Proceedings of the 2022 Winter Simulation Conference
B. Feng, G. Pedrielli, Y. Peng, S. Shashaani, E. Song, C.G. Corlu, L.H. Lee, E.P. Chew, T. Roeder, and P. Lendermann, eds.

SIMULATION TEACHING DURING THE PANDEMIC: REPORT OF AN EXPERIENCE IN A HIGHER EDUCATION PRIVATE INSTITUTION

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ABSTRACT

The COVID-19 pandemic has impacted virtually every sector of our society, including the educational arena. This article reports the experience of discrete-event simulation teaching as part of the industrial engineering curriculum of a higher education private institution in three time instances: the pre-pandemic period (2019), where teaching was in person; the main pandemic period (2020 and the first half of 2021), where teaching was 100% remote, and the hybrid pandemic period (2nd half of 2021). We conducted comparisons of the teaching process along these instances regarding several points, by performing both qualitative and quantitative analyses. This article concludes that, despite some pedagogical difficulties, it was possible to maintain high quality in the teaching-learning process, compatible with the pre-pandemic period. The article also makes a forecast of how the teaching process of this type of discipline will be in the near future, after having been influenced by the pandemic period.

1 INTRODUCTION

The COVID-19 pandemic has led to changes that have impacted virtually every sector of society, obviously also affecting the education area. Some authors go further, stating that the entire educational system, from elementary to higher school, collapsed during the lockdown period throughout the world (Mishra et al. 2020).

This article intends to report the experience in the teaching of simulation, more precisely in the discipline "Operations Research II - Probabilistic Models and Simulation", taught as part of the Industrial Engineering curriculum of a Higher Education Private Institution during the initial pandemic years (2020/2021). It is also intended to discuss several points observed in technology-mediated education in 2020/21 against the pre-pandemic period (2019) when teaching was 100% in-person. Technology-mediated teaching is understood here as synchronous teaching through the use of the Collaborate platform (Blackboard) and Zoom. Since this is a specific case, this article does not intend to draw generalized conclusions, but rather to observe positive and negative points of technology-mediated education and to serve as a reflection for future actions.

This paper is organized as follows. Section 2 outlines a literature review. Section 3 describes the educational scenarios considering three time instances (pre-pandemic, main-pandemic, and hybrid-pandemic). Section 4 performs both qualitative and quantitative analyses of the educational scenarios. Section 5 summarizes our conclusions and presents a forecast of how we believe teaching will be in a near future.

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2 LITERATURE REVIEW

The world educational system, at all levels of education, was strongly affected by the blocking impositions due to the COVID-19 pandemic. In fact, education is among the five sectors most affected by the pandemic, with significant impacts on the production of scientific research, school evasion, and mental health of students (Barros et al. 2020). The shutdown of schools and universities during the pandemic period practically defined online teaching, remotely (with synchronous activities) or distance learning (with synchronous and asynchronous activities) as the mean for the teaching-learning processes continuity (Mishra et al. 2020).

Traditionally, engineering teaching does not stand out in the provision of distance education. For example, according to Cardoso et al. (2019), until 2017 no engineering course in Brazil registered enrollments in distance mode, although there was already an offer of remote classes at the time.

In the engineering teaching context, computer simulation teaching has its particularities. As described by Mesquita et al. (2019), computer simulation is an essential technological tool for management-level professionals responsible for decision-making. Loreto-Gómez et al. (2019) demonstrated that the understanding of intricate theoretical concepts in robotics are simplified with the use of 3D simulations, improving students' academic performance and providing a teaching tool to enhance the way professors teach. Practical activities can also benefit from Virtual Laboratories (essentially, software-mediated simulations) since most universities provided the necessary software to students and professors for free, or at very low costs (Adesoji et al. 2019). Even physical equipment, in some cases, can be replaced by low-cost alternatives, as described by Oliveira et al. (2021), that employed a USB sound module as a financially viable alternative (less than USD 30) to an oscilloscope and a signal generator.

Asynchronous remote experiments for simulation teaching existed long before the isolation impositions of the current pandemic. Loper et al. (2019), for example, described the approach used in a modeling and simulation course for the master's degree in Applied Systems Engineering at Georgia Tech University. The course takes place in hybrid mode, with few mandatory face-to-face meetings and previously recorded online classes. Complex and general-scope tasks are developed in teams (whose members remain throughout the program), while individual experiences are focused on the practical use of specific software. The authors believe that the course approach allows that even after a short period of course (7 weeks) it becomes evident that simulation is a tool of broad use and that students will be able to apply modeling and simulation techniques to real problems in different areas.

The balance between theoretical content and practical applications is a general concern in simulation teaching. According to Collins et al. (2019), courses with academic bias tend to explore idealized problems, presented in classic textbooks, with emphasis on the mathematical and statistical foundations of simulation techniques, while courses focused on market professionals prefer to rely on case studies derived from real simulation projects, focusing on the operational management of simulation software.

Mesquita et al. (2019) conducted an exploratory research with 38 professionals linked to the simulation area of five continents, seeking to understand the challenges and opportunities in the teaching of simulation and how the use of practical projects can produce meaningful learning. Regarding the challenges, the fragility of previous knowledge in statistics and programming and the difficulty in accessing computational resources stood out. On the opportunities for improvement, there was an emphasis on the need for deepening in conceptual modeling and more time for the development of "real world" cases; on the use of practical projects, there was consensus among those surveyed about their importance, especially for the development of teamwork skills, although there are still no lists of "good practice" rules for this type of activity.

The sudden and unplanned shift to massive online teaching due to the pandemic highlighted that the lack of social interaction is one of the main barriers to effective online learning, even surpassing technological issues (Baber 2021; Zboun and Farrah 2021).

The post-COVID-19 educational scenario will continue to require the use of online education platforms in balance with face-to-face classes (hybrid teaching). In a survey on general post-coronavirus scenarios in Brazil, Garcia and Nääs (2020) identified threats as concern scares about the country's economic situation, increased poverty, and lack of jobs, but also highlighted opportunities, such as encouraging the development of new products and new forms of working, as well as humanitarian and social issues. According to Costa (2020), it is expected that there will be a significant transformation in technology-mediated education, based on the teaching experience acquired in pandemic times, especially in the aspect of a better use of available technological resources. Monteiro et al. (2021) assert that it is reasonable to expect, in the return of the possibility of face-to-face teaching, that students want to maintain some perceived advantages in online teaching (for example, the convenience of being at home, freedom of study schedules, cost reduction in general, etc.), without the associated disadvantages, such as lack of contact with colleagues and teachers or fatigue for hours spent in front of the computer, for example. Moise et al. (2021) explicitly state that the "future seems to be towards a blended learning system combining physical and online teaching".

In addition to facing the natural challenges of the future return to face-to-face activities, Higher Education Private Institutions will have to face the fact that, so far, the focus of most research and online teaching-learning initiatives has been on mediating information and communication technologies, and not on the theoretical and/or methodological conceptions of teaching proposals (Cardoso et al. 2019).

3 PROBLEM SCOPE

3.1 Discipline Description

The discipline "Operations Research II - Probabilistic Models and Simulation" is an annual discipline with a weekly workload of 4 class hours and has as main objectives to provide background for the modeling and solution of Operational Research Problems with aleatory nature, whether by the application of Queuing Theory, Monte Carlo simulation, discrete-event simulation or systems dynamics simulation. At the end of the course, students who are approved in the course must be capable of:

- Identifying and modeling problems that can be solved by queuing theory or simulation;
- Using statistical techniques appropriately to carry out a simulation study;
- Evaluating design alternatives through experimentation and optimization;
- Valuing discussions and teamwork.

The content of the subject goes through several topics: introduction to randomness; social justice in queues; Queuing Theory: Cases $M/M/1$, $M/M/1/c$, $M/D/1$, $M/M/s$; what is simulation; practical cases in simulation; Monte Carlo simulation; principles of modeling in simulation; the simulation mechanism (manual simulation); random number generation; input modeling data in simulation; verification and validation of simulation models; statistics applied to simulation (probabilistic distributions, confidence interval, software for data analysis); simulation and optimization; simulation software; introduction to systemic thinking and system dynamics simulation as well other topics in simulation (simulation and lean manufacturing, simulation of material handling systems, and so on).

Although the discipline discusses Monte Carlo simulation and systems dynamics simulation, more than 50% of the course is focused on discrete-event simulation, which is one of the most Operations Research techniques applied in practice (Hillier and Lieberman 2013).

The discipline mixes traditional classes, for the most theoretical aspects, with practical classes (active methodologies) where the student uses simulation software because it is not useful to teach only the use of certain simulation software, without teaching the simulation methodology. In fact, according to Banks et al. (2010), simulation is a discipline, being much more than software.

For Monte Carlo simulations, we adopt MS-Excel; for discrete-event simulation, the Educational Site License version of SIMUL8 software, and, for systems dynamic simulation, the academic version of Vensim software. For the input data modeling, we use Stat::Fit Student Version (free).

The discipline uses 3 basic bibliographic references: the two first establishes the theoretical aspects of discrete-event simulation (Chwif and Medina 2014) and continuous/dynamic simulation (Arantes 2012); the third main reference covers the operational part of the SIMUL8 software (Chwif et al. 2013).

Discipline evaluation is done by electronically delivered tasks through Moodle platform (school's MOOC platform) and assignments. There are two types of tasks: one specific performed during each class and another composed of case studies or projects, which include more comprehensive content. Both types are graded on a numeric scale, generating grades from 0 to 10. In the years 2019 and 2020, the discipline included 4 assignments per year and two substitute assignments. In 2021, it was conducted with 2 assignments per year and one substitutive assignment. The final average grade for approval must be equal to or greater than 6.0.

3.2 Similarities and Differences of the Teaching Models Adopted

In 2019, the discipline was taught with students' presence in a computer laboratory. Although there are theoretical discussions in the discipline curriculum (lectures), the computer lab was used in all of the classes for allocation and flexibility reasons (otherwise, a conventional classroom should be booked in advance). Moreover, if a theoretical content class required the resolution of some exercise on a computer, this would not be possible in a conventional classroom. Each computer lab bench supports up to 4 students, with one computer for 2 students. The maximum laboratory capacity is 40 students. In addition to the students' computers, the laboratory has 2 whiteboards and 1 computer for the teacher, coupled to a ceiling projector (see Figure 1).

Figure 1: Computer lab used in 2019.

Both in 2019 and 2020, the course was taught to two classes during the day and one class in the evening, totaling approximately 128 students per year. In 2021, there were two evening classes and one day class, with approximately 120 students in all.

The beginning of the 2020 school year was face-to-face, but due to the pandemic, after the second half of March, teaching migrated to the technology-mediated model through the Collaborate platform, inside Moodle system. The classes continued to be synchronous, taking place on the same days and times as the respective face-to-face classes.

Initially, the theoretical content classes were recorded in advance and made available on a streaming platform (YouTube), as a guarantee against failures of the synchronous official platform; subsequently, each class was performed synchronously, also recorded and made available to the students. This strategy was used because the teacher was still adapting to conducting synchronous classes on the Collaborate platform. A change that occurred concerning the theoretical content classes during the pandemic period was that the exposition period was reduced to a maximum of 50 minutes since students' attention decays in a virtual environment.

For the practical activity classes, students should run the software on their own machines and when there was doubt, the teacher asked the student to share their screens to check the issue. In a way, there were no major structural changes concerning the backbone of the discipline, only that, instead of being in the classroom, the student attended a class through the collaboration platform and, in the case of practical activities, the student used his or her own computer instead of using the computer at the school laboratory. Most of the activities could be done collaboratively; in this case, the students used their own collaboration platforms (e.g. WhatsApp). In 2021 with the adoption of Zoom platform it was possible to create virtual private rooms, enabling better team collaboration when practical exercise takes place.

From the second semester of 2021, the teaching became hybrid. Therefore, the teacher teaches from the computer lab both to outside students using a collaborative platform and for students that want to be in the lab. Since the student presence at the lab was non-mandatory, students prefer to be remote. It was observed a maximum number of 3 students but the majority of classes were conducted without any students, despite the complaints of some students that school was closed in the first semester of 2021 when teaching was 100% remote.

Therefore, from the teaching point of view, there was no significant change in the way of teaching, the only difference being that the teacher should be at the lab instead of his or her own home.

4 QUALITATIVE AND QUANTITATIVE ANALYSIS

4.1 Qualitative Analysis - Strengths and Weaknesses of the Technology-Mediated Education System

For our qualitative analysis, we will point out two visions: the technology vision and the pedagogical vision. Concerning the technology vision, although an initial adaptation period was necessary, both for the teacher and for the students, the systems adopted (Collaborate and Zoom) proved to be robust, having negligible technical issue occurrences. As the student's socioeconomic profile in question is from higher classes, they had conditions to use up-to-date computers and good internet connections. According to a survey with freshmen students, it was found that about 64% of the respondents have a family income above 8 minimum wages (the monthly payment for engineering course in 2022 stands for, approximately, 3 national minimum wages). In fact, instead of reports of uneven access to digital resources, specifically in our course, another issue was evidenced: around 5% of the students were owners of Apple Computers, running some version of the macOS operating system, while the SIMUL8 simulation software, expected to be used intensively in the course, operates in the Windows operating system environment. Providentially, at the beginning of the pandemic SIMUL8 Corporation, the manufacturer of SIMUL8, released unlimited access to the Student Online version (see Figure 2), in which access to SIMUL8 can be performed in a regular Internet browser, without the need for any type of installation, which solved the problems for the macOS system owners and, at the same time, equalized the computational capacity of all students, since the online version of the simulator runs in the cloud.

Technology-mediated classes had another advantage: as the classes were recorded, students who might miss a class could follow it later or even use the video lessons recorded as reinforcement to the study. When the teacher forgot to start recording at the beginning of the class, usually some students would call his attention to request the recording, highlighting the importance and usefulness of the resource for the students. During practical classes, the majority of the doubts were solved with the student's screen sharing feature, not presenting major difficulties. In summary, from a technological point of view, the system was very responsive to the technology-mediated environment.

From the pedagogical point of view, the technology-mediated system presented some issues. There was a greater lack of motivation and participation of the students during the classes. This can be explained by the less interactive environment (without 'eye to eye'), aggravated by the fact that students never open their cameras, for various reasons. Thus, there was a lack of interaction, mainly visual, which is a strong feedback mechanism for the teaching-learning process. Moreover, as the student could choose to watch the theoretical content recorded later, his participation in the technology-mediated class was not mandatory. Besides that, as the teacher could not ‘look’ at the student and draw his or her attention to the class, he or she could be logged in the class system and can do any other activity rather than learning. On many occasions, at the end of the class, some students were logged in the class session, but were not present in the session, in a phenomenon that we call “virtual evasion”.

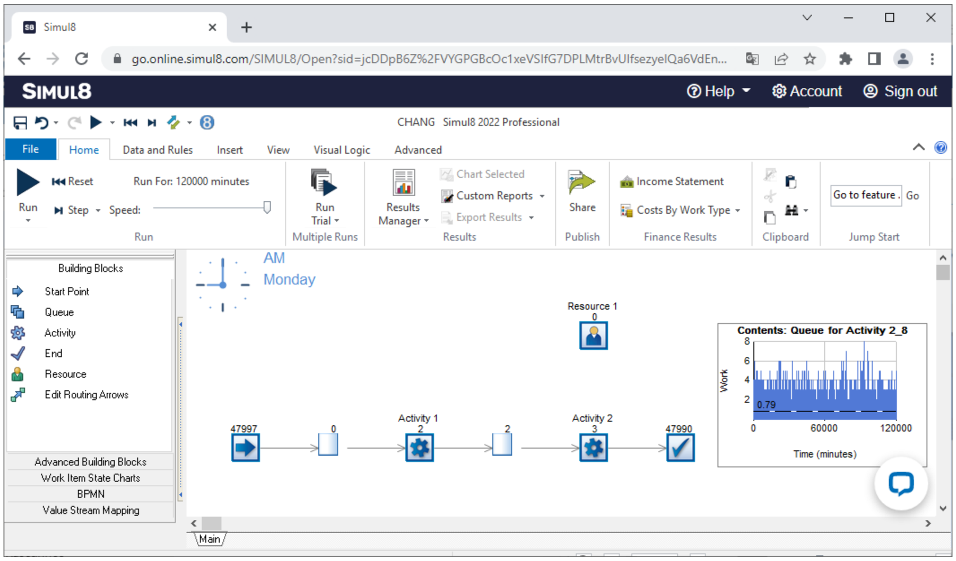

Figure 2: SIMUL8 online screenshot.

Some students reported to the coordinator of the discipline mental health problems arising from the pandemic (such as anxiety and depression), which can be an influential component for the worsening of motivation/participation.

At the beginning of 2021, an informal interview was conducted with a small group of students (around 20) to address the issue “How do you learn?” in search of improving our teaching methods during the pandemic period. Basically, two questions were addressed. The first one was: “What motivates you to study?”. Most answers cited “Practical and dynamic classes” and “Real-life case discussions”. The second question was “What is the best learning format for you?”. The group cited “Annotations”, “Summary”, “Practical projects and assignments”, “Practical examples”, and “Learning by error”.

With this in mind and also to minimize these issues as commented earlier, the teacher decided to reduce the exposure time for the theoretical content classes and whenever possible, demonstrate theoretical aspects with applications, to try to increase motivation. During the performance of exercises, the teacher always tried to encourage the participation of students with questions; however, it was noticed that the students, for various reasons, preferred to normally try to answer their doubts with their classmates. Another point that has been discovered is that many students are ashamed to talk or write in the chat of the collaborative system, so the use of individual chat with the teacher was often encouraged. Thus, with this feature, many students who did not ask began to do so because “I had no colleague to judge it”. We perceived that the technology-mediated system can cause a blockage in teacher/student interaction, even if it is a psychologically originated blockage. Therefore, it is important for the teaching-learning process that such blockages are minimized.

4.2 Quantitative Analysis - Academic Performance

In this section we will compare some indicators of academic performance from 2019 to 2021, reminding that there is no way to draw absolute and comprehensive conclusions about the effectiveness of technology-mediated education, due to the small sample size (1 discipline, 3 school years, and about 120 students per year). Moreover, the evaluation instruments were slightly modified during the pandemic to adapt them to the online environment.

The indicators analyzed are shown in Table 1: final average grade, number of students enrolled, percentage of approval (approved students/enrolled students), and dropout rate (students who finished the course/students enrolled at the beginning of the year).

Although the final average and approval percentage of the 2020 classes are statistically above the corresponding values of the 2019 classes (the corresponding hypothesis tests are described in Appendix A), it cannot be categorically stated that technology-mediated education is more efficient. As mentioned before, the sample is small and the differences can be influenced by many factors, in addition to random variations. Furthermore, the values from 2021 when compared to 2019 are statistically equivalent. What can be concluded is that the academic performance during the pandemic period (2020/2021) was compatible with that of 2019, not showing significant worsening. Another indicator of interest is the withdrawal percentage, which was higher in 2020 (a probable effect of the pandemic), but not representative. Regarding the total number of students enrolled, although it had a shortage in 2020, it raised in 2021, also not indicating a direct effect of the coronavirus pandemic.

Table 1: School performance indicators analyzed.

	2019	2020	2021
Final average grade	6.3	7.3	6.6
Total of enrolled students who finished the course	164	98	122
Approval percentage (approved students/total students)	87%	92%	85%
Withdrawal percentage	0%	2%	0%

Based on these numbers a question shall be raised: "Since the final average grade in 2020 is slightly higher, can we affirm that eye-to-eye interaction is really needed?". We understand that the final grade does not necessarily reflect 100% of the teaching-learning process. Since all assignments were conducted remotely during the pandemic period, some degree of cheating is inevitable, even though we have a large random question bank managed by the school's MOOC. Although we cannot prove it with data, what we believe is that eye-to-eye interaction leads to better student motivation and this can lead to a better teaching-learning process. However, it was observed also that theoretical classes may be recorded and watched in asynchronous mode (e.g. on YouTube), and, in this case, eye-to-eye interaction is not needed.

We also surveyed teachers in our department (Industrial Engineering) asking about three points during the pandemic period (2020-2021): (1) interaction level with students, (2) perception of overall teaching and learning quality, and (3) student's equality of access to digital/computational tools. Regarding point 1, 55% percent of survey participants revealed that there was a significant fall in student interaction, while only 9% revealed that there were no significant changes between face-to-face teaching and remote teaching. Regarding point 2, 64% of respondents addressed that there had been a slight reduction in teaching and learning quality; 27% affirmed that there was a considerable fall. Regarding point 3, all colleagues agreed totally or partially with the statement: "Students of my discipline had adequate access to computational tools necessary to their studies".

5 FINAL REMARKS AND CONCLUSIONS

Despite the difficulties presented, especially affecting pedagogical aspects, two fundamental factors contributed to the development of these impacts when compared to other educational realities:

- A representative part of the students came from more affluent classes, which made technological resources (devices and connections) good enough to minimize the occurrence of technical or connection problems;

- When it comes to higher education, students have, in thesis, greater maturity, experience, and autonomy for learning, increasing the effectiveness of technology-mediated education when compared to another level of teaching (e.g. elementary school).

No one can deny that technology-mediated teaching impairs teacher/student interaction, so it is important to take actions that try to increase it, aiming for student motivation. To the discipline addressed in this work, the main actions were: reduction in theoretical exposition times; emphasis on addressing parallels between theory and real-world; allowing and stimulating individual chat with the teacher and encouraging the student to clarify their doubts during active learning classes.

As for the effectiveness of technology-mediated teaching, although quantitative analysis reveals close values, the best indicator was the experience that the teacher had in guiding a complex extracurricular practical project, conducted by 2 students of the course in 2020, where the teacher was able to evaluate that the concepts taught were learned and applied (at least by these 2 students). The conclusion that can be learned from this is that it is possible that technology-mediated teaching especially in operational disciplines such as simulation is effective, but that this depends on the teacher's strategy, as well as on the motivation and willingness to learn from the student side.

From this point, it is envisaged that, in the near future, the teaching especially of this type of discipline will be highly impacted by the pandemic period, maintaining characteristics of hybrid teaching, where there will be components of face-to-face teaching along with distance learning. In this way, we believe that, when everything returns to normal:

- Teaching will return being face-to-face, but without mandatory presence;
- During the class, the teacher will be present at the lab and also may be connected to the technology-mediated education system, where part of the students can attend classes remotely;
- Classes with theoretical content (especially) can be recorded for the students who miss them or for the students that would like to reinforce learning;
- Assignments will return to be face-to-face, but can be technology-mediated using platforms such as Moodle.

Finally, it is expected that the report of this experience will be of value for discussions and reflections aimed at improving the teaching and learning process in face of the challenges we are still experiencing and those that are to come.

APPENDIX A

To evaluate the final average grade along the 2019-2021 period we conducted statistical hypothesis tests using Minitab 18 and R 4.1.0. As depicted in Figures 3 to 5, all the samples were highly skewed.

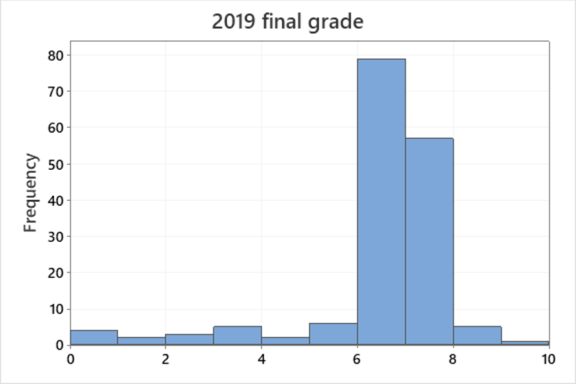

Figure 3: Histogram of 2019 final grade.

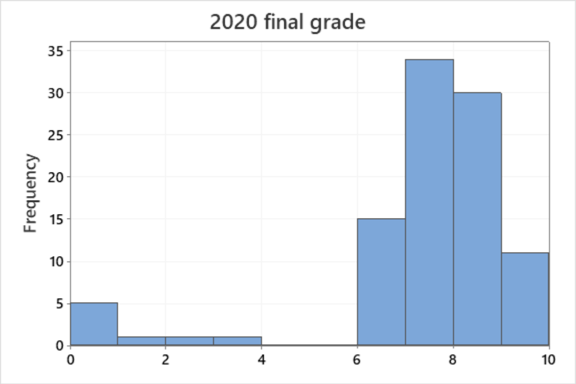

Figure 4: Histogram of 2020 final grade.

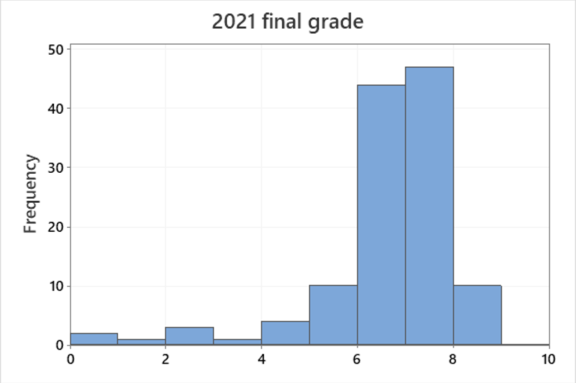

Figure 5: Histogram of 2021 final grade.

To formally investigate data normality, we conducted a Shapiro-Wilk test in the samples: the null hypothesis is that "sample distribution is normal". Assuming a significance level of 5%, we found out that none of the samples could be considered normal distributed (reported p-values in Table 2).

Table 2: Shapiro-Wilk normality tests results.

	2019	2020	2021
p-value	$2.379 \cdot 10^{-15}$	$6.113 \cdot 10^{-13}$	$2.484 \cdot 10^{-11}$

Due to non-normality, we conducted a non-parametric comparison test (Kruskal-Wallis rank sum test) to check if the final average grade were the same in each year (null hypothesis); the alternative was that at least one group differs from the others. Since p-value = $2.451 \cdot 10^{-14}$ (rank sum statistic = 62.68), we concluded that, at least in one year, the final average grade significantly differs from the others. Using a pairwise Wilcoxon comparison test, we confirmed that the final average grade in 2020 was statistically higher than the others, which proved to be equivalent to each other – see Table 3 and Figure 6.

Table 3: Pairwise comparison for final grade (test p-value).

	2019	2020
2020	$7.5 \cdot 10^{-14}$	–
2021	0.053	$5.7 \cdot 10^{-9}$

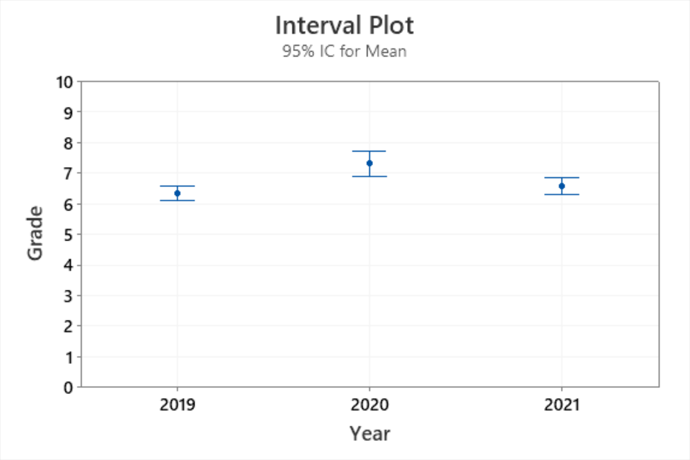

Figure 6: Interval plot for the final grade.

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