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IMPROVING DISTANCE LEARNING PROCESS IN ENGINEERING EDUCATION USING DESIGN OF EXPERIMENTS: RE-DESIGN OF AN ONLINE INDUSTRIAL ENGINEERING COURSE DURING AND BEYOND THE PANDEMIC COVID-19

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Abstract: This study aims to improve the quality of the learning process in engineering education. The COVID-19 health crisis pushed the scientific community to review teaching practices and reconsider their effectiveness. Engineering education and learning were not an exception to that. This article introduces a case study using the Design of Experiments method to improve engineering education quality, especially in the distance learning process. In this case study, we focused on designing the process of distance learning and its quality by working on the case of two industrial engineering classes (2021 and 2022 classes) in a Moroccan public engineering school. The collaboration between the teacher and these two engineering students' classes in their third year of industrial engineering enabled us to identify factors influencing learning quality. Then, we determined the optimal combinations of these factors for better quality by analyzing the results of the experiments. The Design of Experiments successfully implemented in manufacturing can also be applied to engineering education settings. The result of this study would help teachers and decision-makers understand the factors that influence the quality of learning to improve the distance learning process.

Keywords: Engineering education; Design education; Distance learning; Design of experiments; Improvement; Covid-19

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1. INTRODUCTION

Today, the integration of Information and Communication Technologies (ICT) is an indispensable factor in improving the quality of learning in higher education (Popenici and Kerr, 2017). At the same time, artificial intelligence is currently creating new challenges for all organizations, including higher education systems. Indeed, the transition from the traditional university to the SMART UNIVERSITY has become a strategic issue for higher education institutions that are entering the digital age by bringing together several actors in the framework of research and development (Kendall and Alam, s. d.).

Morocco has been following this same logic since 2013 with the launch of the Maroc Numeric 2013 project, the project for the integration of ICT in education, the LAWHATI project, and the INJAZ project to make available online courses, such as MOOCs (Massive open online courses), and educational content management platforms or LMSs (Learning management content) such as Moodle (Modular object-oriented dynamic learning environment) (Riyami, 2018)

In engineering schools, the practical application of theoretical knowledge and professional skills is essential. However, due to the health circumstances of the Covid-19 pandemic, most courses requiring hands-on training in addition to theory have not been delivered face-to-face, and practical training's outcome is being questioned. In this context, research into the effectiveness and use of this type of engineering learning is being addressed in several ways and from many perspectives that can be categorized under three main themes (Kocdar *et al*., 2021) (Ferdig *et al*., 2020).

Table 1. Distance learning perspectives

Topic	Object	Previous studies
Technology-enhanced engineering distance learning	Addresses the role of ICTs in supporting learning and teaching	Robb Lindgren and David DeLiema (Lindgren and DeLiema, 2022) EDUCAUSE Publications (*2019 Horizon Report*, n.d.) Jonas Hatzenbühler, Oded Cats and Erik Jenelius

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		(Hatzenbühler *et al*., 2022) C. R. Graham (Graham, 2004) K. Katzis, C. Dimopoulos, M. Meletiou-Mavrotheris, and I.-E. Lasica (Katzis *et al*., 2018) J. Khalfallah and J. Ben Hadj Slama (Khalfallah and Ben Hadj Slama, 2019) T. A. Koszalka and Y. Wu (Koszalka and Wu, 2010) W. Morton and J. Uhomoibhi (Morton and Uhomoibhi, 2011) A. Rahman and V. Ilic (Rahman and Ilic, 2018) S. Martin and al (Martin *et al*., n.d.)
E-learning and m-learning	E-learning corresponds to the 5th generation of distance education provided by the Internet M-learning is the use of mobile technologies such as smartphones and tablets, virtual reality, mixed reality, and Internet of Things (IoT) devices in the learning and teaching process	Joseph Cavanaugh, Stephen J. Jacquemin, and Christine R. Junker (Cavanaugh *et al*., 2022) EDUCAUSE Publications (*2019 Horizon Report*, n.d.) V. Milićević and al.(Milićević *et al*., 2021) M. Kara (Kara, 2020) C. Terkowsky, S. Frye, and D. May (Terkowsky *et al*., 2019) P. Kalansooriya and A. Marasinghe (Kalansooriya *et al*., 2015)
Virtual and remote labs	There is no common and universal definition since there are several strategies for using remote laboratories	Yin Huang, Farshad Amini, Chao Jiang and Jianjun Yin (Huang *et al*., 2022) Xie, C. Li, X. Huang, S. Sung, and R. Jiang (Xie *et al*., 2020) W. Morton and J. Uhomoibhi (Morton and Uhomoibhi, 2011) A. Rahman and V. Ilic (Rahman and Ilic, 2018) Mavrotheris and I.-E. Lasica (Katzis *et al*., 2018) R. Heradio, L. de la Torre, D. Galan, F. J. Cabrerizo, E. Herrera-Viedma, and S. Dormido (Heradio *et al*., 2016)

Previous studies have focused on the technology aspect and the development of distance learning tools and materials. Hence the need to provide more inputs to further develop these courses by examining the feedback of its stakeholders, including student and faculty satisfaction, identifying problems, and making improvements.

The TESF (Teaching Experiments and Student Feedback method) is a methodology that has been designed to be applied to a face-to-face course to improve certain aspects of teaching, such as the relevance of the recommended study material or the teacher's ability to interact with students (Barone *et al*., n.d.). It was limited to the feedback received from students only. In our study, we adapted this methodology to a distance learning course by extending it to the teacher's feedback as well as the introduction of tangible assessment means such as online tests.

As a result, we have developed the TESTF (Teaching Experiments and Student and Teacher Feedback) method. It is a methodology for course management by considering the feedback of the student, the return of the teacher, and the results of tests and evaluations as tools to measure the quality of a distance learning course.

2. METHODOLOGY

2.1 TESF/TESTF

The TESF methodology (Barone and Franco, 2010b) in its initial version is based on the fact that learning is a service process in which the student is the main stakeholder for the university service (Barone and Franco, 2010a). By applying this methodology, the teacher can improve certain aspects of his teaching using the design of experiments (DOE) method.

Figure 1. shows that the implementation of this method follows the PDSA (Plan-Do-Study-Act) continuous improvement approach. (Donnelly and Kirk, 2015). The Plan step represents the planning phase of the experiments by identifying the objectives and by relying on the students' requirements. The Do step represents the phase of conducting experiments. The Study phase represents the analysis of the results obtained. These results are collected using a feedback tool inspired by the SERVQUAL (SERviceQUALity) model. (Parasuraman *et al*., 1985) and submitted to a sample of students participating in the course to measure satisfaction. And the Act phase represents the implementation of improvement actions.

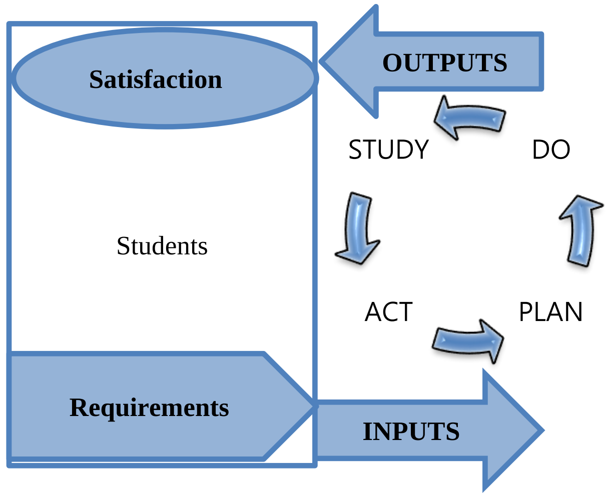

Figure 1. The management system of a university course according to the TESF method

In this study, we will work with the TESTF method by considering the student and the teacher as the two main actors in the teaching activity (Figure 2.). The result of the experiments will be based on the measurement of their satisfaction.

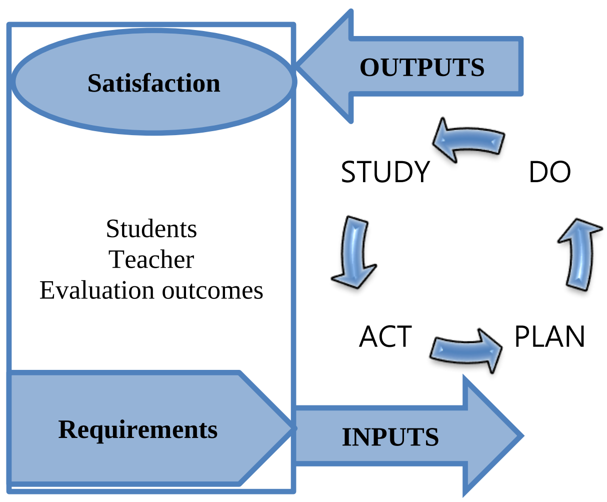

Figure 2. The management system of a university course according to the TESTF method

2.2 Design of Experiments (DOE)

The design of the experiment method provides an experimental protocol to model or predict response based on variability factors. By determining a relationship between two types of quantities, namely, the response: which corresponds to the physical quantity studied and the factors: which correspond to the physical quantities modifiable by the experimenter and supposed to influence the variations of the response (Montgomery, 2012). Once this relationship is determined, the optimal combinations of factor levels can be chosen to have the best-desired response.

Indeed, the principle of the method consists in simultaneously varying the levels of one or more factors (which are discrete or continuous variables) at each test. This will make it possible, on the one hand, to greatly reduce the number of experiments to be carried out while increasing the number of factors studied and, on the other hand, to detect the interactions between the factors and the determination of the so-called optimal setting of these factors concerning the response (Montgomery, 2012).

2.3 Conceptual Model of The Measured Quality of A Distance Learning Course

A university course represents a basic service process offered by higher education systems (Chui *et al*., 2016). Recently in Morocco, studies have been conducted on the quality of university service based on the satisfaction of the student as the main customer of this service (Goumairi *et al*., 2020) (Cherqaoui *et al*., n.d.). However, the definition of stakeholders (customers) of universities is more complicated. Students, faculty, academic staff, businesses, student families, and society are all different customers of the education system (Abdullah, 2006).

In this study, we will work on a distance learning course. We assumed that the quality of a distance learning course is the combination of the quality perceived by the student, the quality perceived by the teacher, and the quality represented by the grades of assignments and tests.

$$Q = \text{quality perceived by the student} \cup \text{quality perceived by the teacher} \cup \text{quality measured by the result of the tests} \cup \varepsilon \quad (1)$$

with Q is the Quality of Distance Learning;
U is the logical symbol union;
and ε is the unmeasured quality, it is assumed to be negligible.

In our model, we assumed that part of the quality perceived by the student coincides with the quality perceived by the teacher in the form of an intersection. In other words, in this area of intersection, the teacher and the student have the same perception of the quality of the course (Figure 1). According to the same logic, the quality evaluated by the tests joins those perceived by the student and the teacher in two areas of intersection.

We then collected the results of the experiment from the feedback of:

- SERVQUAL questionnaires for the student (APPENDIX A)
- SERVQUAL questionnaires for teachers (APPENDIX B)
- Student Responses to the Learning Test

At the end of each session, the students were asked to take a test of knowledge. Every test is a quiz of questions relating to the chapters treated during the same session. The percentage of correct answers represents the quality assessed by these tests rated q1.

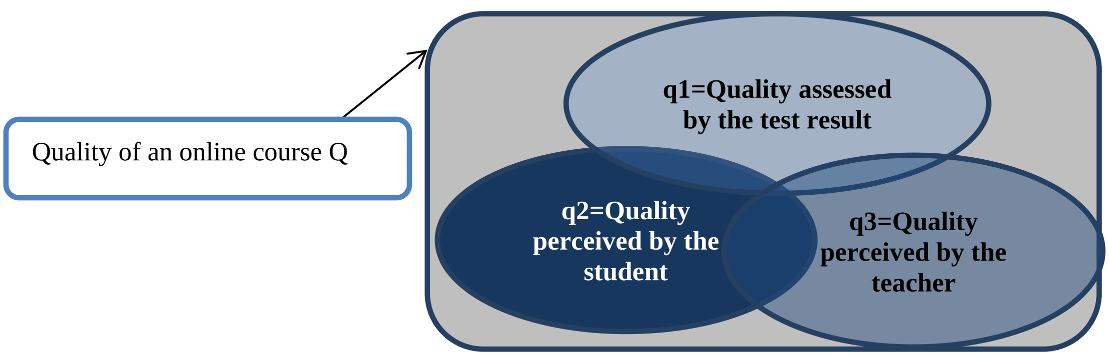

Figure 3. Conceptual model of the representation of the measured quality of a distance learning course

2.4 Factors influencing a distance learning course

In response to the COVID-19 pandemic, universities inevitably face unpredictable challenges such as insufficient experience in online teaching, content preparation, and insufficient educational technological support (Bao, 2020) and (Basak *et al*., 2018). Indeed, Moroccan higher education institutions have embraced distance learning alternatives such as online courses by videoconference. This type of conference is not new, and several international studies have been conducted to identify educational factors that can influence the quality of distance learning.

According to these previous studies (Seung-Hun, 2020) indicated that students prefer real-time online lectures over recorded lectures, and (Park *et al*., 2012) stated that Visio conferences increase motivation and participation. This type of e-learning is an information system that integrates several dimensions of education, including the digital platform, learning materials, audio, video, text, discussion, and quizzes. It should be noted that e-learning leads to convincing academic results, career development, and improved social status (Alsabawy *et al*., 2016).

An online engineering course is considered in our study as a service process that requires a design of audio and video content which correspond to the content of the technical subject to be taught (Siron *et al*., 2020). Moreover, in the context of the service, identifying what to measure, describing the process and how to measure is a major challenge. These measures depend heavily on the person providing the service. Variations related to human nature cannot be easily controlled, as service processes always have human interventions in service delivery (Antony *et al*., 2014).

3. CASE STUDY

3.1 Situation

This study was conducted in collaboration with two engineering students' classes in their third year of industrial engineering at a Moroccan public engineering school as part of a supply chain optimization (SCO) course. These are two successive classes, namely the class of 2021 (class A) and the class of 2022 (class B). These two classes experienced the first change in pedagogical approaches caused by the Covid-19 pandemic. The students went through 4 months (March, April, May, and June of the year 2020) of distance learning.

A rapid and unusual transition from normal (face-to-face) teaching to a new mode of distance learning, which represented several constraints opposite the training of engineers. The population covered in our study is a group of 30 engineering students aged between 22 and 23, distributed as follows:

Table 2. Population characteristic

Class	Characteristic	Division	N
A	Gender	M	5
		F	5
B	Gender	M	11
		F	9

3.2 Hypothesis

We adopted the conceptual model presented in Figure 1, modeling a distance learning course as a box whose inputs are the influencing factors and the output is quality Q (see Figure 2)

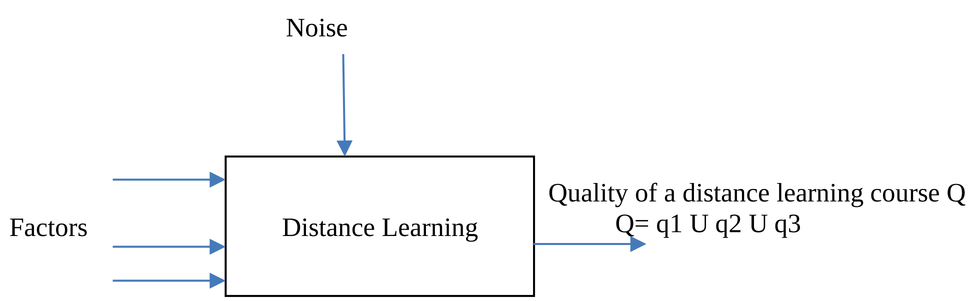

Figure 4. Learning model

The first version of this online course was carried out during the state of a health emergency. Its design did not have time to be very well thought out. After this first experience, at the end of June 2020, a brainstorming was conducted by a group of 28 students in class A and their SCO teacher to identify the major factors that influence distance learning.

The quality of a distance technical course was considered as a function of factors relating to the following three elements: Means, Teacher, and Student (Figure 3). The first factor related to the Means dimension represents the presence of the practical part and technical case studies in the content of the online course, the second factor related to the Teacher dimension corresponds to the audio-visual presentation of the teacher and students during the explanations, and the third factor related to the Student dimension represents the interaction of the students in the course and their active participation.

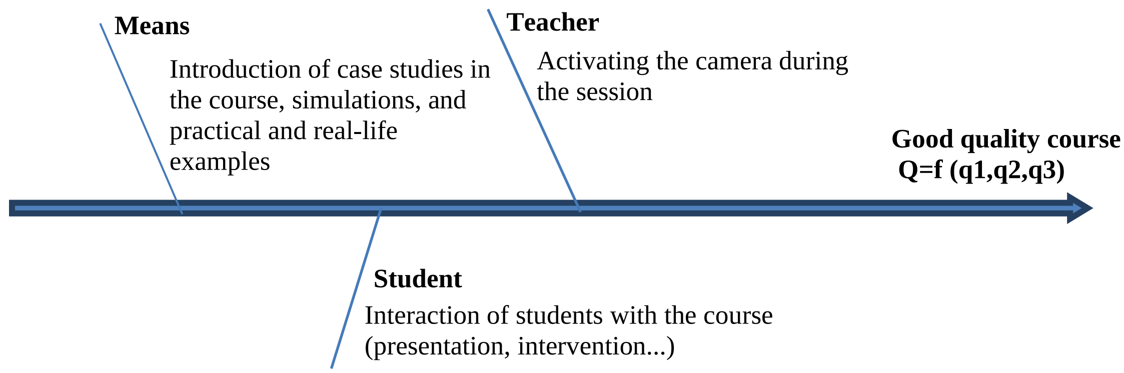

Figure 5. Cause and Effect Diagram for a Good Quality Course

Then we determined the levels for each of the three factors. We considered two levels for each factor, as described in Table 3.

Table 3. Factors Levels

Factor index	Factors	Level 1	Level 2
A	Introduction of case studies in the course, simulations, and practical and real-life examples	Lack of practical examples and real case study	Presence of practical examples and real case study
B	Activating the camera during the session	Disabling the camera during the course	Activating the camera during the course
C	Interaction of students with the course (presentation, intervention...)	Presentation of the theoretical part without student interaction	Active learning with student interaction

We chose three factors of two levels, so the number of experiments is $2^3 = 8$. Each factor was studied at two levels to minimize the size of the experiment. According to Montgomery, it is preferable to limit the number of levels of factors at the beginning of modeling. Generally, he recommends the choice of two levels to begin the process modeling studies (Montgomery, 2012). These experiments were conducted during 8 courses of three and a half hours. Each session corresponds to an experiment with levels of factors selected by the plan of experiments table (Table 3), which reveal to be controlled and maintained by the teacher throughout the session.

3.3 Experiments

The choice of experiments according to time was conducted randomly. The lowest level of each factor is presented by -1, and the highest level is presented by 1 (representation of Yates (Yates, 1933)). This experimental plan was conducted for two successive academic years (2020/2021 and 2021/2022) with the collaboration of two classes of the same engineering curriculum (class A and class B).

Table 4. Design of experiments

Experiment	A	B	C
1	-1	-1	-1
2	1	-1	-1
3	-1	-1	1
4	1	-1	1
5	-1	1	-1
6	1	1	-1
7	-1	1	1
8	1	1	1

To measure the response, a student was selected to monitor the experiment to keep the information on the questionnaires anonymous. His role was to assign a number for each student that would be an alternative for their name and surname on the forms. Only the student manager knows these attributions, which have not been communicated to the teacher, to ensure the anonymous and credible nature of the answers.

During each session, students take a knowledge test related to the chapters covered during that same session, and towards the end, they are invited to fill in a questionnaire (APPENDIX A) about satisfaction anonymously by reporting only their numbers. The teacher also fills in another questionnaire towards the end of each session (APPENDIX B). Both questionnaires were developed according to the SERVQUAL model, which represents the basis for the calculation of the two qualities, q2 and q3. The result of the knowledge test represents the evaluated quality q1.

Table 5. Results of the design of experiments for the two school years 2020-2021 and 2021-2022

School year	Experiment	q1	q2	q3
2020-2021 Class A	1	50	-0.181	-2.2778
	2	75	-0.153	-1.6667
	3	55.6	-0.181	-0.1667
	4	93.75	-0.153	0
	5	75	-0.228	-2.6667
	6	50	-0.173	-2
	7	75	-0.247	-0.3333
	8	50	-0.181	-0.38889
2021-2022 Class B	1	80	-0.14	-2.3
	2	100	-0.06	-0.2
	3	83	0.075	-0.3
	4	100	0.06	-1.8
	5	88	-0.125	-2.3
	6	75	-0.025	-0.3
	7	75	0.1	0
	8	80	-0.067	-1.4

4. RESULTS

4.1 Class A

The next part of the study involves analyzing data using Minitab software to assess the influence of main and interaction effects. The effect of a factor is the difference between medium qualities at high and low levels. For example, the average quality of test results q1 for factor A at a high level (case of presence of practical examples and real case study in the course session) is calculated as follows:

$$\mathrm{A}(+) = \frac{1}{4} \times (75 + 93.75 + 50 + 50) = 67.1875$$

Similarly, the average quality of test results q1 for factor A at a low level (case of absence of practical examples and real case study in the course session) is calculated as follows:

$$\mathrm{A}(-) = \frac{1}{4} \times (50 + 55.6 + 75 + 75) = 63.9$$

Effect of factor A:

$$\mathrm{A} = 67.1875 - 63.9 = 3.2875$$

This means when practical examples are introduced into the course, the test result improves by 3.2875% correct answers. In the same way, we worked on the effects of other factors B and C. Figure 6 shows the effects diagram for q1.

We found that the introduction of case studies in the course, simulations, and practical examples in the course (factor A), as well as the student's interaction with the course (presentation, intervention...) (factor C), are the two factors that have a positive effect on the test result. Camera activation during the course decreases quality q1 by 24.35%

The best combinations of factors for better q1 quality are:

- Presence of practical examples and real case study
- Disabling the camera during the course
- Active learning with student interaction

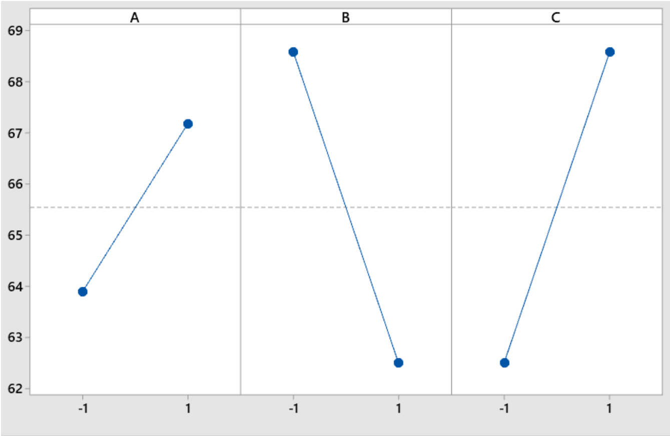

Figure 6. Diagram of main effects for quality q1-class A

We practiced the same method for the calculation of the effects of the factors on the two Quality q2 and q3, and we selected the best combinations respectively for q2:

- Presence of practical examples and real case study
- Disabling the camera during the course
- Presentation of the theoretical part without interaction with the students.

And for q3:

- Presence of practical examples and real case study
- Disabling the camera during the course
- Active learning with student interaction

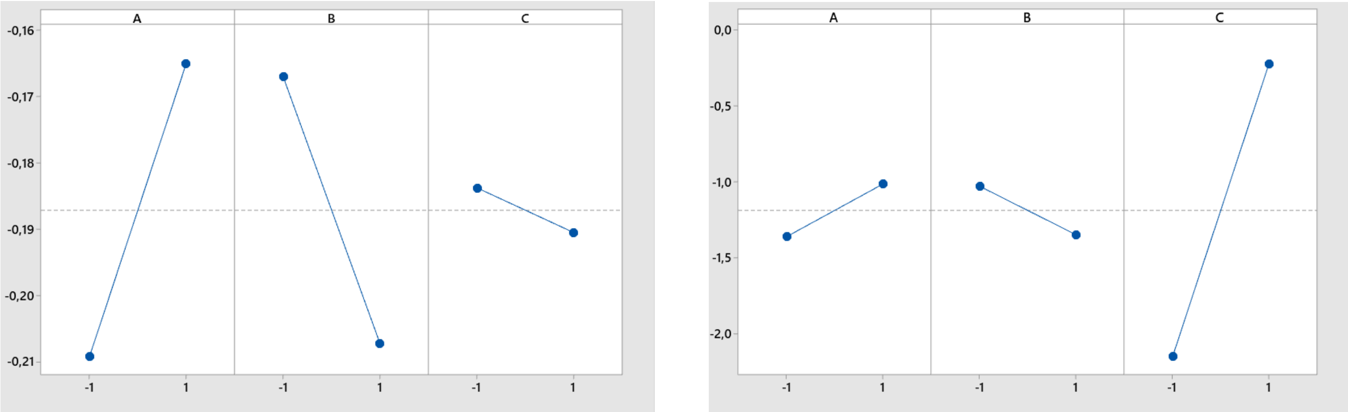

Figure 7. Main effect diagrams for grades q2 (left) and q3 (right) -class A

By analyzing the interaction effects between the three factors (APPENDIX C), we noticed that there is only a slight interaction between all the factors for the different qualities (the quasi-parallel lines) except for the interaction between A and B for quality q1, which is important.

4.2 Class B

Following the same calculation approach used previously with class A, we have determined the optimal combinations of factors to have the best qualities q1, q2, and q3. These combinations are described as follows.

For q1:

- Presence of practical examples and real case study
- Disabling the camera during the course
- Presentation of the theoretical part without student interaction

For q2:

- Presence of practical examples and real case studies (no considerable effect)
- Disabling the camera during the course
- Active learning with student interaction

and for q3:

- Presence of practical examples and real case study
- Activation of the camera during the course
- Active learning with student interaction

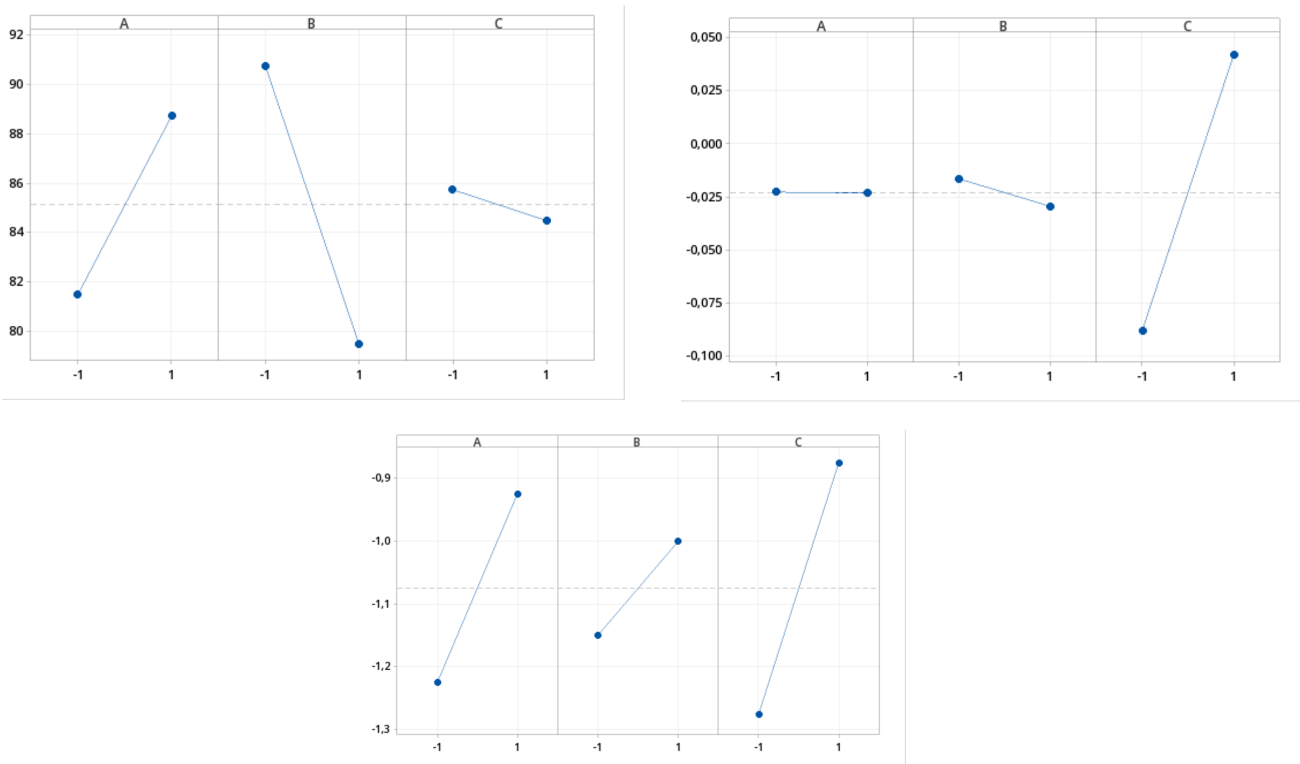

Figure 8. Main effect diagrams for grades q1 (left), q2 (right), and q3 (bottom) -class B

By analyzing the interaction effects between the several factors (APPENDIX D), we noticed that there is a difference compared to the study conducted on class A. Several interactions have been detected between all factors for the different qualities except a few that are mild (namely, the interactions between factors A and C and between factors B and C for quality q1 and the interaction between factors A and B for quality q3).

5. ANALYZE AND DISCUSSION

5.1 Main Findings of The Present Study

As per this case study's result, we note for the 2020-2021 academic year, the introduction of practical cases and real studies in this engineering course has significantly improved the quality of the course for the three Qualities (q1, q2, and q3). This result was confirmed during the second study of the year 2021-2022 for both qualities (q1 and q3) and no effect for q2.

Disabling the students' cameras and the teacher's cameras has a positive effect on the test results of both classes A and B as well as on the satisfaction of students in class A (this effect is not accentuated by the same intensity for class B). It also has a small effect on teacher satisfaction (Figures 7 and 8) for class A and a negative effect on teacher satisfaction for the second experiment (class B).

Active learning and student interaction with the course improve student performance (improved test scores) and increase teacher satisfaction (improved quality q3). However, they have a small negative effect on student satisfaction (class A). For class B, this interaction has a relatively negative effect (small effect) on test scores and a positive effect on teacher and student satisfaction.

5.2 Implication and Explanation of Findings

The introduction of real case studies has a positive effect on all types of qualities. The engineering course represents a kind of student preparation for the job market. This requires the study of practical case studies in parallel with the theoretical basis.

During the first transition to distance learning, the activation of cameras had a negative effect on all qualities. This could be explained by the fact that the students of class A were not accustomed to this type of lesson and that the activation of the webcams intimidates them, especially students who do not have favorable conditions (professional work background, free and quiet space...). In the second version of the course, cameras' activation does not have the same negative effect on student satisfaction (a relatively negligible effect). Moreover, we can notice that for all the qualities, the effect of this factor is not significant except for the quality q2 in the first version, which significant $p\text{-value}=0.011\leq 0.05$ (APPENDIX E)

Active learning and interaction of students with the course improve all types of qualities except student satisfaction in the first version of this type of course. This may be due to the inadequacy of this type of learning or that how students are involved in the course is not appealing.

5.3 Comparison with Other Studies

According to Daun, the training of engineers and the development of technical skills represent an important challenge in addition to the development of theoretical knowledge (Daun *et al*., n.d.). Walton claims that the motivation of engineering students is practically maintained by approaching current industrial studies, which allows students to see the practical application in the theoretical knowledge field (*Practical application of theoretical knowledge - ProQuest*, n.d.).

Research shows that online learning effectiveness is negatively mediated by communication problems, internet problems, and unfavorable home conditions (Prasetyanto *et al*., 2022) and (Kruszewska *et al*., 2022). Aykan adds to these challenges faced by the students: the problems of time management and a lack of knowledge and experience in this type of course (Aykan and Yıldırım, 2022).

Active learning is effective for distance/online learning. Ahshan claims that interaction with students increases their motivation to learn (Ahshan, 2021). In addition, this interaction positively influences teacher engagement in the course, according to (Cavinato *et al*., 2021).

All these comparisons support the explanations we have made.

6. CONCLUSION

Today, e-learning is no longer an option, but a necessity and its development are now indispensable. The use of the method of DOE, which is no longer reserved for the industrial field, has made it possible to re-design the course process based on the feedback of students and teachers. From the analysis of results provided by the application of this methodology, the following conclusion can be concluded;

- The introduction of actual case studies and practical examples in the course is an essential point for the effectiveness of the course "Supply Chain Optimization".
- Disabling the students' cameras improves their satisfaction and positively influences their test results. But, it can negatively affect teacher satisfaction.

- Teacher-student interaction improves teacher and student satisfaction as well as test scores.

Based on the above prescriptions, in the next distance version of the course, the teacher will use an introduction of real case studies and practical examples in each session of his course. Moreover, he avoids activating the student camera unless he deems it necessary. He is encouraged to create opportunities for interaction with students during class. To maintain this lasting improvement, we plan to apply this methodology iteratively by being part of the continuous improvement loop shown.

We recommend the adoption of the TESTF methodology also in other contexts relating to engineering education: other face-to-face or distance courses, other courses, and program design. This will provide an interesting field of new relevant research

In our study, we were interested in global class satisfaction. We worked in our SERVQUAL model with the means (of the perception and expectation scores) to calculate the global quality. This quality represents the overall satisfaction of the class and does not take into account the variability between the students since its calculation is based on the average. This point represents a limitation of our study. In other words, our SERVQUAL model for students' perspective is limited to global students' satisfaction.

A second limitation of our study lies in the fact that the experiment was conducted for a small number of students and was conducted for a single course. We plan to extend this method to other courses to cover a large number of students and to study other factors that could influence this type of learning.

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APPENDIX A

At the end of each session, a SERVQUAL questionnaire was sent to students to measure their level of satisfaction with the quality of the course of the same session.
The questionnaire is developed based on the conceptual model (Figure 8), assuming that the quality of the course, from the perspective of the students, depends on the three dimensions: the Teacher-Student interaction, the course content, and the course structure.

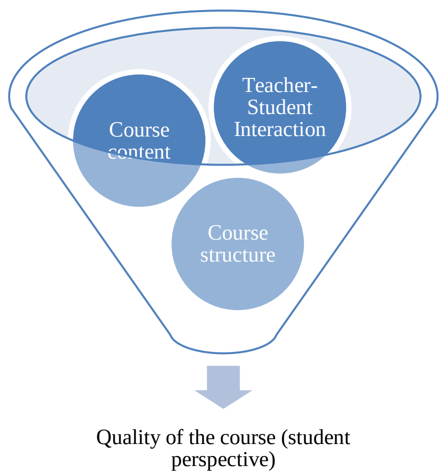

Figure 9. Conceptual model of course quality from the student's perspective

The SERVQUAL questionnaire consists of two sections; the first is about perception, and the second is about expectations. The difference between perception and expectations represents the quality of the course from the student's point of view.

Table 6: SERVQUAL questionnaire for the student's perspective

	Dimensions	Questions	Responses (Likert scale)
Perception	Teacher-Student Interaction	Is the teacher available to help students?	1 2 3 4 5 Very dissatisfied 0 0 0 0 0 Very satisfied
		Is the teacher active in explaining his course?	
		Does the teacher encourage intervention with his students?	
	Course Content	Does the course content meet the needs of the material?	
		Is the quality of the presentation and explanations good?	
		Is the course content updated?	
		Is the content rich in terms of technical knowledge?	
		Are course materials posted online on time?	
		Can students interact with the content using a variety of tools (e.g., PowerPoint presentations, video, or audio intervention...)?	
	Course structure	Is the organization of the course good?	
		Is the quality of the course material good?	
		Is the distribution of the theoretical and practical parts of the course consistent?	
Expectations	Teacher-Student Interaction	The teacher is available to help students	1 2 3 4 5 Not at all important 0 0 0 0 0 Very important
		The teacher is active in explaining his course	
		The teacher encourages the intervention of his students	
	Course content	The course content satisfies the needs of the material	
		The quality of the presentation and explanations is good	
		Course content is updated	
		The content is rich in terms of technical knowledge	

		Course materials are posted online on time	
		Can students interact with the content using a variety of tools (e.g., PowerPoint presentations, video, or audio intervention...)	
	Course Structure	The organization of the course	
		The quality of the course material	
		The correct distribution of the theoretical and practical parts of the course	

APPENDIX B

At the end of each session, the teacher fills in a SERVQUAL questionnaire to measure his level of satisfaction. This questionnaire has been developed in the same way as the student questionnaire based on the same conceptual model (Figure 8).

Table 7. The teacher SERVQUAL questionnaire

	Dimensions	Questions	Responses (Likert scale)
Perception	Teacher-Student Interaction	were you active in explaining the course this session?	1 2 3 4 5 Very dissatisfied 0 0 0 0 0 Very satisfied
		Were students encouraged to speak with you during the session?	
	Course Content	Does the course content meet the needs of the material?	
		Is the quality of the presentation and explanations good?	
		Is the course content updated?	
		Is the content rich in terms of technical knowledge?	
		Are course materials posted online on time?	
		Can students interact with the content using a variety of tools (e.g., PowerPoint presentations, video, or audio intervention...)?	
	Course structure	Is the organization of the course good?	
		Is the quality of the course material good?	
Expectations	Teacher-Student Interaction	The teacher is active in explaining his course	1 2 3 4 5 Not at all important 0 0 0 0 0 Very important
		The teacher encourages the intervention with his students	
	Course Content	The course content satisfies the needs of the material	
		The quality of the presentation and explanations	
		Course content is updated	
		The content is rich in terms of technical knowledge	
		Course materials are posted online on time	
		Can students interact with the content using a variety of tools (e.g., PowerPoint presentations, video, or audio intervention...)	
	Course structure	The organization of the course	
		The quality of the course material	

APPENDIX C

For the year 2020, these are the diagrams of interaction effects between the three factors for q1 (left) and q1 (right), and q3 (the bottom).

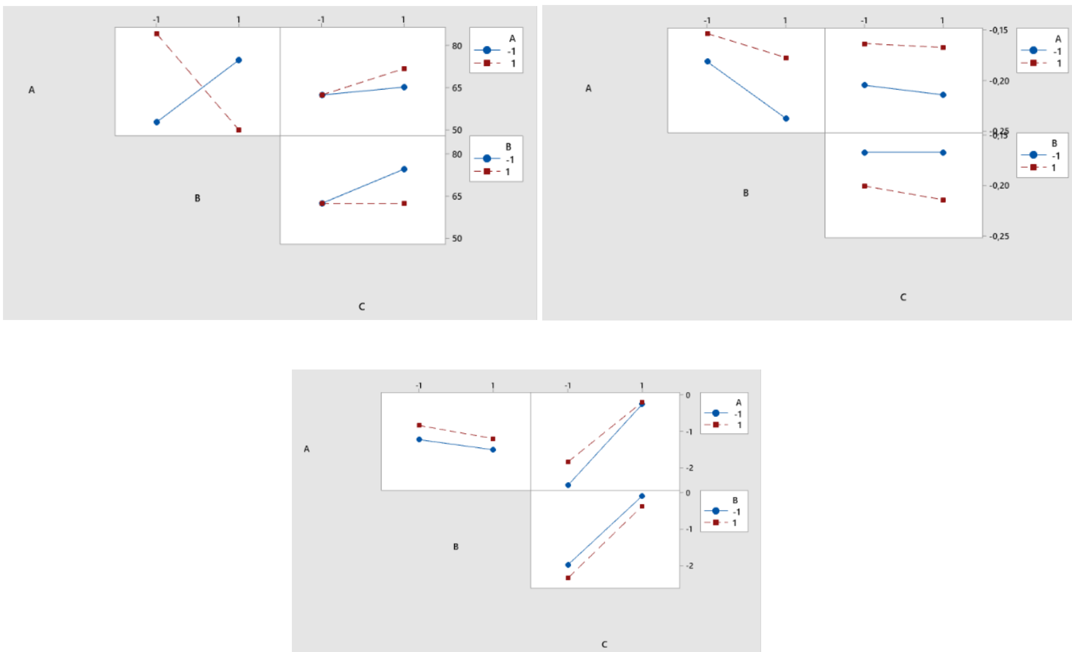

Figure 10. Diagrams of interaction effects between factors for q1 (left) and q1 (right), and q3 (the bottom)-Class A

APPENDIX D

For the year 2021, these are the diagrams of interaction effects between the three factors for q1 (left) and q1 (right), and q3 (the bottom).

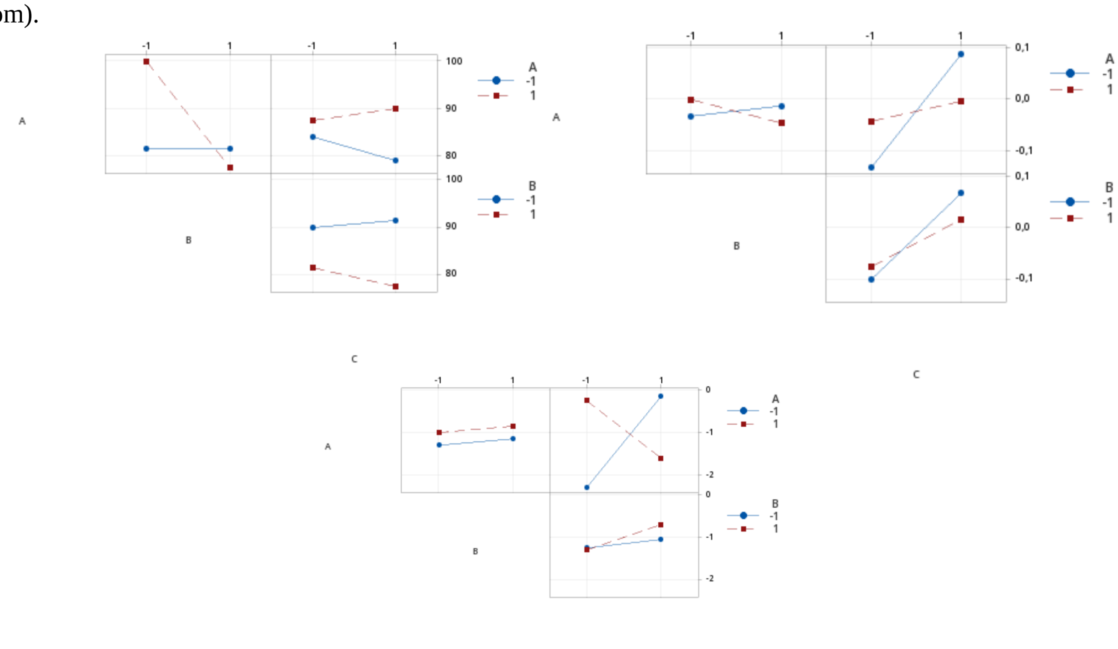

Figure 11. Diagrams of interaction effects between the three factors for q1 (left) and q1 (right), and q3 (the bottom) - Class B

APPENDIX E

The result of the analysis of variance for the three qualities (q1, q2, and q3) for the two classes A and B, calculated using the Minitab software, is as follows:

Class A

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	169,85	56,62	0,13	0,936
Linear	3	169,85	56,62	0,13	0,936
A	1	21,62	21,62	0,05	0,833
B	1	74,12	74,12	0,17	0,699
C	1	74,12	74,12	0,17	0,699
Error	4	1717,71	429,43		
Total	7	1887,56			

Analysis of variance for q1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0,007247	0,002416	14,88	0,012
Linear	3	0,007247	0,002416	14,88	0,012
A	1	0,003916	0,003916	24,12	0,008
B	1	0,003240	0,003240	19,95	0,011
C	1	0,000091	0,000091	0,56	0,495
Error	4	0,000650	0,000162		
Total	7	0,007897			

Analysis of variance for q2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	7,8995	2,63315	56,40	0,001
Linear	3	7,8995	2,63315	56,40	0,001
A	1	0,2411	0,24113	5,16	0,085
B	1	0,2041	0,20406	4,37	0,105
C	1	7,4543	7,45426	159,67	0,000
Error	4	0,1867	0,04669		
Total	7	8,0862			

Analysis of variance for q3

Class B

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	361,375	120,458	1,37	0,372
Linear	3	361,375	120,458	1,37	0,372
A	1	105,125	105,125	1,20	0,336
B	1	253,125	253,125	2,88	0,165
C	1	3,125	3,125	0,04	0,860
Error	4	351,500	87,875		
Total	7	712,875			

Analysis of variance for q1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0,033879	0,011293	1,80	0,287
Linear	3	0,033879	0,011293	1,80	0,287
A	1	0,000001	0,000001	0,00	0,993
B	1	0,000338	0,000338	0,05	0,828
C	1	0,033540	0,033540	5,34	0,082
Error	4	0,025145	0,006286		
Total	7	0,059023			

Analysis of variance for q2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0,54500	0,18167	0,12	0,945
Linear	3	0,54500	0,18167	0,12	0,945
A	1	0,18000	0,18000	0,12	0,751
B	1	0,04500	0,04500	0,03	0,873
C	1	0,32000	0,32000	0,21	0,673
Error	4	6,21000	1,55250		
Total	7	6,75500			

Analysis of variance for q3

Figure 12: the result of the analysis of variance

Abbreviations

TESTF: Teaching Experiments and Student and teacher Feedback; DOE: Design of Experiments; ICT: Information and Communication Technologies; MOOCs: Massive open online courses; LMSs: Learning management content; Moodle: Modular object-oriented dynamic learning environment; The TESF: Teaching Experiments and Student Feedback method; PDSA: Plan-Do-Study-Act; SERVQUAL: SERviceQUALity; SCO: Supply Chain Optimization.

Declarations

Acknowledgments
Not applicable.

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Not applicable.

Availability of data and materials
The data generated and analyzed during this study are included in this published article. Additional material can be shared upon reasonable request.