivariate Analysis of Variance                |
| <b>NOVA IMS</b> | NOVA Information Management School               |
| <b>RO</b>       | Research Objective                               |
| <b>RQ</b>       | Research Question                                |
| <b>SD</b>       | Standard Deviation                               |

# 1. INTRODUCTION

The outbreak of COVID-19 has triggered the world in all areas of activity. Higher education institutions faced the challenge of how to continue teaching while keeping the safety from the public health crisis that is uncertain. The responses to address the challenge generally fall into three categories: maintaining face-to-face (F2F) teaching with social distancing, creating hybrid models (limiting the number of students on campus) or moving to online instruction (Iglesias-Pradas et al., 2021). COVID-19 has become a catalyst for educational institutions worldwide to search for innovative solutions in a relatively short period of time.

The COVID-19 pandemic temporarily sped up the transition to digital teaching (Daumiller et al., 2021). It has forced universities to re-organize their teaching (Secundo et al., 2021), and it “may stay for quite a while, but it will eventually go away” (Ng, 2021). As long as it “stays”, it is crucial to ensure the effectiveness of hybrid teaching (HT) and also explore its potential to provide recommendations for possible improvements and adjustments for the future. This sudden shift not only challenged the students but also the professors who had to rethink some of their teaching practices by embracing digital technologies. Regarding emergency remote teaching (ERT), many skills are required of professors when teaching online such as time and space management, virtual management techniques, and the ability to engage the students through virtual communication (Easton, 2003).

On March 12<sup>th</sup>, 2020, the Portuguese Government announced new measures and recommendations to combat COVID-19 which included suspending all F2F education activities starting from March 16<sup>th</sup>, 2020. With these new measures, NOVA IMS conducted the rest of the 2nd-semester of 2019/20 wholly online. For the next academic year, 2020/21, it was announced the adoption of HT, which combines presential and remote modes of class attendance, rotating the students weekly to limit the number of students on-site by 50%. To provide the students attending the classes remotely with the same learning experience as the students in the classroom, the university installed the classrooms with adequate equipment so that everyone could see, hear, and interact with the professor. Having this teaching approach adopted for an unclear period is crucial to ensure the quality of teaching and learning.

It remains to see how the quality of teaching and learning was impacted by the shift from F2F to ERT and HT. This study aims to understand whether students’ academic performance was affected by the transition from traditional F2F teaching to ERT and HT during a pandemic circumstance and provide insights on the quality of ERT and HT adopted at NOVA IMS.

Most of the existing literature on the transition from F2F to blended/remote/hybrid teaching was conducted out of the emergency circumstances where the transition from F2F to blended and/or online teaching is done under the premise that the instructional changes are carefully planned and is carried out voluntarily by the teaching staff (Iglesias-Pradas et al., 2021). During the onset of the pandemic, the shifting happened suddenly and in an unplanned way, limiting the time to make the decisions. Some of the studies that address the comparison considering the emergency circumstance focus on the comparison between traditional and fully online teaching methods, which is different from the HT approach that will be addressed in this study.

The majority of these studies used statistical tests such as ANOVA, Student’s T-test, and Mann-Whitney U test to compare the differences in students’ academic outcomes across different teaching modes.

All of them used student's final grades to measure academic performance. The results from the existing studies on this topic revealed either a better academic performance in remote and blended teaching when compared with traditional F2F teaching, or no significant differences in academic performance across the different teaching modes (Alducin-Ochoa & Vázquez-Martínez, 2016; El Said, 2021; Goette et al., 2017; Iglesias-Pradas et al., 2021; Kuhn, 2019; Ravat et al., 2021). The previous studies seem to have produced mixed findings regardless of being a forced transition or not.

Alternative views offered by meta-analysis also support the idea that either the student's academic performance in remote teaching is higher than in F2F courses, or there are no significant differences between both (Iglesias-Pradas et al., 2021; Shachar & Yoram, 2003; Zhao et al., 2005).

Higher education institutions need more research to verify if their students are making the same progress in traditional, online, and hybrid courses, regardless of the mode of delivery (Kuhn, 2019). Being the pandemic a recent health crisis, research that compares the performance of emergency remote and hybrid teaching with traditional teaching is quite scarce. Contributing to filling this gap, this study compares F2F teaching with both ERT and HT approaches adopted at NOVA IMS as an emergency and temporary solution to cope with the restrictions brought by the COVID-19 pandemic. The results of this study will be useful for the pedagogical council and all the professors from NOVA IMS to understand the impact on students' academic performance when shifting from F2F to ERT and HT and take action for possible improvements.

The research question of this study is to measure whether ERT and HT deliver the same level of effectiveness and quality, or even better when compared with traditional F2F teaching. To conduct this comparison, students' performance is measured by focusing on the students' grades and passing rates. In this way, the research question is formulated as follows:

**RQ:** Are there any differences in Information Management bachelor's degree students' academic performance between the courses delivered in traditional F2F teaching, ERT, and HT?

To answer the RQ, the subsequent research objectives (RO) are defined:

- **RO1:** Understand if the percentage of approvals is similar between F2F, ERT and HT, across the 2nd-semester courses.
- **RO2:** Understand if the percentage of students achieving a specific grade range is similar between F2F, ERT and HT, across the 2nd-semester courses.
- **RO3:** Understand if the percentage of approvals is similar between F2F, ERT and HT, across the 2nd-semester courses, by taking into consideration the year of the program (1, 2, 3).

A dataset containing all the grades from the students at NOVA IMS was collected to do an initial analysis to understand the patterns and to gain insights into students' outcomes across different teaching modes. Then a bachelor's degree program was selected as the focus of this study by aggregating the past three academic years (2018/19; 2019/20; 2020/21) grades from 18 courses from the 2nd-semester. Descriptive methods of data mining and inferential statistics were used to analyze the data collected across different teaching modes.

This master thesis is structured as follows: Chapter 1 introduces the context of the study area and identifies the central topic involved. Chapter 2 reviews the literature on the teaching delivery modes in this study, describes the main supporting technologies for ERT and HT, as well literature on

differences in academic performance between different teaching modes. Chapter 3 details the methodology of the research strategy. Chapter 4 and 5 reports and discusses the results, respectively; Chapter 6 concludes the findings of this research. Chapter 7 outlines the limitations and possible recommendations for future work.

## **2. LITERATURE REVIEW**

Learning Analytics (LA) seeks to collect, analyze, and report student data, find patterns in student behaviour, and display relevant information in suggestive manners. Society of Learning Analytics Research<sup>1</sup> defined LA as “the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environment in which it occurs” (Popescu & Leon, 2018). LA supports several educational tasks: analysis and visualization of data, providing feedback for the instructor, providing recommendations for students, predicting student performance, student modelling, detecting student behaviours, clustering students, planning, and scheduling. This study contributes to understanding if the students’ academic performance was impacted by the transition from traditional F2F teaching to ERT and HT during a pandemic circumstance.

### **2.1. TEACHING MODALITY**

#### **2.1.1. Traditional or F2F Teaching**

There is no generally agreed definition for the existing teaching approaches, different authors might use the same term to refer to two different teaching approaches (Williams et al., 2021). In this study, traditional or F2F teaching is referred to as an approach where the students and lecturers are physically present in the classroom, involving spontaneous verbal communication (Nasution et al., 2021). Before the COVID-19 pandemic, the classes at NOVA IMS were delivered in F2F.

#### **2.1.2. Emergency Remote Teaching**

In remote teaching, the student and the teacher are physically separated (Bergdahl & Nouri, 2021; Rumble, 2019) and the student participates in a planned learning activity (Bergdahl & Nouri, 2021; Holmberg, 1994). The teaching modality offered as the result of the transition to the digital environment due to the COVID-19 pandemic cannot be labelled as “online learning” but “emergency remote teaching” (Hodges et al., 2020; Iglesias-Pradas et al., 2021; Rapanta et al., 2020). The difference between both concepts lies in the fact online learning results from careful instructional design and planning, while ERT emerges as a response to an emergency where the instructional delivery is temporarily shifted to fully remote solutions without time for the teachers to re-design or adjust their teaching methods to meet the new teaching environment (Bergdahl & Nouri, 2021). The key term here is “temporary”, as ERT assumes that teaching will return to the original format once the emergency ends (Iglesias-Pradas et al., 2021). This teaching modality, referred to as ERT, was adopted at NOVA IMS during the rest of the 2nd-semester of the academic year 2019/20 due to the aggravation of the pandemic situation in the country that suspended all F2F classes.

#### **2.1.3. Hybrid Teaching**

HT models vary in scope and form. It may be based on online lectures and F2F discussions, or it may integrate online materials as a complement to F2F classes (Alavi, 1994; Chingos et al., 2017; Scaringella et al., 2022). In this study, HT is referred to as a classroom that connects both on-site and remote students during synchronous teaching (Bergdahl & Nouri, 2021; Scaringella et al., 2022). With the

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<sup>1</sup> <https://solaresearch.org>

emergence and evolution of COVID-19, HT mode was adopted at NOVA IMS in the academic year 2020/21 with the main goal to reduce the number of students inside the faculty while maintaining personal contact. This type of HT was already happening in some European countries as a response to educational needs for students whose absenteeism is related to physical or psychological illness limitations (Bergdahl & Nouri, 2021).

## **2.2. SUPPORTING TECHNOLOGIES IN ERT AND HT**

From the literature, the technologies adopted for remote teaching vary from university to university or even country to country. The most common tools used for real-time video-conferencing were Zoom, Google Meet & Hangout, and Microsoft Teams (Bergdahl & Nouri, 2021; Iglesias-Pradas et al., 2021; Jacques et al., 2021). Most of these tools include chat functions that can be useful when there are problems related to audio or an unstable internet connection.

Regarding real-time video conferencing tools at NOVA IMS, Zoom was the most used to provide synchronous classes. The links and learning materials were made available in a learning management system (LMS), Moodle, that was already being used at the university prior to the COVID-19 pandemic. Students who attended the classes remotely had to connect at the class hour on a given platform – Zoom or Microsoft Teams. To provide the students attending remotely the same learning experience as the on-site students, the university equipped the classrooms with adequate equipment – camera and microphone – so that everyone could see, hear, and interact with each other, minimizing the limitations of distance.

The implementation of ERT and HT requires that students have access to computers or tablets. To ensure that everyone has a device to attend the classes remotely, the students could request computers from the university for a period. Even though most of the students have personal devices.

## **2.3. ACADEMIC PERFORMANCE IN DIFFERENT TEACHING MODES**

Several studies have been conducted to compare academic performance and students' perception across different teaching modes, most of them carried out outside of emergency circumstances, differing from the COVID-19 health crisis. For example, Alducin-Ochoa et al. (2016) conducted an investigation that compared the students' results when trained through traditional teaching and blended teaching, in the School of Technical Architecture of the University of Seville with the students enrolled in the Material Science course. The research aimed to "demonstrate whether the benefits of blended learning could be compared to those achieved by classroom education". The investigation found out the students had more academic success when trained in the blended teaching mode. The methods used were Pearson's coefficient to check the correlation between grades and teaching mode, Student's t-test to compare the averages of the grades, and ANOVA to determine if there are significant differences between the grades.

Goette et al. (2017) compared the academic performance of 114 undergraduate abnormal psychology course students by focusing on whether F2F or blended modalities are associated with student learning outcomes. Data analysis was based on final examination grades and final course grades using the Mann-Whitney U test. The results revealed identical learning outcomes.

Yen et al. (2018) conducted a three-way comparison of traditional, online, and blended teaching approaches in undergraduate Children Development course to determine whether there were differences in students' academic performance and satisfaction across different modalities, using MANOVA (Multivariate Analysis of Variance) and linear regression. It found that students performed equally well, and they were equally satisfied with their learning experiences across three teaching approaches.

Kuhn (2019) conducted research to ascertain whether there were variances in academic performance among the students taking an educational technology course in F2F, online, and hybrid learning environments, in an American university. The students' scores were analyzed using two-way ANOVA and the findings indicated no difference in academic performance by teaching delivery mode.

Existing meta-analyses that compared F2F with distance learning either support that the academic performance is higher in online learning than in F2F courses (Shachar & Yoram, 2003) or no significant differences between both in final course grades (Jahng et al., 2007; Zhao et al., 2005).

The previously mentioned studies were conducted outside of the emergency context. This study focuses on ERT and HT which is a strategy where half of the class attends the classes on-site and the other half remotely through a virtual platform in which the students alternate weekly between attending F2F and remotely. More recently, due to the disruption caused by the COVID-19 pandemic, several studies emerged that compare academic performance when shifting from traditional teaching to ERT/hybrid/blended teaching. For instance, Iglesias-Pradas et al. (2021) analyzed the move ERT at the School of Telecommunication Engineering (Universidad Politécnica de Madrid) using quantitative data from students enrolled in Telecommunication Engineering bachelor's degree. It focused on the impact of organizational aspects, instruction-related variables, and the use of supporting technologies, on students' performance. The results revealed an increase in students' performance under ERT. The statistical methods used include ANOVA and Student's t-test.

Daumiller et al. (2021) compared the semester before shifting to online teaching with the semester with enforced online teaching, during the COVID-19 pandemic, by focusing on the faculty members' achievement goals, attitudes, burnout/engagement, and teaching quality. The results pointed to the relevance of faculty goals and attitudes for successful online teaching.

Ravat et al. (2021) compared blended teaching with traditional teaching on physiotherapy students intending to determine students' theoretical and clinical performance in both teaching modalities. A two-tailed Student's t-test was used to determine if there was a significant difference between the marks obtained. Moreover, students' perceptions of blended teaching during the COVID-19 pandemic were analyzed. The authors concluded that blended teaching improved the theoretical grades, indicating that knowledge acquisition was improved, but no statistically significant difference was found in clinical performance. Most of the students showed a preference for blended teaching over traditional or online teaching methods.

Spencer et al. (2021) through the use of existing grade and student survey data from undergraduate students, investigated the differences in student success rate between F2F and online courses as well the student perceptions of online courses outside of the pandemic situation. The results suggested that students performed better in, and had a preference toward, the F2F teaching format. The overall

perceptions of online courses were positive. Binary logistic regression was used to compare the occurrence of passing grades across the different teaching modalities.

El Said (2021) investigated the effect of the sudden shift from F2F to online distance learning due to the COVID-19 lockdown at an Egyptian university. It compared the grades of 276 students who completed the courses F2F in 2019 and 372 students who completed the same course fully online in 2020. A T-test was used to compare the final grades between the two groups, Chi-square was used to compare the grade distribution for both groups and a two-way ANOVA test was applied to assess the differences between the multiple Grade Point Average (GPA) means. The results indicated no statistically significant difference in students' grades. The author concluded that the unplanned and fast move to distance teaching during the pandemic did not result in a poor learning experience.

The majority of the researchers addressed the comparison of students' performance by measuring factors such as course grades, GPA test scores, and course completion or retention rates (Drysdale et al., 2013; Singh et al., 2016; Spencer & Temple, 2021). In this study, academic performance was measured using students' passing rates and the percentage of students achieving a specific grade range.

Most, or at least part, of the previous studies on online learning, might not be applicable to this situation as we are observing the changes in teaching mode caused by the COVID-19 pandemic under the lens of ERT. Being COVID-19 of a recent pandemic, most of the previous studies were conducted in non-forced transition and produced mixed findings (Drysdale et al., 2013), ranging from better academic performance in blended teaching to similar academic performance between different teaching modes. The results from the previous analyses vary and seem to depend on the type of analysis and the sample of the study (Iglesias-Pradas et al., 2021). For instance, analysis of single courses may provide different results from those that analyse the overall courses.

Table 1 summarizes some more relevant reviews from the literature on the focus of this study. It briefly shows the teaching modes compared, the methodology used and the findings. Some authors compared three teaching modes (F2F, online, blended/hybrid) and others two teaching modes (F2F, ERT/Blended/Online). The studies conducted before 2020 were all under a planned and voluntary shift in teaching mode, while the ones from 2021 are mostly conducted during an emergency. Most of the authors used statistical tests to compare the differences in the students' grades and the results either support no significant differences or improvement in academic performance under remote or blended teaching. From the literature review, it is expected to find either a slight increase in academic performance in ERT and HT or no significant differences in academic performance across different teaching modes. A different result might indicate an unsuccessful implementation of ERT and HT and emphasize the need for careful planning when moving to remote teaching (Iglesias-Pradas et al., 2021).

Table 1 - Literature review summary

| Author                        | Teaching modes compared    | Methodology                                                                                                                                                                                        | Conclusion                                                                                                                                                                                                   |
|-------------------------------|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Alducin-Ochoa et al. (2016)   | F2F vs. Blended            | Pearson's coefficient (correlation between grades and teaching method); Student's t-test (compare the averages of the marks); ANOVA (determine if there are significant differences between marks) | The students had more academic success in blended teaching when compared to F2F teaching.                                                                                                                    |
| Goette et al. (2017)          | F2F vs. Blended            | Mann-Whitney U test (compare final exam grades and final course grades across both teaching modes)                                                                                                 | The same course presented in a F2F and a hybrid modality was associated with nearly identical learning outcomes in terms of student evaluations and final exam scores.                                       |
| Yen et al. (2018)             | F2F vs. Online vs. Blended | MANOVA (compare exam, research papers and final course grades); linear regression (compare students' satisfaction)                                                                                 | The students performed equally well on all three examinations, research paper, and the overall course total grade across three teaching modalities.                                                          |
| Kuhn (2019)                   | F2F vs. Online vs. Hybrid  | 2-way ANOVA (compare project grades)                                                                                                                                                               | No significant difference in the WebQuest scores of students in F2F, online, or hybrid sections of an undergraduate educational technology course.                                                           |
| Iglesias-Pradas et al. (2021) | F2F vs. ERT                | 1-way ANOVA (test differences in grades); t-tests (differences in final grades between courses in 2nd semester of 2019/20 across different variables)                                              | Increase in students' academic performance under ERT.                                                                                                                                                        |
| Ravat et al. (2021)           | F2F vs. Blended            | 2-tailed Student's t-test (difference between grades)                                                                                                                                              | Blended teaching significantly improved the students' theoretical marks in a physiotherapy orthopaedics module, when compared to F2F teaching, but no significant difference in clinical performance.        |
| Spencer et al. (2021)         | F2F vs. Online             | Binary logistic regression (compare the occurrence of passing grades)                                                                                                                              | The overall model found that students are 1.27 times less likely to obtain an ABC (pass) in online courses compared to F2F courses.                                                                          |
| El Said (2021)                | F2F vs. ERT                | T-test (compare quizzes, course work and final exam grades); 2-way ANOVA (compare the difference between GPA means); Chi-square test (compare grade distribution)                                  | No statistically significant difference in students' grades. In addition, the unplanned and rapid move to online distance learning at the time of the pandemic did not result in a poor learning experience. |

### 3. METHODOLOGY

The methodological approach of the thesis is Natural Science, while Positivism is the research philosophy to be followed as the research was based on previous studies. Quantitative research methods are applied in this study.

Descriptive modelling is an unsupervised learning method, meaning that it tries to find relationships between input rather than a specific target variable which is the case of predictive modelling. Its main goal is to extract information and knowledge from large amounts of data to support decision-making and problem-solving. Descriptive modelling was applied in this study as the initial part to understand the data available and based on that understanding, decide on which program to select as the focus for this study.

Statistics is considered as being a collection of mathematical techniques to characterize and interpret data. Statistical methods can be classified as either descriptive or inferential. Descriptive statistics is about describing the sample data on hand, while inferential statistics is about drawing inferences and conclusions about the characteristics of the population based on the findings from a sample (Allua & Thompson, 2009; Sharda et al., 2017). Inferential statistics are based on the process of hypothesis testing and can be classified as either parametric or nonparametric. The selection of the technique depends on the characteristics of the data available.

In this study, both descriptive and inferential methods were used to extract valuable information and knowledge on students' academic performance in the last three academic years when different teaching modalities were experienced by the students.

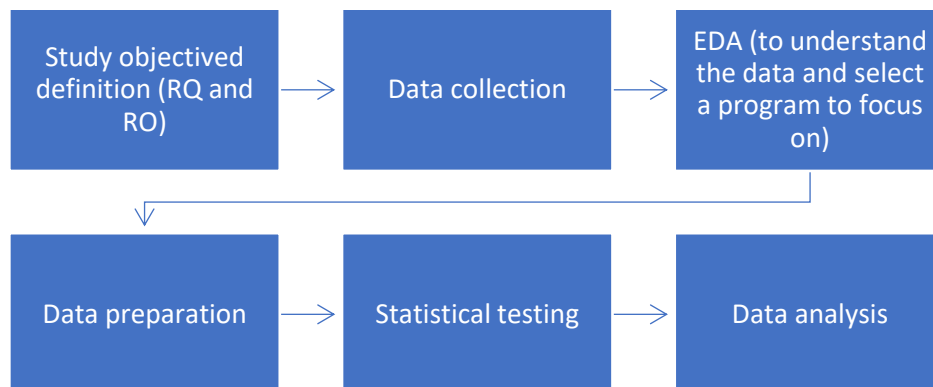


Figure 1 – Methodological steps

The steps represented in Figure 1 and detailed below were performed in this study:

- 1. Data collection** – After having the study objectives defined in Chapter 1, we proceeded to the selection of the necessary data from a database. The study was conducted on students at NOVA IMS from the academic year 2018/19 to 2020/21. In the academic year 2018/19 and the 1st-semester of 2019/20 the classes were delivered in the traditional F2F method, for the rest of the semester of 2019/20 the classes were delivered fully online due to the state of emergency decreed by the Portuguese government, and 2020/21 was the academic year when the HT was adopted by the university. In this way, three data sets containing all student grades from the last three academic years (2018/19 to 2020/21) were provided by the IT department of NOVA IMS to gather all the grades obtained across different teaching modes.
- 2. Exploratory data analysis** – The data sets were anonymously analyzed, having as variables: academic year, degree, program, course, period, year, completion status and final grade. The Exploratory Data Analysis (EDA) proceeded to gain a better understanding of the data sets collected and to uncover initial insights, the relevant relationship between variables and possible data quality problems to be solved in the next phase.
- 3. Data preparation** – This step aims to solve data quality problems and enrich the data sets to maximize the amount of knowledge that can be extracted from them by transforming and creating new variables from the existing ones, and limiting the data set to the program selected to focus on based on the previous step, considering the objectives defined in Chapter 1, and preparing the data to meet the usage requirements of the statistical tests to be applied in the next step.
- 4. Statistical testing** – After having the data preprocessed, data normality was tested using the Shapiro-Wilk test, and then Levene's test was performed to check the homoscedasticity of the groups that came out as normally distributed. Depending on the results from Shapiro-Wilk and Levene's test, ANOVA or Kruskal-Wallis test was applied to determine whether there are significant differences in the percentage of approvals across different academic years as well as by the year of the program, and the percentage of students achieving a specific grade range across the three different teaching modes.
- 5. Data analysis** – This step corresponds to Chapter 4 and displays the main results from the exploratory analysis and statistical tests. Afterwards, the RQ and RO were answered in Chapter 5 along with the comparisons of the results and patterns with the findings from the previous studies.

The EDA and statistical tests were performed using Jupyter Notebook (version 6.1.4) and Python language (version 3.8).

### 3.1. DATA COLLECTION

The data sets were provided by the IT department of the university. NOVA IMS offers a wide range of programs ranging from Bachelor, Postgraduate, Master, and Doctoral degrees. In the past three academic years – 2018/19, 2019/20 and 2020/21 – NOVA IMS had 1922, 2145 and 2417 students enrolled, respectively. For this study, all the courses from Bachelor, Postgraduate and Master were included in EDA, except the Doctoral programs and the students who were enrolled in some courses without being enrolled in a program. The sample collected is composed of three data sets containing all the final grades of the students from two bachelor's degrees, six master's degree programs (each with several specializations), and 21 postgraduate programs. It also includes the grades from the mobility students who were attending a mobility program at the university (Erasmus, exchange). The scale of the final grade is from 0 to 20 values, where a final grade below 10 values means reproval.

The data sets collected are composed as the following table:

Table 2 - Data sets' composition

| Data set name   | Academic year | Number of records | Teaching mode |
|-----------------|---------------|-------------------|---------------|
| <b>Dataset1</b> | 2018/19       | 11,554            | F2F           |
| <b>Dataset2</b> | 2019/20       | 13,721            | F2F + ERT     |
| <b>Dataset3</b> | 2020/21       | 15,618            | HT            |

Each of the data sets is composed of the following variables:

Table 3 - Data sets' variables

| Variable             | Description                                                          | Data type | Example data                      |
|----------------------|----------------------------------------------------------------------|-----------|-----------------------------------|
| <b>Academic year</b> | Academic year of the final grade                                     | Ordinal   | 2018/19; 2019/20; 2020/21         |
| <b>Degree</b>        | Academic degree given to a student after the completion of a program | Nominal   | Bachelor; Master; Post-graduation |
| <b>Program</b>       | Program                                                              | Nominal   | Master in Information Management  |
| <b>Course</b>        | Curricular unit                                                      | Nominal   | Business Intelligence I           |
| <b>Period</b>        | Period of the year                                                   | Nominal   | S1; S2                            |
| <b>Year</b>          | Year of the program                                                  | Ordinal   | 1; 2; 3                           |
| <b>Status</b>        | Curricular unit completion status                                    | Nominal   | Approved; Reproved                |
| <b>Grade</b>         | Student final grade for a curricular unit                            | Discrete  | 18                                |

### 3.2. EXPLORATORY DATA ANALYSIS

Three datasets were merged before importing into the Jupyter notebook to conduct the exploratory analysis.

Table 4 - Descriptive statistics of numerical variable by academic year

| Variable | Academic Year | Count  | Count % | Mean  | Median | Min | Max | SD   | Mode | Skew  | Kurtosis |
|----------|---------------|--------|---------|-------|--------|-----|-----|------|------|-------|----------|
| Grade    | 2018/19       | 11,554 | 28.25   | 14.40 | 15     | 0   | 20  | 3.63 | 16   | -1.51 | 3.19     |
|          | 2019/20       | 13,721 | 33.55   | 14.80 | 16     | 0   | 20  | 3.74 | 16   | -1.93 | 4.66     |
|          | 2020/21       | 15,618 | 38.19   | 14.93 | 16     | 0   | 20  | 3.72 | 17   | -1.81 | 4.30     |

From Table 4 it is possible to verify the mean of the final grades increased slightly from 14.40 in 2018/19, to 14.80 and 14.93 in the following two academic years. The median increased from 15 in 2018/19 to 16 in the following two academic years, while the mode remained at 16 in 2018/19 and 2019/20 and it increased to 17 in the next academic year. The skewness of the three academic years is all negative meaning that the distribution of the final grades is left-skewed (the left tail is longer), therefore the mean value is smaller than the median and mode. The positive kurtosis values ( $>3$  leptokurtic) indicate that the distribution of the final grades is peaked and has tick tails (Figure 2).

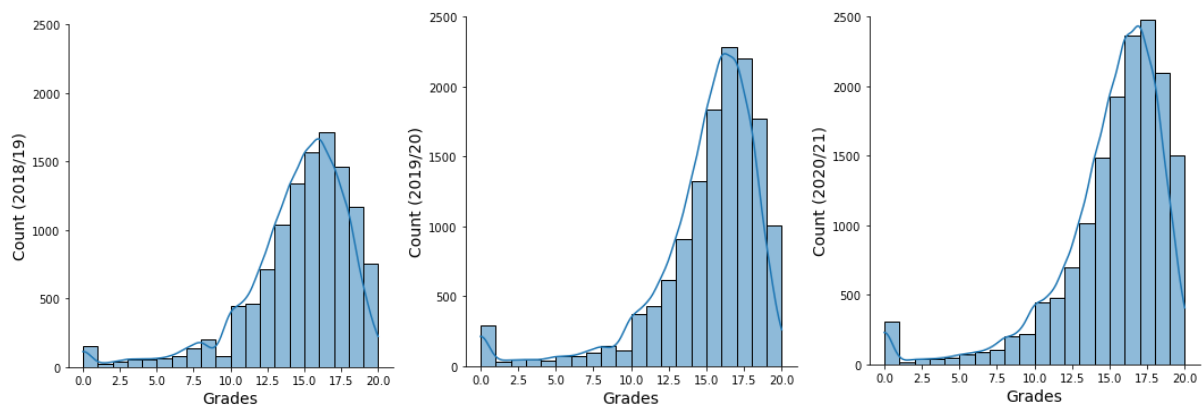


Figure 2 – Count of grades obtained by the students in each academic year

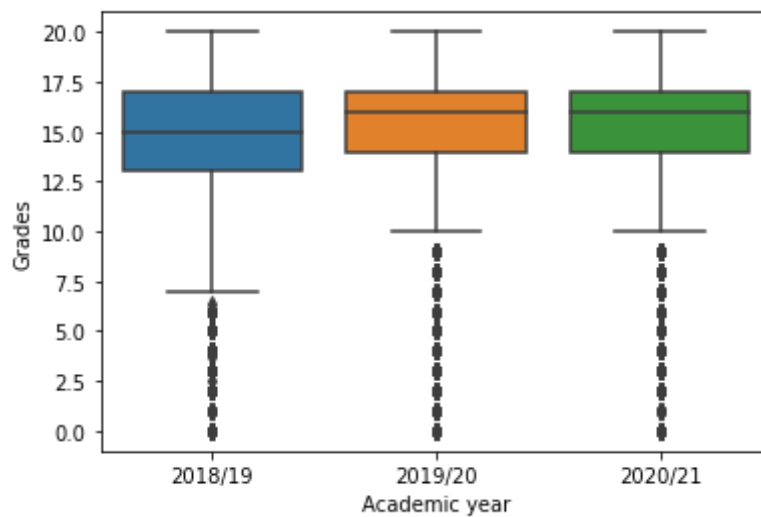


Figure 3 - Grades distribution by academic year

Figure 3 shows that the overall distributions of the grades across three academic years are similar, except for the academic year 2018/19 which presents lower minimum and median values when compared to the following two academic years.

Table 5 - Descriptive statistics of categorical variables by academic year

| Academic Year | Variable | Count  | Unique | Top                                | Frequency |
|---------------|----------|--------|--------|------------------------------------|-----------|
| 2018/19       | Degree   | 11,554 | 4      | Master                             | 3,868     |
|               | Program  |        | 30     | Bachelor in Information Management | 2,458     |
|               | Course   |        | 379    | Research Methodologies             | 178       |
|               | Period   |        | 2      | S1                                 | 5,957     |
|               | Year     |        | 3      | 1                                  | 8,913     |
|               | Status   |        | 2      | Approved                           | 10,668    |
| 2019/20       | Degree   | 13,721 | 4      | Master                             | 5,619     |
|               | Program  |        | 28     | Master in Information Management   | 2,857     |
|               | Course   |        | 322    | Research Methodologies             | 238       |
|               | Period   |        | 2      | S1                                 | 7,307     |
|               | Year     |        | 3      | 1                                  | 11,103    |
|               | Status   |        | 2      | Approved                           | 12,766    |
| 2020/21       | Degree   | 15,618 | 4      | Master                             | 7,553     |
|               | Program  |        | 27     | Master in Information Management   | 3,379     |
|               | Course   |        | 316    | Research Methodologies             | 340       |
|               | Period   |        | 2      | S1                                 | 8,277     |
|               | Year     |        | 3      | 1                                  | 13,108    |
|               | Status   |        | 2      | Approved                           | 14,497    |

From the descriptive statistics (Table 5), the overall dataset is mostly composed of master's students' grades, followed by bachelor's and postgraduates. The same pattern is verified when the dataset is sorted by academic year, except for the academic year 2019/20 when the number of postgraduate students' grades is higher than bachelor's. Most of the students concluded the curricular units with an approved status. In-depth (Table 6), in the academic year 2018/19, approximately 92.33% of students approved the curricular units and 7.67% reproved; in 2019/20, 93.04% of students approved and 6.69% reproved; in 2020/21, 92.82% approved and 7.18% reproved. The course completion rate throughout the three academic years was stable, with small variations.

Table 6 - Percentage of approvals and reprovals by academic year

| Status   | 2018/19 | 2019/20 | 2020/21 |
|----------|---------|---------|---------|
| Approved | 92.33%  | 93.04%  | 92.82%  |
| Reproved | 7.67%   | 6.96%   | 7.18%   |

### ***Average grade by degree***

From Table 7 we can observe the mean grade for bachelor's, post-graduation and master's degrees increased slightly over the three academic years. For the mobility category, the mean grade decreased from 2018/19 to 2019/20 and increased in 2020/21. This oscillation can be due to the continuously decreasing number of mobility students caused by the restrictions on travelling during the COVID-19 pandemic, affecting the Erasmus and exchange students.

Table 7 - Descriptive statistics of grades by academic year and degree

| Academic Year | Degree          | Mean  | Median | Mode | SD   | Count % |
|---------------|-----------------|-------|--------|------|------|---------|
| 2018/19       | Bachelor        | 13.54 | 14     | 16   | 3.84 | 33.48   |
|               | Post-graduation | 15.11 | 16     | 16   | 3.17 | 29.54   |
|               | Master          | 14.67 | 15     | 15   | 3.60 | 34.52   |
|               | Mobility        | 13.76 | 14     | 14   | 3.75 | 2.45    |
| 2019/20       | Bachelor        | 13.94 | 15     | 16   | 4.11 | 27.97   |
|               | Post-graduation | 15.57 | 16     | 16   | 3.07 | 29.40   |
|               | Master          | 14.92 | 16     | 16   | 3.78 | 40.95   |
|               | Mobility        | 13.51 | 14     | 16   | 3.82 | 1.68    |
| 2020/21       | Bachelor        | 14.05 | 15     | 16   | 4.22 | 27.38   |
|               | Post-graduation | 15.58 | 16     | 17   | 3.20 | 23.11   |
|               | Master          | 15.13 | 16     | 17   | 3.57 | 48.36   |
|               | Mobility        | 14.37 | 15     | 15   | 3.45 | 1.15    |

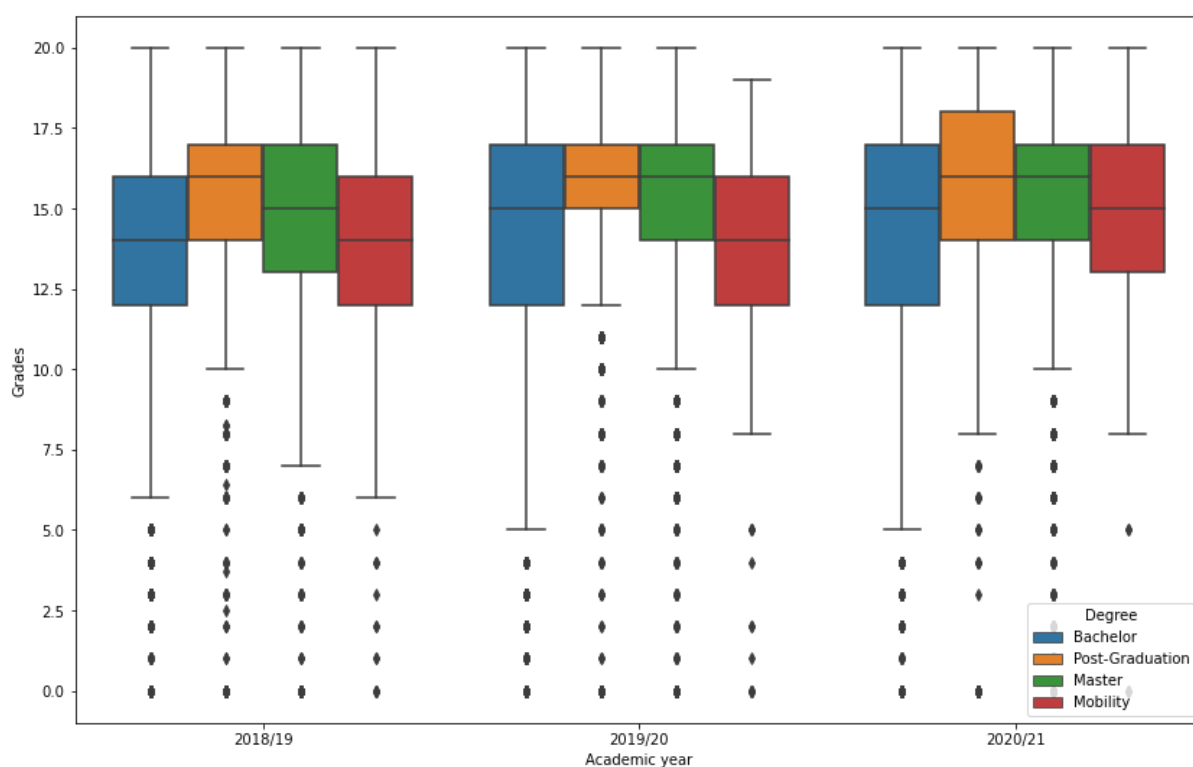


Figure 4 - Grades distribution by degree and academic year

The grades distribution across different degrees (Figure 4) maintained similar in three academic years, with slight differences in postgraduate students' grades.

Table 8 - Percentage of approvals and reprovals by degree and academic year

| Status   | Degree          | 2018/19 | 2019/20 | 2020/21 |
|----------|-----------------|---------|---------|---------|
| Approved | Bachelor        | 88.24   | 89.21   | 88.21   |
|          | Post-Graduation | 95.87   | 96.48   | 95.87   |
|          | Master          | 93.31   | 93.42   | 93.98   |
|          | Mobility        | 91.90   | 87.39   | 92.74   |
| Reproved | Bachelor        | 11.76   | 10.79   | 11.79   |
|          | Post-Graduation | 4.13    | 3.52    | 4.13    |
|          | Master          | 6.69    | 6.58    | 6.02    |
|          | Mobility        | 8.10    | 12.61   | 7.26    |

When analyzing the percentage of approvals by degree (Table 8), it is possible to verify that different degrees had different evolution throughout the three academic years. The percentage of students passing a course from bachelor's and post-graduation degrees increased from 2018/19 to 2019/20 and decreased in the next academic year. For the master's degree, the percentage of approvals continuously increased throughout the three academic years. Regarding the mobility students, the approval percentage decreased significantly from 2018/19 to 2019/20 and increased significantly in the next academic year.

### ***Average grade by program***

Analyzing the grades per program, the majority registered an increase in the average grade throughout the three academic years. In a more detailed analysis, bachelor's programs' mean grades have increased throughout the three academic years. The master programs mean grade also registered an increase from 2018/19 to 2020/21, except for *Master of Science in Geospatial Technologies* and *Master in Data Science and Advanced Analytics*. Regarding the post-graduation programs, from 2018/19 to 2020/21, around 69% of the programs' mean grades increased.

This analysis found that there are some courses that only existed in one or two of the academic years. These courses were removed since making the comparison unreasonable.

### ***Average grade by semester***

Comparing the 1st-semester across the three academic years (Table 9), the mean grade increased from 14.16 to 14.58 in 2019/20, and 14.86 in 2020/21 when the classes were delivered in hybrid mode. The 2nd-semester registered a similar evolution that increased from 14.64 to 15.09 in 2019/20 and a slight decrease of 0.08 in 2020/21.

Table 9 - Descriptive statistics of grades by academic year and semester

| Academic Year | Semester | Mean  | Median | Mode | SD   | Count % |
|---------------|----------|-------|--------|------|------|---------|
| 2018/19       | 1        | 14.16 | 15     | 16   | 3.62 | 51.56   |
|               | 2        | 14.64 | 15     | 16   | 3.62 | 48.44   |
| 2019/20       | 1        | 14.58 | 15     | 16   | 3.72 | 53.25   |
|               | 2        | 15.09 | 16     | 17   | 3.75 | 46.75   |
| 2020/21       | 1        | 14.86 | 16     | 17   | 3.67 | 53.00   |
|               | 2        | 15.01 | 16     | 17   | 3.78 | 47.00   |

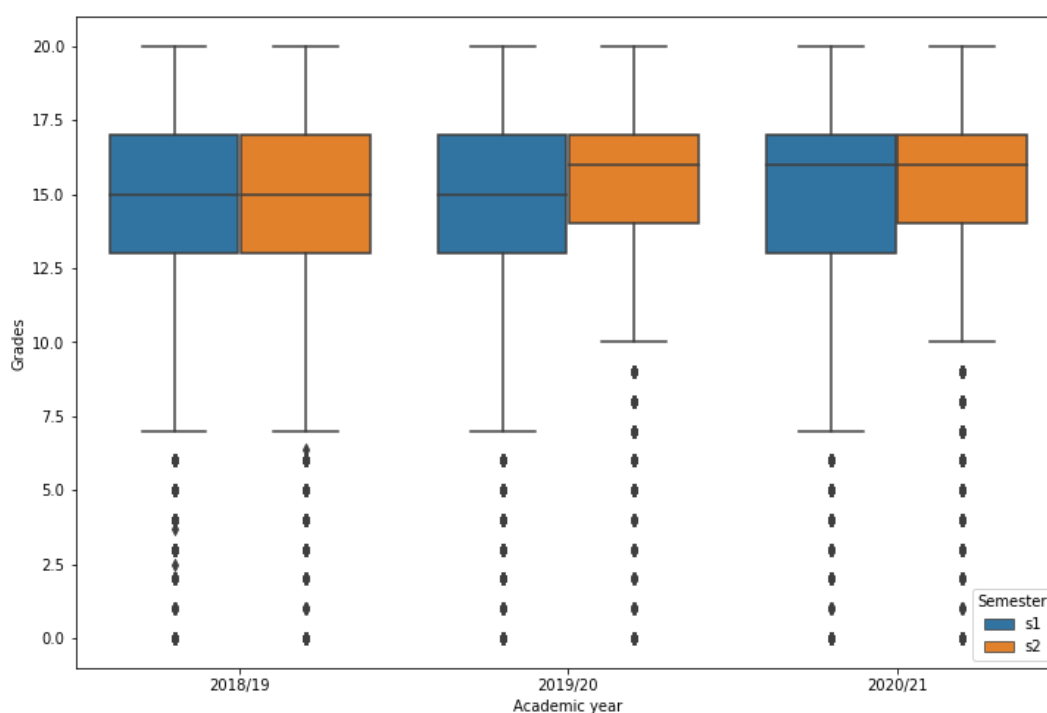


Figure 5 - Grades distribution by semester and academic year

Figure 5 shows the grades are similar between the 1st and 2nd-semester of the academic year 2018/19. Observing the academic year 2019/20, the 1st-semester grades remained similar to the previous academic year, while in the 2nd-semester the median of the final grades increased from 15 to 16, and the minimum also increased from 7.5 to 10. Important to note that the rest of the 2nd-semester was conducted in ERT mode, where all the classes and exams were conducted remotely. In the academic year, 2020/21 the characteristics of the grades of both semesters remained similar to the previous academic year, except the median grade of the 1st-semester increased from 15 to 16.

Table 10 - Percentage of approvals and reprovals by semester and academic year

| Status          | Semester | 2018/19 | 2019/20 | 2020/21 |
|-----------------|----------|---------|---------|---------|
| <b>Approved</b> | <b>1</b> | 91.42   | 92.30   | 92.87   |
|                 | <b>2</b> | 93.30   | 93.89   | 92.77   |
| <b>Reproved</b> | <b>1</b> | 8.58    | 7.70    | 7.13    |
|                 | <b>2</b> | 6.70    | 6.11    | 7.23    |

Table 10 shows an increase (0.88 and 0.57 percentual points) in the percentage of students passing the course during the 1st-semester from 2018/19 to 2020/21. Analyzing the 2nd-semester, the passing percentage increased by 0.59 percentual points from 2018/19 to 2019/20 and decreased by 1.12 percentual points from 2019/20 to 2020/21. For the first two academic years, the 2nd-semester was the semester with the highest percentage of approval. While in the last academic year, under HT, the pattern was different, the students performed slightly better in the 1st-semester.

### ***Average grade by year of the program***

Analyzing the grades by year of the program across the three academic years (Table 11), an increase was verified in all three years. In the first-year of 2018/19, the mean grade was 14.58 and increased to 14.94 and 14.96 in the following two academic years. For the second-year, the mean grade was 13.20 in 2018/19 and increased to 13.68 and 14.46 in the following two academic years. Concerning the third-year, which is only taken by bachelor students, the mean grade was 14.49 in 2018/19 and increased to 14.99 and 15.18 in the subsequent two academic years. The median and the mode of the grades also increased throughout the three academic years.

The first-year is the year with the most grades released since it includes students from all degrees, then is the second-year, which only includes the grades from bachelor and master students and the master's students only have to conduct the thesis. Finally, the third-year is the year with the least grades released as the bachelor's is the only three-year degree at NOVA IMS.

Table 11 - Descriptive statistics of grades by academic year and year of the program

| <b>Academic Year</b> | <b>Year</b> | <b>Mean</b> | <b>Median</b> | <b>Mode</b> | <b>SD</b> | <b>Count %</b> |
|----------------------|-------------|-------------|---------------|-------------|-----------|----------------|
| <b>2018/19</b>       | <b>1</b>    | 14.58       | 15            | 16          | 3.60      | 77.14          |
|                      | <b>2</b>    | 13.20       | 14            | 15          | 3.78      | 12.36          |
|                      | <b>3</b>    | 14.49       | 15            | 16          | 3.35      | 10.50          |
| <b>2019/20</b>       | <b>1</b>    | 14.94       | 16            | 16          | 3.74      | 80.92          |
|                      | <b>2</b>    | 13.68       | 14            | 15          | 3.81      | 10.43          |
|                      | <b>3</b>    | 14.99       | 16            | 18          | 3.43      | 8.65           |
| <b>2020/21</b>       | <b>1</b>    | 14.96       | 16            | 17          | 3.78      | 83.93          |
|                      | <b>2</b>    | 14.46       | 15            | 16          | 3.32      | 8.46           |
|                      | <b>3</b>    | 15.18       | 16            | 17          | 3.46      | 7.61           |

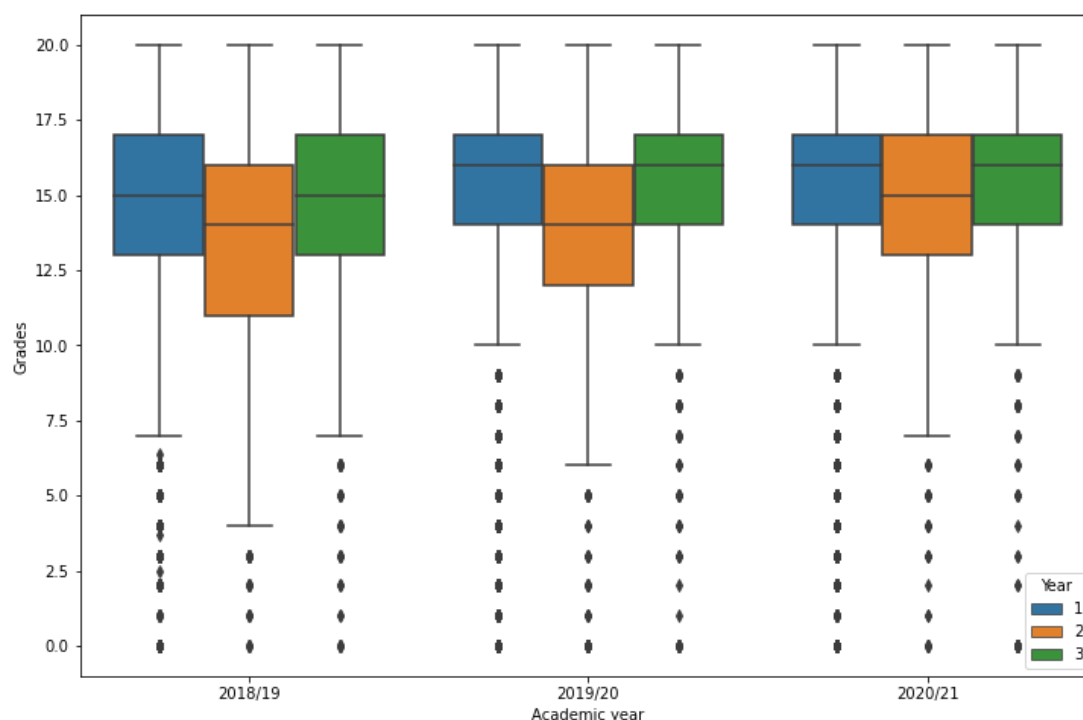


Figure 6 - Grades distribution by year of the program and academic year

By analysing the boxplots in Figure 6, the grades distribution from 2019/20 and 2020/21 are more similar than compared with 2018/19, except for the second-year.

Table 12 - Percentage of approvals and reprovals by year and academic year

| Status   | Year | 2018/19 | 2019/20 | 2020/21 |
|----------|------|---------|---------|---------|
| Approved | 1    | 93.01   | 93.32   | 92.74   |
|          | 2    | 86.70   | 90.15   | 91.83   |
|          | 3    | 93.98   | 93.93   | 94.78   |
| Reproved | 1    | 6.99    | 6.68    | 7.26    |
|          | 2    | 13.30   | 9.85    | 8.17    |
|          | 3    | 6.01    | 6.07    | 5.22    |

Analyzing the students passing percentage by year of the program (Table 12), the first-year approval percentage increased from 2018/19 to 2019/20 and decreased in the next academic year. In the second-year, the passing percentage increased significantly and continuously from 2018/19 to 2020/21. The third-year followed a different evolution, in which the percentage of approval decreased slightly from 2018/19 to 2019/20 and increased significantly from 2019/20 to 2020/21. For the three academic years, the year with the highest percentage of approvals was the third, followed by first, then second.

### 3.3. DATA PREPARATION

After inspection of the data sets, this study decides to focus on the Information Management bachelor's degree at NOVA IMS, since it has more in common courses across the three academic years in analysis. A separate dataset containing the 2nd-semester course-level aggregated student grades from the Information Management bachelor's degree was prepared. This study only focuses on the courses from the 2nd-semester as the academic year 2019/20 was taught in 2 different methods due to the state of emergency decreed during the COVID-19 pandemic. More precisely, the 1st-semester courses were delivered in F2F, the 2nd-semester started on February 10<sup>th</sup>, 2020, and until March 16<sup>th</sup>, 2020, the classes were delivered in F2F and then were moved to ERT.

The courses taken by the students who were in a mobility program were removed as they did not attend the classes at NOVA IMS during their mobility period. Since the number of students in each course may differ, to make comparisons possible, the relative rates (percentage of approvals and percentage of students achieving a specific grade range) were calculated for each course (Iglesias-Pradas et al., 2021).

The identification of outliers was made, as outliers are extreme values that do not follow the trend of the remaining data (Larose, 2015). It is important to remove these extreme values since they can impact the distribution of the data, generating unreliable results. One non-mandatory course was removed since it contains very few students enrolled.

Table 13 shows the new data set that is composed of three groups containing the 2nd-semester courses approval rate and the number of students achieving a specific grade range from the past three academic years (2018/19; 2019/20; 2020/21).

Table 13 – New data set composition

| Group   | Description                                                                        | Teaching mode | N courses |
|---------|------------------------------------------------------------------------------------|---------------|-----------|
| 18/19s2 | Course-level aggregated grades from academic year 2018/19 2 <sup>nd</sup> semester | F2F           | 18        |
| 19/20s2 | Course-level aggregated grades from academic year 2019/20 2 <sup>nd</sup> semester | F2F + ERT     | 18        |
| 20/21s2 | Course-level aggregated grades from academic year 2020/21 2 <sup>nd</sup> semester | HT            | 18        |

### 3.4. STATISTICAL TESTING

To test the differences in academic performance across the three academic years, one-way ANOVA and Kruskal-Wallis test were used depending on the characteristics of the group. One-way ANOVA is a parametric test that determines whether the groups' means in comparison are equal (Gelman, 2005). It tests the following hypothesis:

**H<sub>0</sub>:** The mean value of the students' approval rate is equal across the three teaching modes.

**H<sub>1</sub>:** There is at least one teaching mode with a different mean value of the students' approval rate.

**H<sub>0</sub>:** The mean value of the percentage of students achieving a specific grade range is equal across the three teaching modes.

**H<sub>1</sub>:** There is at least one teaching mode with a different mean value of the percentage of students achieving a specific grade range.

**H<sub>0</sub>:** The mean value of the students' approval rate by year of the program is equal across the three teaching modes.

**H<sub>1</sub>:** There is at least one teaching mode with a different mean value of the students' approval rate by year of the program across the three teaching modes.

ANOVA assumes (i) that the groups and the observations used are independent, (ii) the groups originated from normal populations and (iii) homogeneity of variance of the populations. The first requirement is verified since it is assumed that students of the different courses from one specific academic year and semester are not the same as the ones from the next academic year and semester. To check if the groups come from normal populations (second requirement), the normality test named Shapiro Wilk test (1965) was performed for each group to test the following hypothesis:

**H<sub>0</sub>:** The group comes from a normally distributed population.

**H<sub>1</sub>:** The group does not come from a normally distributed population.

Regarding the third requirement, Levene's test (1960) was performed to verify the homoscedasticity of the different populations by testing the following hypothesis:

**H<sub>0</sub>:** The populational variance is equal across the groups.

**H<sub>1</sub>:** The populational variance is not equal across the groups.

For the groups in that normality is not verified, a non-parametric test was chosen. The statistical test chosen to be applied is the Kruskal-Wallis test (Gonzalez et al., 2020), proposed by Kruskal and Wallis in 1952, which is a non-parametric equivalent to the ANOVA method for testing whether groups originated from the same distribution. It does not assume the normal distribution of the data and it extends the Mann-Whitney U test to more than two groups. Kruskal-Wallis test assumes that the (i) groups drawn from the population are random, the (ii) observations are independent of each other and the (iii) measurement scale for the dependent variable is ordinal, ratio or interval (Kruskal & Wallis, 1952). Essentially, the test determines if the medians of the groups in comparison are equal across the three academic years. The following hypothesis are defined to test Kruskal-Wallis:

**H<sub>0</sub>:** The median value of the students' approval rate is equal across the three teaching modes.

**H<sub>1</sub>:** There is at least one teaching mode with a different median value of the students' approval rate.

**H<sub>0</sub>:** The median value of the percentage of students achieving a specific grade range is equal across the three teaching modes.

**H<sub>1</sub>:** There is at least one teaching mode with a different median value of the percentage of students achieving a specific grade range.

**H<sub>0</sub>:** The median value of the students' approval rate by year of the program is equal across the three teaching modes.

**H<sub>1</sub>:** There is at least one teaching mode with a different median value of the students' approval rate by year of the program across the three teaching modes.

For all the hypotheses defined, if the  $p$ -value is less than the chosen alpha level, then the null hypothesis is rejected. On the other hand, if the  $p$ -value is greater than the chosen alpha level, then the null hypothesis cannot be rejected. Upon rejection of the ANOVA and Kruskal-Wallis test null hypothesis, it would be necessary to conduct multiple pairwise comparisons to identify which groups differ from each other (Dinno, 2015).

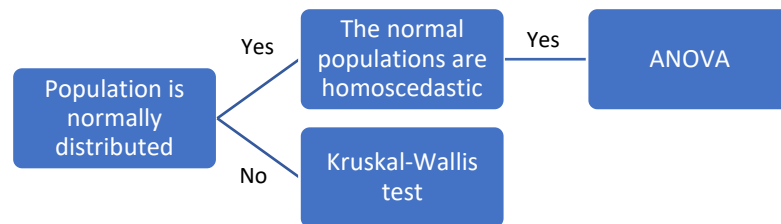


Figure 7 - Statistical test selection process

## **4. DATA ANALYSIS**

The program under analysis in this study is the Information Management bachelor's degree. It is a 3-year program, each year is composed of two semesters. The first two years and the 1st-semester of the third-year the courses are all mandatory that are common for all the students. While in the 2nd-semester of the third-year, the student can choose among a wide range of courses available to take. Being the 2nd-semester of the third-year courses non-mandatory, the student can opt to participate in an Erasmus program. The study plan is composed of 180 ECTS, of which 150 ECTS correspond to mandatory courses and 30 ECTS correspond to optional courses (last semester of the program). Each academic year, around 65 new students are admitted to the program. In the first-year, the student has in total 12 mandatory courses, 6 courses in each semester; in the second-year the students have 10 mandatory courses, 5 courses in each semester; in the 1st-semester of third-year the students have 6 mandatory courses and, in the 2nd-semester the student has to choose a number of optional courses to obtain the necessary 30 ECTS.

Traditionally, all the courses are delivered F2F. Until the 2nd-semester of the academic year 2019/20 all the courses were F2F, and with the aggravation of the COVID-19 pandemic situation, all the classes and evaluations were moved to online (ERT) until the end of the academic year. In the next academic year, 2020/21, it was announced the adoption of HT at NOVA IMS. Since the ERT happened in the 2nd-semester of 2019/20, this study focuses on the 2nd-semester courses across the three academic years. Additionally, due to the technology-oriented program, most – if not all – students are proficient in the use of digital technologies and own laptops, which mitigates the potential impacts of remote teaching.

### **4.1. DIFFERENCES IN THE PERCENTAGE OF STUDENTS PASSING THE COURSE**

The percentage of students passing each course versus the number of students across the 2nd-semester of the three academic years, differentiating between mandatory and optional courses were plotted in Figure 8. For the optional courses, the passing rate was always 100%, except for 1 course in 2018/19, two courses in 2019/20, and three in 2020/21. Even though, those courses have a passing rate higher or equal to 90%. Important to note, during the semester of ERT and HT, more students were taking the optional courses, due to the COVID-19 pandemic restrictions fewer students were opting to participate in the Erasmus program. Regarding the mandatory courses, no significant differences were found. In 2018/19 two courses had a passing rate equal to and below 80%, in 2019/20 only one course with a passing rate of approximately 80%, and in 2020/21 there were three courses with a passing rate equal to or below 80%.

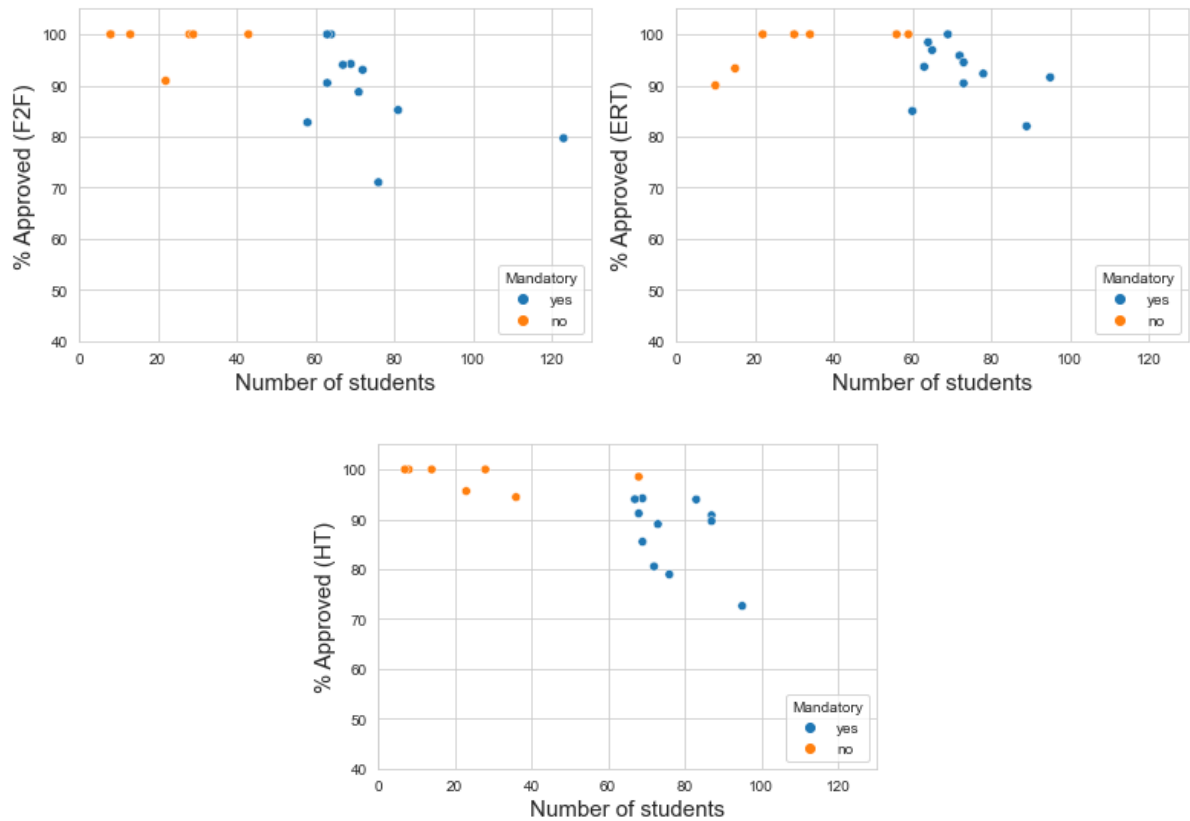


Figure 8 - Number of students vs. percentage of students who passed the course across three academic years by the electiveness of the courses

When analysing the differences in the passing rates across different teaching modes (Figure 9), no significant differences were found. The mean and median passing rates for 2018/19, 2019/20, and 2020/21 were 93%, 94%; 95% for both mean and median; and 92%, 94%, respectively. The passing rate in the 2nd-semester of 2019/20 (ERT) was less spread across the courses.

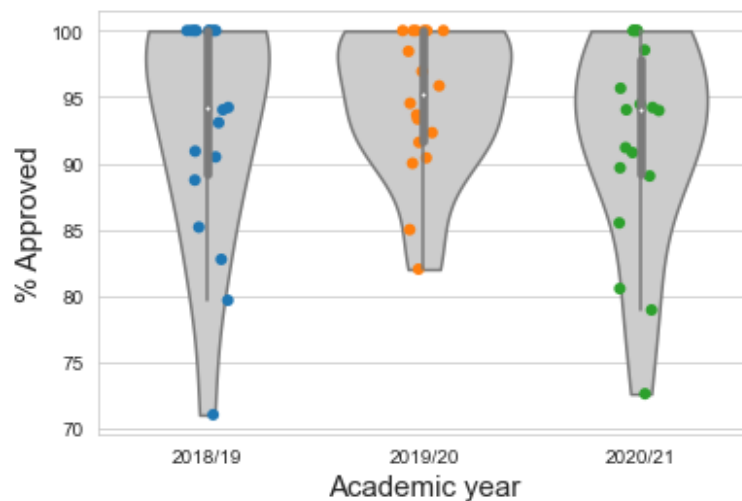


Figure 9 - Differences in the percentage of students passing the course across three academic years

The number of students in non-mandatory courses is typically lower than in mandatory courses, thus the analysis of the global data will be complemented by a separate analysis of the electiveness of the

courses. Figure 10 reveals that when the electiveness is accounted for, no significant differences were found across the three academic years in the study. The mean and median for the mandatory courses were 89%, 90% (2018/19); 92%, 94% (2019/20); and 87%, 90% (2020/21), respectively. It is visible in the violin plots that the maximum passing rate in the mandatory courses decreased in the semester of HT from 100% to approximately 95%. Concerning the non-mandatory courses, the mean passing rate in the 2nd-semester of 2018/19 was 99% and 98% for the following two academic years. The median was maintained at 100% across the three academic years.

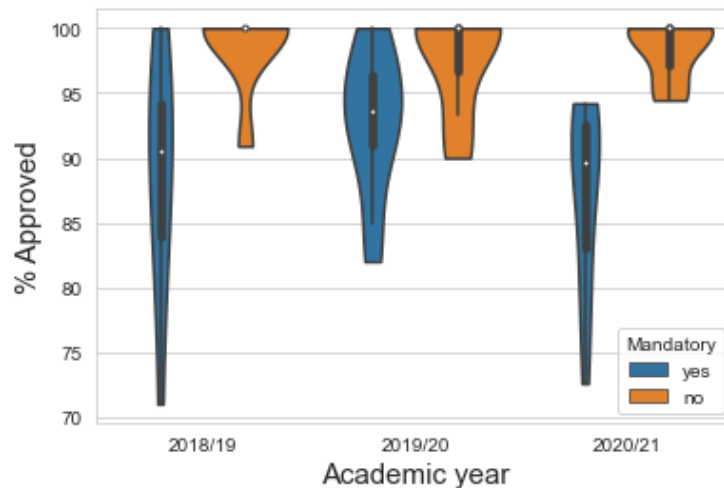


Figure 10 - Differences in the percentage of students passing the course across three academic years by electiveness of the courses

As previously mentioned in Sub-chapter 3.4, the Shapiro-Wilk test was applied to check the normality of the groups. Considering a  $\alpha = 5\%$ , the  $H_0$  is rejected for all the groups regarding the approval rate since the  $p$ -values are lower than 0.05 (Table 14). There is evidence that the  $H_0$  is invalid, meaning the groups does not come from a normally distributed population. In this way, to test the statistical differences, we proceeded with the Kruskal-Wallis test. Considering a  $\alpha = 5\%$ , the  $H_0$  is not rejected as the  $p$ -value is higher than the significance level of 0.05 (Table 15). Thus, there is no evidence to state that there are differences, statistically significant, between the median of the percentage of approvals across the different teaching modes.

Table 14 - Shapiro-Wilk test results for the percentage of students passing the course

| Group             | Statistic | $p$ -value | Conclusion   |
|-------------------|-----------|------------|--------------|
| 18/19s2_approvals | 0.83      | 0          | Reject $H_0$ |
| 19/20s2_approvals | 0.88      | 0.02       | Reject $H_0$ |
| 20/21s2_approvals | 0.89      | 0.04       | Reject $H_0$ |

Table 15 - Kruskal-Wallis test result for the percentage of students passing the course

| Groups      | Statistic | $p$ -value | Conclusion         |
|-------------|-----------|------------|--------------------|
| % approvals | 1.12      | 0.57       | Don't Reject $H_0$ |

## 4.2. DIFFERENCES IN THE PERCENTAGE OF STUDENTS IN DIFFERENT GRADE RANGES

This section explores the data on a per-grade basis across all courses. The grades were categorized into 4 categories: [10-12], [13-15], [16-18], [19-20]. The mean and median percentage of students achieving grade range [10-12] in 2018/19, 2019/20, and 2020/21 were 15%, 13%; 14%, 8%; and 9%, 1%, respectively. Analyzing Figure 11, the number of courses with a percentage of students achieving between 10 and 12 values decreased (between 5 and 6 percentual points for the mean; between 7 and 12 percentual points for the median) in 2020/21 under HT when compared to the previous two academic years. While the percentage of students achieving a grade higher than 18 values increased in some courses in 2019/20 (ERT) and, more significantly, in 2020/21 (HT). The mean percentage of students achieving a grade higher than 18 increased approximately between 1 and 7 percentual points from 2018/19 to 2019/20 and 2019/20 to 2020/21, respectively. Additionally, it is clear from the violin plots that the tail of the distribution has become flatter over the three academic years, meaning that there are more courses with students achieving grades higher than 18 values. The remaining grade ranges stayed similar across the different teaching modes.

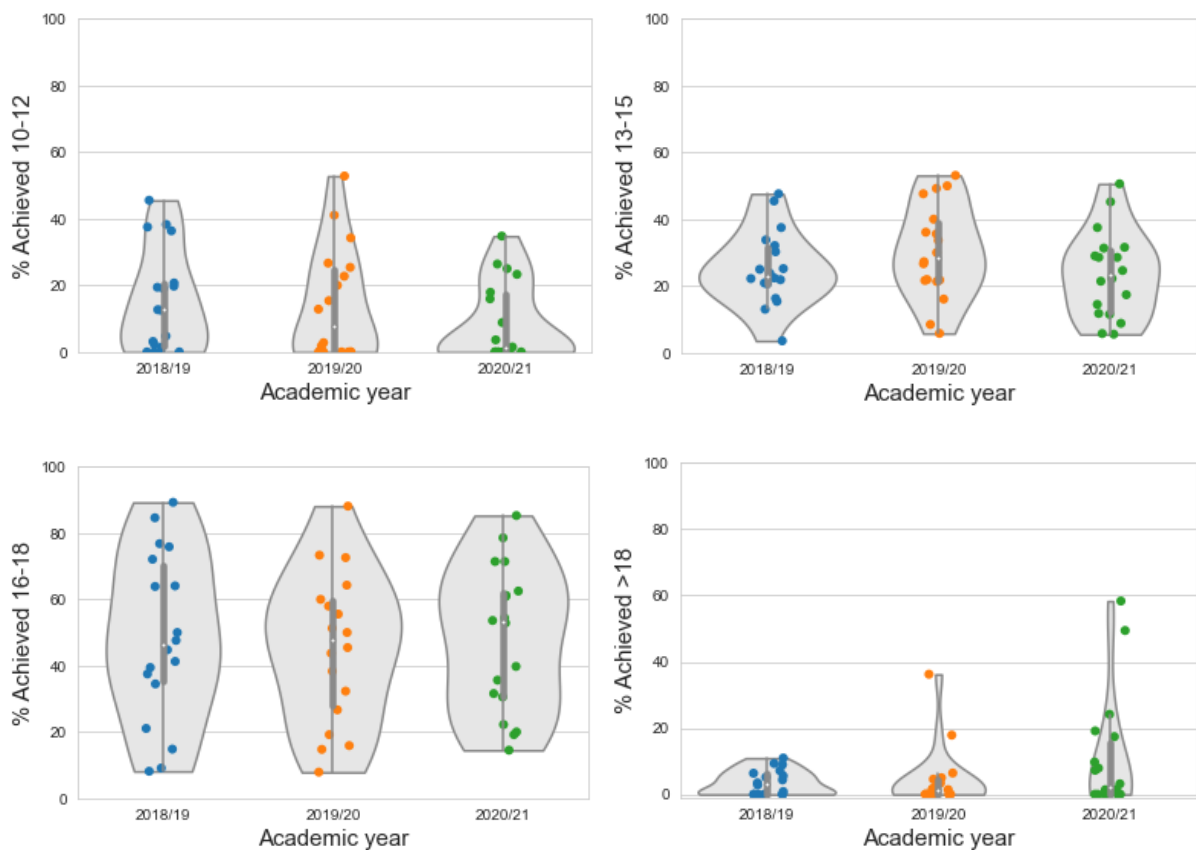


Figure 11 - Differences in the percentage of students in different grade ranges across three academic years

When the electiveness of the courses is accounted for (Figure 12), the differences are sustained across non-mandatory courses that had less percentage of students achieving [10-12] grade range from 2018/19 to 2020/21. The distribution has become flatter (platykurtic) over the three academic years for the percentage of students who achieved [10-12] in mandatory courses. While the differences verified in the grade range >18 values are visible in both mandatory and optional courses. Analysing

the category [16-18] for the mandatory courses, the maximum percentage decreased over the three academic years (from 77% to 61%), while the minimum percentage increased in the last academic year (HT). For the non-mandatory courses, the minimum percentage increased from 9% to 30% of students achieving [16-18] throughout the three academic years.

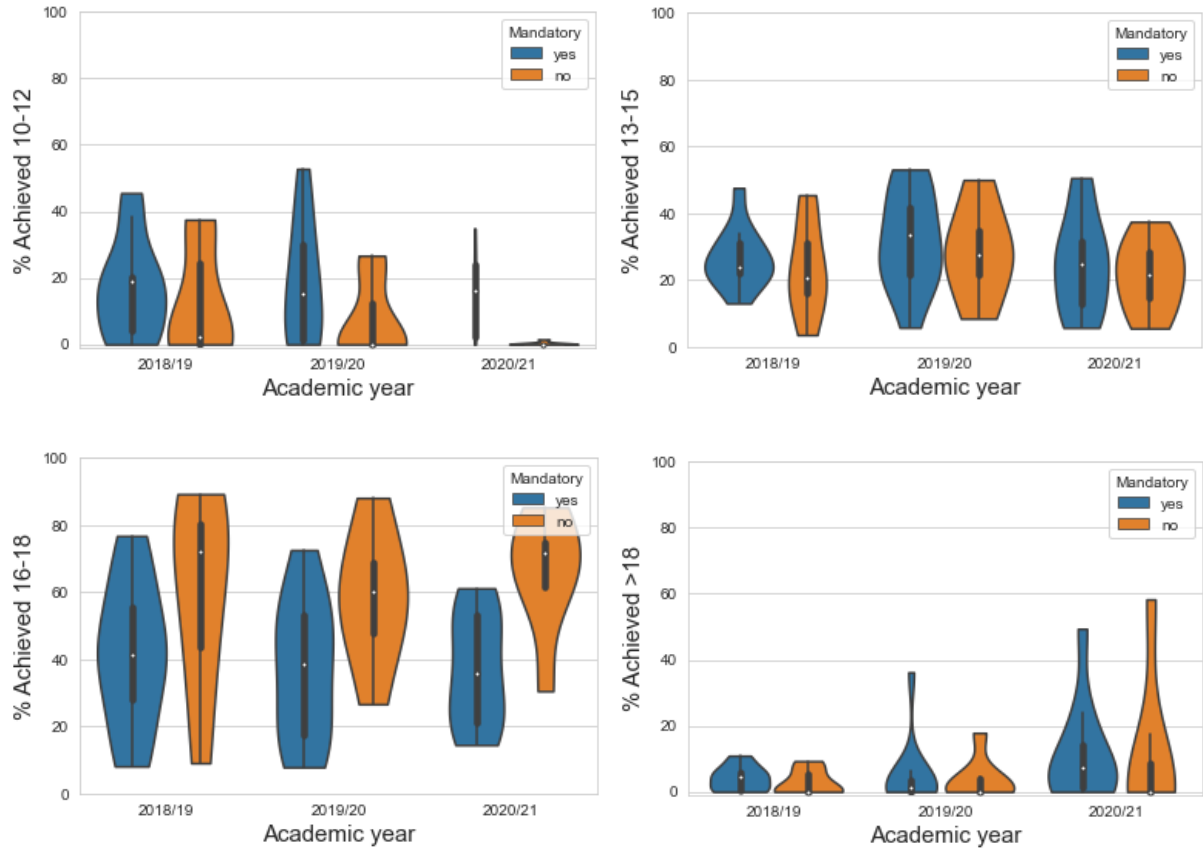


Figure 12 - Differences in the percentage of students in different grade ranges across three academic years by electiveness of the courses

When testing the normality (Table 16), the groups containing the percentage of the students that achieved [10-12] and [19-20] came out as not normally distributed ( $p$ -value < 0.05) and for those groups Kruskal-Wallis test was applied. The other groups containing the percentage of students who achieved [13-15] and [16-18] came out as normally distributed ( $p$ -value > 0.05) and for those groups, the homogeneity of variances (Table 17) was tested and verified using Levene's test ( $p$ -value > 0.05). So, we proceeded with ANOVA to test the differences.

Table 16 - Shapiro-Wilk test results for the percentage of students achieving a specific grade range

| Group         | Statistic | $p$ -value | Conclusion         |
|---------------|-----------|------------|--------------------|
| 18/19s2_10-12 | 0.86      | 0.01       | Reject $H_0$       |
| 19/20s2_10-12 | 0.83      | 0          | Reject $H_0$       |
| 20/21s2_10-12 | 0.76      | 0          | Reject $H_0$       |
| 18/19s2_13-15 | 0.96      | 0.64       | Don't Reject $H_0$ |
| 19/20s2_13-15 | 0.96      | 0.61       | Don't Reject $H_0$ |
| 20/21s2_13-15 | 0.96      | 0.55       | Don't Reject $H_0$ |

|                       |      |      |                    |
|-----------------------|------|------|--------------------|
| <b>18/19s2_16-18</b>  | 0.95 | 0.48 | Don't Reject $H_0$ |
| <b>19/20s2_16-18</b>  | 0.97 | 0.87 | Don't Reject $H_0$ |
| <b>20/21s2_16-18</b>  | 0.95 | 0.38 | Don't Reject $H_0$ |
| <b>18/19s2_&gt;18</b> | 0.86 | 0.01 | Reject $H_0$       |
| <b>19/20s2_&gt;18</b> | 0.55 | 0    | Reject $H_0$       |
| <b>20/21s2_&gt;18</b> | 0.70 | 0    | Reject $H_0$       |

Table 17 - Levene's test results for the percentage of students achieving grade range [13-15] and [16-18]

| <b>Groups</b> | <b>Statistic</b> | <b><i>p</i>-value</b> | <b>Conclusion</b>  |
|---------------|------------------|-----------------------|--------------------|
| <b>13-15</b>  | 0.86             | 0.43                  | Don't Reject $H_0$ |
| <b>16-18</b>  | 0.21             | 0.81                  | Don't Reject $H_0$ |

Table 18 - ANOVA and Kruskal-Wallis test results for the percentage of students achieving a specific grade range

| <b>Groups</b> | <b>Statistic</b> | <b><i>p</i>-value</b> | <b>Conclusion</b>  |
|---------------|------------------|-----------------------|--------------------|
| <b>10-12</b>  | 1.99             | 0.37                  | Don't Reject $H_0$ |
| <b>13-15</b>  | 1.34             | 0.27                  | Don't Reject $H_0$ |
| <b>16-18</b>  | 0.10             | 0.91                  | Don't Reject $H_0$ |
| <b>&gt;18</b> | 1.37             | 0.50                  | Don't Reject $H_0$ |

For ANOVA and Kruskal-Wallis test, the  $H_0$  is not rejected for all the grade ranges since the *p*-value is higher than the significance level ( $\alpha$ ) of 0.05 (Table 18). Thus, there is no evidence to state that there are differences, statistically significant, between the percentage of students achieving a specific grade range across different teaching modes. Even though some differences were identified in the violin plots for grade range [10-12] and [19-20], the statistical tests reveal that the differences are not significant.

#### **4.3. DIFFERENCES IN THE PERCENTAGE OF STUDENTS PASSING THE COURSE BY YEAR OF THE PROGRAM**

This section further explores students' approval rate in each course across the different years of the program (Figure 13), given that the course level and electiveness are different. The approval rate of the first-year courses from 2020/21 (HT) had a mean and median lower than the previous two academic years. The second-year courses had their distribution curve becoming less flat throughout the three academic years, meaning that the percentage of approvals of the courses was becoming more concentrated between 85% and 95% rather than sparse. Regarding the third-year courses, no significant differences were found in the passing rate. Reminding that the courses from the first and second-year of the program are all mandatory, and the courses from the 2nd-semester of the third-year are all non-mandatory for the bachelor's degree that this study focuses on. Being all non-

mandatory, the students can opt to participate in an Erasmus program during the last semester of their program.

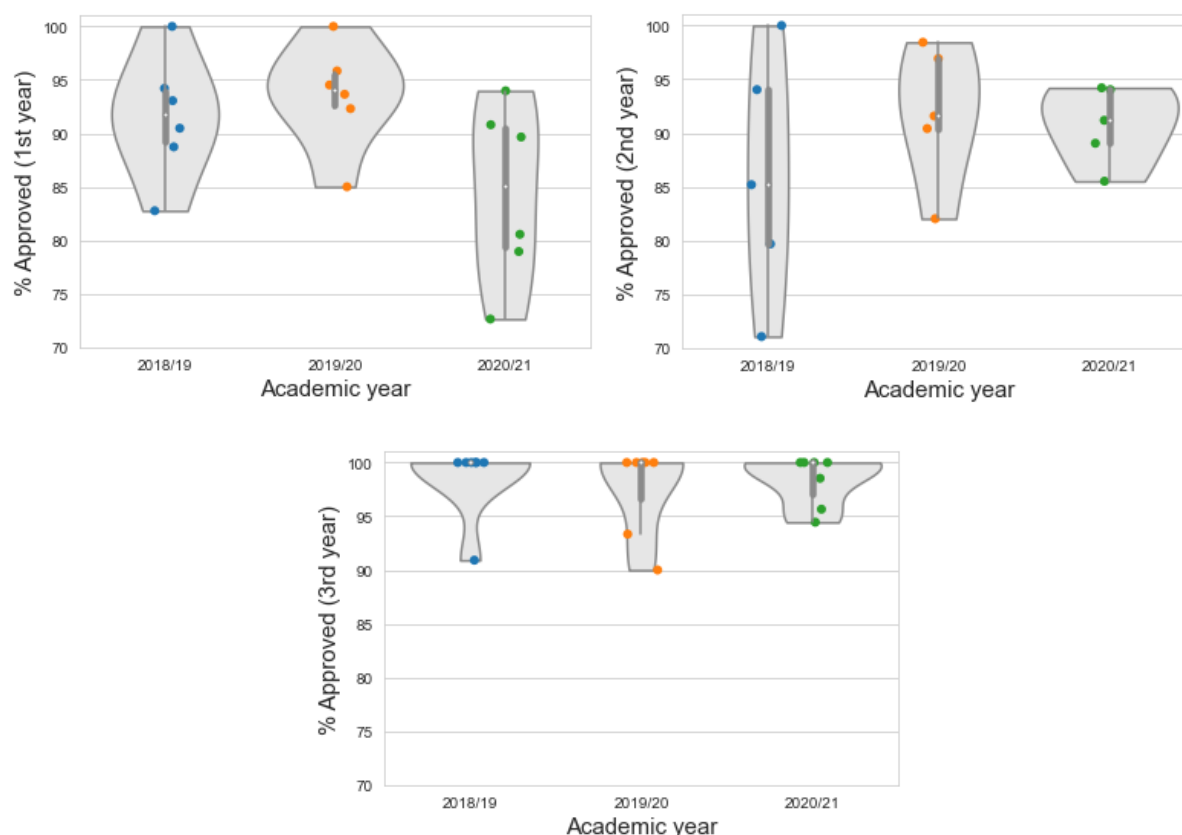


Figure 13 - Differences in the percentage of students passing the course e across three academic years by year of the program

The Shapiro-Wilk test (Table 19) shows that all the groups containing the data from the first and second-year of the program are normally distributed when considering a  $\alpha = 5\%$  ( $p$ -value  $> 0.05$ ). For those groups, the homogeneity of variances (Table 20) was also tested and verified ( $p$ -value  $> 0.05$ ). Concerning the data from the third-year of the program, the groups came out as not normally distributed ( $p$ -value  $< 0.05$ ).

The results from ANOVA and Kruskal-Wallis (Table 21) reveal that the differences in the passing rate by year of the program across different teaching modes are not statistically significant ( $p$ -value  $> 0.05$ ).

Table 19 - Shapiro-Wilk test results for the percentage of students passing the course by year of the program

| Group      | Statistic | $p$ -value | Conclusion         |
|------------|-----------|------------|--------------------|
| 18/19s2_a1 | 0.99      | 0.98       | Don't Reject $H_0$ |
| 19/20s2_a1 | 0.94      | 0.64       | Don't Reject $H_0$ |
| 20/21s2_a1 | 0.93      | 0.57       | Don't Reject $H_0$ |
| 18/19s2_a2 | 0.98      | 0.95       | Don't Reject $H_0$ |
| 19/20s2_a2 | 0.93      | 0.58       | Don't Reject $H_0$ |
| 20/21s2_a2 | 0.92      | 0.50       | Don't reject $H_0$ |

|                   |      |      |                       |
|-------------------|------|------|-----------------------|
| <b>18/19s2_a3</b> | 0.45 | 0    | Reject H <sub>0</sub> |
| <b>19/20s2_a3</b> | 0.65 | 0    | Reject H <sub>0</sub> |
| <b>20/21s2_a3</b> | 0.74 | 0.01 | Reject H <sub>0</sub> |

Table 20 - Levene's test results for the percentage of students passing the 1<sup>st</sup> and 2<sup>nd</sup> year courses

| <b>Groups</b>              | <b>Statistic</b> | <b><i>p</i>-value</b> | <b>Conclusion</b>           |
|----------------------------|------------------|-----------------------|-----------------------------|
| <b>1<sup>st</sup> year</b> | 2.13             | 0.15                  | Don't Reject H <sub>0</sub> |
| <b>2<sup>nd</sup> year</b> | 2.72             | 0.11                  | Don't Reject H <sub>0</sub> |

Table 21 - ANOVA and Kruskal-Wallis test results for the percentage of students passing the course by year of the program

| <b>Groups</b>              | <b>Statistic</b> | <b><i>p</i>-value</b> | <b>Conclusion</b>           |
|----------------------------|------------------|-----------------------|-----------------------------|
| <b>1<sup>st</sup> year</b> | 3.27             | 0.07                  | Don't Reject H <sub>0</sub> |
| <b>2<sup>nd</sup> year</b> | 0.79             | 0.48                  | Don't Reject H <sub>0</sub> |
| <b>3<sup>rd</sup> year</b> | 0.73             | 0.69                  | Don't Reject H <sub>0</sub> |

## 5. DISCUSSION

In answering the RO1 and RO3, no statistically significant differences were found in the percentage of students passing the 2nd-semester courses across different teaching modes, even when the year of the program is accounted for. With the respect to RO2, the results revealed no significant differences in the percentage of students achieving a specific grade range across different teaching modes. Although, the graphical analysis revealed a slight decrease in the percentage of students achieving the grade range [10-12] and an increase in the percentage of students achieving a grade higher than 18 values from F2F to HT.

Based on the results, it is important to refer that when comparing the semesters of ERT and HT, even though the teaching method was not the same, due to the peak of the pandemic after Christmas and New Year, many students still stayed at home at the beginning of the 2nd-semester of 2020/21. In this way, a small number of students were in the classrooms at the university, while most were attending the classes remotely through an online platform (Zoom, Microsoft Teams). Additionally, despite the HT requiring the students being attending the classes on-campus in a weekly rotation approach, various students did not follow the rotation therefore several students ended up attending the classes remotely for more than a week. Thus, HT almost resembles the ERT that took place in the 2nd-semester of 2019/20.

In answering the RQ of this study, we did not observe statistically significant differences in students' academic performance between the courses delivered in traditional F2F teaching, ERT, and HT. The stability in academic performance under different teaching modes may have derived from an improvement in students learning strategies and self-regulation skills while having ERT and HT methods. Regarding the organizational aspects, It could be argued, as Iglesias-Pradas et al. (2021) did, that the university was relatively well prepared for the COVID-19 crisis in terms of technical infrastructure; a fully functional instance of Moodle has been in place for several years, and most courses use Moodle as an educational content repository and communication channel with the students. The transition to ERT posed some challenges in scaling the system to ensure the quality of service for a higher number of concurrent users, and the professors had to find methods to deliver the tests and exams online and, in a way, to prevent cheating situations. For the HT implemented in the academic year 2020/21, the university incorporated the necessary technology to ensure an equal experience between the students attending the classes remotely and on-site. The attitude towards incorporating the necessary resources (Kuhn, 2019; Wilson, 2001) and digital readiness are also crucial to implement an efficient and effective HT.

Iglesias-Pradas et al. (2021) also supported the effect of the individual aspects, such as instructors' and students' digital skills, that might help explain the findings of this study. An aspect worth mentioning is the characteristic of the university which is a technical oriented considering its specialization in information management courses, most instructors have technology competencies. Iglesias-Pradas et al. (2021) defended that it is reasonable to think that it may have been a contributing factor to the effective and rapid deployment of ERT and HT. Regarding the students' side, there is prior evidence of the positive relationship between digital skills and academic performance (Iglesias-Pradas et al., 2021; Kim et al., 2019). Most students are proficient in the use of digital technologies and have their own devices – smartphones, tablets, laptop computers – that they already use during the F2F classes to

take notes and complete their assignments. Thus, these factors may have contributed to mitigating the negative impacts of the sudden move to remote teaching.

During the 2nd-semester of ERT and HT, all the evaluations (tests, exams, project defences) were conducted remotely. El Said (2021) suggested in his study an adjustment in alternative assessment and evaluation methods to adapt the teaching mode. Some courses from NOVA IMS have turned to multi-choice question tests, which may have been perceived as easier by students, and are better suited to assess knowledge rather than skill (Hettiarachchi et al., 2016; Iglesias-Pradas et al., 2021), which makes problematic to compare the results obtained under ERT and HT with those of F2F. It is important to consider the possibility of the existence of cheating behaviours, despite the effort from the instructors in making measures to prevent those behaviours such as the use of proctoring software, plagiarism detection software (Turnitin) and requesting the students to keep the camera on during the test or exam. Cheating can be defined as “a transgression against academic integrity which entails taking an unfair advantage that results in a misrepresentation of a student’s ability and grasp of knowledge”(Moten et al., 2013). Previous studies support the idea that students perceive cheating to be easier and more prevalent in online courses, and that non-proctored remote exams include more cheating behaviours than proctored ones as Balderas & Caballero-Hernández (2020) observed in online exams in Computer Science and Engineering course during the pandemic in Spain. There is evidence that the cheating behaviour in online classes is as much as four times greater than that in presential classes (Kuhn, 2019; Lanier, 2006; Moten et al., 2013). Given the autonomy of the students and their separation from the instructor, the ability to engage in cheating is inherently easier. Therefore, we cannot discard the potential effect of cheating behaviours among some students during the ERT and HT.

The bachelor program in study opens about 64 vacancies in each academic year, it could be argued that the sample size impacted the results of the study. Additionally, during the 2nd-semester of the third-year of the program, the students are given the opportunity to participate in an Erasmus program which reduces the number of students from the bachelor’s degree enrolled in the non-mandatory courses. Iglesias-Prada et al. (2021) reasoned that the sample of the study also seem to impact the results from the previous studies.

Due to the scarcity of studies that compares traditional teaching mode with ERT and HT mode, the studies that compare traditional teaching with blended teaching, which is not the same as HT, were also considered in the literature review. Studies that compare student performance between traditional and online classes have some inconsistent findings (Bray et al., 2007; Brown & Liedholm, 2002; Figlio et al., 2010; Gratton-Lavoie & Stanley, 2009; Harmon & Lambrinos, 2006; Kuhn, 2019; Parsons-Pollard et al., 2008; Shachar & Yoram, 2003). Similar to the findings of this study, some previous studies provided evidence that there is no significant difference in the students’ grades in traditional, online and blended teaching modes (El Said, 2021; Goette et al., 2017; Kuhn, 2019; Yen et al., 2018). Two meta-analyses conducted by Jahng et al. (2007) and Zhao et al. (2005) also found no significant differences for aggregated courses. The results from the current study show that despite the rapid move to ERT it did not result in a poorer academic performance which confirms a recent study conducted by El Said (2021) during the COVID-19 crisis.

The stability of the academic performance across the academic years in the study supports that the implementation of a temporary ERT and HT at NOVA IMS did not negatively impact the students’

performance in terms of courses grades and passing rate. It can be argued that the ERT and HT delivered the same level of effectiveness as traditional F2F teaching.

## 6. CONCLUSION

The present study analyzed the performance of ERT and HT at NOVA IMS, during the COVID-19 pandemic, by comparing the Information Management bachelor's degree students' grades from the 2nd-semester of three academic years -2018/19, 2019/20, 2020/21 - where three different teaching modes were experienced – F2F, ERT, and HT, respectively. The study of the effects of the COVID-19 pandemic on higher education and the implementation of ERT has been arousing interest among scholars since the COVID-19 crisis. This study, limited in the scope of one institution and program, has some distinctive characteristics to offer a contribution to this recent field of knowledge since it addresses both ERT and HT.

It is important to point out that there is a big difference between ERT and a real move to online teaching, with the key word here being “emergency”. For this study, both literature on the voluntary move to remote teaching and HT due to emergency circumstances were reviewed. The analysis provided evidence of similar results to those of existing research comparing traditional F2F with blended teaching and/or online teaching/ERT. The findings from this study suggest that student's final grades and approval rates were not negatively impacted by the sudden move to ERT and planned HT at NOVA IMS. The results from the statistical tests suggested that the differences in academic performance across different teaching modes were not significant, meaning that there was a certain level of stability in the student's academic performance. The university's organizational factors along with a decent technical infrastructure implementation and the digital readiness of the professors and students may have contributed to the successful implementation of ERT and HT.

Thus, despite the sudden move to ERT and the adoption of HT at NOVA IMS, it did not result in poorer students' academic performance when compared to the before COVID-19 pandemic traditional F2F teaching. HT adopted at NOVA IMS as a temporary solution to cope with the COVID-19 crisis can be an effective teaching mode to address nowadays needs and changes. Moreover, the COVID-19 pandemic should be taken as an opportunity to improve digital readiness among higher education institutions and instead of fully returning to the ways in which higher education institutions worked before the pandemic, it is possible to think about a more flexible teaching system such as a hybrid teaching involving combined solutions.

## **7. LIMITATIONS AND FUTURE WORK**

This study has certain limitations. Firstly, the data was specific to one program, the Information Management bachelor's degree, and it could be extended to more programs. Secondly, it only focused on the teaching mode, not considering other factors that could have also impacted the student's academic performance. A more in-depth analysis of factors affecting students' outcomes should provide a more holistic view of academic performance. The third limitation is the absence of students' and instructors' views and perceptions of the move to ERT and HT methods that would provide insights to complement those obtained from the results of this study. The last limitation concerns the fact that HT adopted at NOVA IMS to cope with the COVID-19 pandemic was a very specific teaching mode that limited the literature review on HT mode.

There are two points worthy of being explored in future work. First, extend the research to other programs taking into account factors that accompanied the transition to ERT and/or HT, including for example the different evaluation typologies adopted by the professors and students' self-regulation habits. The second is to better understand and improve the HT mode by administering a questionnaire or/and an interview to the students and lecturers to understand their opinion about the experience and the transition of the teaching modes.

## BIBLIOGRAPHY

- Alavi, M. (1994). Computer-mediated collaborative learning: An empirical evaluation. *MIS Quarterly: Management Information Systems*, 18(2), 159–174. Scopus. <https://doi.org/10.2307/249763>
- Alducin-Ochoa, J. M., & Vázquez-Martínez, A. I. (2016). Academic Performance in Blended-Learning and Face-to-Face University Teaching. *Asian Social Science*, 12(3), 207. <https://doi.org/10.5539/ass.v12n3p207>
- Allua, S., & Thompson, C. B. (2009). Inferential Statistics. *Air Medical Journal*, 28(4), 168–171. <https://doi.org/10.1016/j.amj.2009.04.013>
- Balderas, A., & Caballero-Hernández, J. A. (2020). Analysis of Learning Records to Detect Student Cheating on Online Exams: Case Study during COVID-19 Pandemic. *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality*, 752–757. <https://doi.org/10.1145/3434780.3436662>
- Bergdahl, N., & Nouri, J. (2021). Covid-19 and Crisis-Prompted Distance Education in Sweden. *Technology, Knowledge and Learning*, 26(3), 443–459. <https://doi.org/10.1007/s10758-020-09470-6>
- Bray, N. J., Harris, M. S., & Major, C. (2007). New verse or the same old chorus?: Looking holistically at distance education research. *Research in Higher Education*, 48(7), 889–908. <https://doi.org/10.1007/s11162-007-9054-7>
- Brown, B., & Liedholm, C. (2002). Can Web Courses Replace the Classroom in Principles of Microeconomics? *American Economic Review*, 92, 444–448. <https://doi.org/10.1257/000282802320191778>
- Chingos, M. M., Griffiths, R. J., Mulhern, C., & Spies, R. R. (2017). Interactive Online Learning on Campus: Comparing Students' Outcomes in Hybrid and Traditional Courses in the University System of Maryland. *Journal of Higher Education*, 88(2), 210–233. Scopus. <https://doi.org/10.1080/00221546.2016.1244409>
- Daumiller, M., Rinas, R., Hein, J., Janke, S., Dickhäuser, O., & Dresel, M. (2021). Shifting from face-to-face to online teaching during COVID-19: The role of university faculty achievement goals for attitudes towards this sudden change, and their relevance for burnout/engagement and student evaluations of teaching quality. *Computers in Human Behavior*, 118, 106677. <https://doi.org/10.1016/j.chb.2020.106677>
- Dinno, A. (2015). Nonparametric Pairwise Multiple Comparisons in Independent Groups using Dunn's Test. *The Stata Journal*, 15(1), 292–300. <https://doi.org/10.1177/1536867X1501500117>
- Drysdale, J. S., Graham, C. R., Spring, K. J., & Halverson, L. R. (2013). An analysis of research trends in dissertations and theses studying blended learning. *The Internet and Higher Education*, 17, 90–100. <https://doi.org/10.1016/j.iheduc.2012.11.003>
- Easton, S. S. (2003). Clarifying the Instructor's Role in Online Distance Learning. *Communication Education*, 52(2), 87–105. <https://doi.org/10.1080/03634520302470>

El Said, G. R. (2021). How Did the COVID-19 Pandemic Affect Higher Education Learning Experience? An Empirical Investigation of Learners' Academic Performance at a University in a Developing Country. *Advances in Human-Computer Interaction*, 2021, 1–10. <https://doi.org/10.1155/2021/6649524>

Figlio, D., Rush, M., & Yin, L. (2010). Is It Live or Is It Internet? Experimental Estimates of the Effects of Online Instruction on Student Learning. *National Bureau of Economic Research, Inc, NBER Working Papers*, 31. <https://doi.org/10.1086/669930>

Gelman, A. (2005). Analysis of variance—Why it is more important than ever. *The Annals of Statistics*, 33(1), 1–53. <https://doi.org/10.1214/009053604000001048>

Goette, W. F., Delello, J. A., Schmitt, A. L., Sullivan, J. R., & Rangel, A. (2017). Comparing Delivery Approaches to Teaching Abnormal Psychology: Investigating Student Perceptions and Learning Outcomes. *Psychology Learning & Teaching*, 16(3), 336–352. <https://doi.org/10.1177/1475725717716624>

Gonzalez, T., Rubia, M. A. de la, Hincz, K. P., Comas-Lopez, M., Subirats, L., Fort, S., & Sacha, G. M. (2020). Influence of COVID-19 confinement on students' performance in higher education. *PLOS ONE*, 15(10), e0239490. <https://doi.org/10.1371/journal.pone.0239490>

Gratton-Lavoie, C., & Stanley, D. (2009). Teaching and Learning Principles of Microeconomics Online: An Empirical Assessment. *Journal of Economic Education - J ECON EDUC*, 40, 3–25. <https://doi.org/10.3200/JECE.40.1.003-025>

Harmon, O., & Lambrinos, J. (2006). *Online Format vs. Live Mode of Instruction: Do Human Capital Differences or Differences in Returns to Human Capital Explain the Differences in Outcomes?*

Hettiarachchi, E., Balasooriya, I., Mor, E., & Huertas, M. A. (2016). Chapter 3 - e-Assessment for Skill Acquisition in Online Engineering Education: Challenges and Opportunities. In S. Caballé & R. Clarisó (Eds.), *Formative Assessment, Learning Data Analytics and Gamification* (pp. 49–64). Academic Press. <https://doi.org/10.1016/B978-0-12-803637-2.00003-8>

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, M. (2020). *The Difference Between Emergency Remote Teaching and Online Learning*.

Holmberg, B. (1994). *Theory and Practice of Distance Education* (2nd ed.). Routledge. <https://doi.org/10.4324/9780203973820>

Iglesias-Pradas, S., Hernández-García, Á., Chaparro-Peláez, J., & Prieto, J. L. (2021). Emergency remote teaching and students' academic performance in higher education during the COVID-19 pandemic: A case study. *Computers in Human Behavior*, 18.

Jacques, S., Ouahabi, A., & Lequeu, T. (2021). Synchronous E-learning in Higher Education during the COVID-19 Pandemic. *2021 IEEE Global Engineering Education Conference (EDUCON)*, 1102–1109. <https://doi.org/10.1109/EDUCON46332.2021.9453887>

Jahng, N., Krug, D., & Zhang, Z. (2007). Student Achievement in Online Distance Education Compared to Face-to-Face Education. *European Journal of Open, Distance and E-Learning*, 10(1), Article 1. <https://old.eurodl.org/?p=archives&year=2007&halfyear=1&article=253>

- Kim, H. J., Hong, A. J., & Song, H.-D. (2019). The roles of academic engagement and digital readiness in students' achievements in university e-learning environments. *International Journal of Educational Technology in Higher Education*, 16(1), 21. <https://doi.org/10.1186/s41239-019-0152-3>
- Kruskal, W. H., & Wallis, W. A. (1952). Use of Ranks in One-Criterion Variance Analysis. *Journal of the American Statistical Association*, 47(260), 583–621. <https://doi.org/10.2307/2280779>
- Kuhn, P. R. (2019). *A Case Study on the Differences in Scores of Undergraduate Students in Traditional, Online, and Hybrid Classes*. 76.
- Lanier, M. (2006). Academic Integrity and Distance Learning. *JOURNAL OF CRIMINAL JUSTICE EDUCATION Academy of Criminal Justice Sciences*, 17. <https://doi.org/10.1080/10511250600866166>
- Larose, D. T. (2015). *Data Mining and Predictive Analytics*. John Wiley & Sons.
- Levene, H. (1960). *Robust Tests for Equality of Variances*.
- Moten, J., Fitterer, A., Brazier, E., Leonard, J., & Brown, A. (2013). Examining online college cyber cheating methods and prevention measures. *Electronic Journal of E-Learning*, 11, 139–146.
- Nasution, A. K. P., Surbakti, A. H., Zakaria, R., Wahyuningsih, S. K., & Daulay, L. A. (2021). Face to Face Learning vs Blended Learning vs Online Learning (Student Perception of Learning). *Journal of Physics: Conference Series*, 1783, 012112. <https://doi.org/10.1088/1742-6596/1783/1/012112>
- Ng, P. T. (2021). Timely change and timeless constants: COVID-19 and educational change in Singapore. *Educational Research for Policy and Practice*, 20(1), 19–27. <https://doi.org/10.1007/s10671-020-09285-3>
- Parsons-Pollard, N., Lacks, R. D., & Grant, P. H. (2008). A comparative assessment of student learning outcomes in large online and traditional campus-based introduction to criminal justice courses. *Criminal Justice Studies*, 21(3), 239–251. <https://doi.org/10.1080/14786010802355826>
- Popescu, E., & Leon, F. (2018). Predicting Academic Performance Based on Learner Traces in a Social Learning Environment. *IEEE Access*, 6, 72774–72785. <https://doi.org/10.1109/ACCESS.2018.2882297>
- Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2020). Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity. *Postdigital Science and Education*, 2(3), 923–945. <https://doi.org/10.1007/s42438-020-00155-y>
- Ravat, S., Barnard-Ashton, P., & Keller, M. M. (2021). Blended teaching versus traditional teaching for undergraduate physiotherapy students at the University of the Witwatersrand. *South African Journal of Physiotherapy*, 77(1). <https://doi.org/10.4102/sajp.v77i1.1544>
- Rumble, G. (2019). *The Planning and Management of Distance Education*. Routledge. <https://doi.org/10.4324/9780429288661>
- Scaringella, L., Górska, A., Calderon, D., & Benitez, J. (2022). Should we teach in hybrid mode or fully online? A theory and empirical investigation on the service–profit chain in MBAs. *Information & Management*, 59(1), 103573. <https://doi.org/10.1016/j.im.2021.103573>

- Secundo, G., Mele, G., Vecchio, P. D., Elia, G., Margherita, A., & Ndou, V. (2021). Threat or opportunity? A case study of digital-enabled redesign of entrepreneurship education in the COVID-19 emergency. *Technological Forecasting and Social Change*, 166, 120565. <https://doi.org/10.1016/j.techfore.2020.120565>
- Shachar, M., & Yoram, N. (2003). Differences Between Traditional and Distance Education Academic Performances: A Meta-Analytic Approach. *International Review of Research in Open and Distance Learning*, 4. <https://doi.org/10.19173/irrodl.v4i2.153>
- Shapiro, S. S., & Wilk, M. B. (1965). An Analysis of Variance Test for Normality (Complete Samples). *Biometrika*, 52(3/4), 591–611. <https://doi.org/10.2307/2333709>
- Sharda, R., Delen, D., & Turban, E. (2017). *Business Intelligence, Analytics, and Data Science: A Managerial Perspective* (4th ed.).
- Singh, S. P., Malik, S., & Singh, P. (2016). *Factors Affecting Academic Performance of Students*. 4.
- Spencer, D., & Temple, T. (2021). Examining Students' Online Course Perceptions and Comparing Student Performance Outcomes in Online and Face-to-Face Classrooms. *Online Learning*, 25(2). <https://doi.org/10.24059/olj.v25i2.2227>
- Williams, H., Haynes, M., & Kim, J. (2021). Dual Teaching: Simultaneous Remote and In-Person Learning During COVID. *Proceedings of the 22st Annual Conference on Information Technology Education*, 111–116. <https://doi.org/10.1145/3450329.3476867>
- Wilson, C. (2001). *Faculty Attitudes about Distance Learning*. 2.
- Yen, S.-C., Lo, Y., Lee, A., & Enriquez, J. (2018). Learning online, offline, and in-between: Comparing student academic outcomes and course satisfaction in face-to-face, online, and blended teaching modalities. *Education and Information Technologies*, 23(5), 2141–2153. <https://doi.org/10.1007/s10639-018-9707-5>
- Zhao, Y., Lei, J., Lai, B. Y. C., & Tan, H. S. (2005). What Makes the Difference? A Practical Analysis of Research on the Effectiveness of Distance Education. *Teachers College Record*, 49.