Research Article

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The Show Must Go On II: Statistics In (Engineering) Higher Education

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Abstract: The COVID-19 pandemic forced Portuguese higher education institutions to go home and teach online. Therefore, we had an online experience teaching the Statistics course to the Social Service degree. Viewing this school year experience, we decided to make some changes in the Statistical courses of Informatics, Mechanical and Civil Engineering degrees. Our main concern is still the uncertainty of what is yet to come in the next first semester: face-to face or emergency remote education. In this work we present our ideas in order to develop our students' skills – collaboration, communication, citizenship/culture, creativity, and critical thinking – through their probability and statistics course and as part of their degree's curricula.

Keywords: Higher education; engineering; learning; statistics; skills.

1 Introduction

Due to COVID-19 pandemic, Portuguese higher education institutions faced the challenge to change from face-to-face delivery of courses to digitally teaching for distance learning in order to prevent the spread of the coronavirus. According to Bozkurt et al. (2020):

“The educational practices during the Covid-19 pandemic are denoted with different terms in different countries (e.g., distance education, e-learning, online education, homeschooling, etc.). However, these terms do not quite capture what is being practiced during the interruption of education, which can better be described as emergency remote education.”

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It was quite a test: one day you are at the university in the same room of the students, the next class we should meet the students using a virtual conference platform. It happened to us in the third week of March 2020. Therefore, we had an online experience teaching the statistics course to the Social Service degree. Viewing this school year experience – emergency remote education, we decided to make some changes to the statistical courses of Informatics, Mechanical and Civil Engineering degrees. Furthermore, at this time we still don't know how the first semester of the school year 2020/2021 will take place: all face-to-face classes (face-to-face); online theoretical classes and face-to-face theoretical-practical or laboratory classes (blended learning); if the COVID-19 pandemic spreads again, switch to online classes – emergency remote education. At the same time, the “creation or deeper modification of teaching and learning processes to fulfill the needs” (Kedra & Kaltsidis, 2020) of probability and statistics courses taught to those engineering degrees need to be made. In this work we present our ideas, planning, strategies and assessment proposal for the first semester of 2020/2021 that we think we can ensure in either learning type with minor adjustments. These are made in order to develop our students' skills – collaboration, communication, citizenship/culture, creativity, and critical thinking – through their probability and statistics course and as part of their degree's curricula.

2 Framework

Once according to Bozkurt et al. (2020):

“The pandemic has shown the need for a pedagogy of care, over a need to teach the curriculum. Now, more than ever before, educators are thinking about learners beyond their role in the classroom to the difficulties they may be facing in their personal lives. This care and concern are an important trait that needs to be developed and strengthened as it is not only needed in times of crisis but always. The pandemic has also highlighted the need to shift to more student centered practices and pedagogies that emphasize the process of learning and student experience and engagement online, rather than merely being assessed at the end.”

As we have experienced, switching to remote education overnight “is disruptive to the status quo, as you would expect with such a major new approach, and it is completely realistic to expect there to be less delivery in the classroom” (Hubbard, 2013, p.17). Teacher intervention was greater since we need to devise other ways to implement the individual and collaborative learning with our students and, at the same time, different resources and tasks (e.g., small video with introduction to classes or with exercises solving) were done and other platforms were used (e.g., Moodle, Padlet, Jamboard). And those adjustments are in line with the work of Bozkurt et al. (2020), as we mentioned.

The application of education, learning and social-behavioural sciences research “has and continues to influence engineering education” (Froyd, Wankat, & Smith, 2012). So, we have to plan, choose the strategies and decide the assessment protocol in order to present them to the students in the course syllabus (FUC, the curricular unit file Portuguese acronym). First, we need to present the students with the topics list we will cover, but the learning outcomes that students have to achieve at the end of the course have to be explicit to them “and assessment is criterion-referenced to see how well the outcomes have been attained.” (Biggs & Tang, 2011, p.14). And these “outcomes-based approaches (...), as well as assessment tasks, teaching and learning activities are also aligned to the outcomes, in order that students are helped to achieve those outcomes more effectively.” (Biggs & Tang, 2011, p.14). The present work is a descriptive presentation of the planning we devised for next school year and that we think may work in either form of teaching (face-to-face or remote education) and it is in line with complex learning (van Merriënboer, Clark & Croock, 2002).

In the design of the curricular units the use of learning outcomes and Bloom’s Taxonomy “is having a noticeable influence on the engineering education community” (Froyd et al., 2012). The planning will also be based in the 4C/ID instructional design model (van Merriënboer et al., 2002), teaching and learning methods, and assessment. In this instructional design model, four components are interrelated and they are the basis for complex learning: (a) learning tasks, (b) supporting information, (c) information given at the moment just-in-time (JIT) and (d) partial practical task. Instructional methods for each component are grouped with the basic learning processes involved in complex learning (van Merriënboer et al., 2002). We also took into account the educational protocol to support the development of critical thinking (Elen et al., 2019).

3 Proposal presentation

3.1 The course

From the FUC of the courses of one of the engineering degrees, the workload, the contact hours and the ECTS¹ are presented in Figure 1. That is, the contact hours in a face-to-face learning system is 2 hours/week/15 weeks of theoretical classes (T) and 2 hours/week/15 weeks of theoretical-practical (TP) or practical-laboratory (PL) classes; the tutorial classes (OT) are 8 minutes/week/15 weeks, and the autonomous work is 6 hours/week/15 weeks. Nevertheless, maybe the next first semester will somehow be different since we expect to have remote education in the theoretical classes and only face-to-face learning for OT or PL classes.

The teaching contents are the usual for an engineering course of “Statistical Methods” or “Probability and Statistics” (Figure 2).

3.2 The learning outcomes

At the end of the statistical course the students should be able to select statistical concepts and data analysis methods to apply in their engineering fields (Figure 3). Throughout the semester course, the learning outcomes (LO) become more demanding. This is because at the end of the semester the students have to accomplish the major outcome of their statistical course.

The objectives defined in each topic will be pursued using strategies that also promote the development of critical and creative thinking skills. For each topic, the learning outcome is defined using the verbs presented in Figure 3, which belong to the categories identified. The categories identified with competences of critical and creative thinking are mainly analysis and evaluation (and synthesis; adapted from Silva & Lopes, 2015, pp. 19-28). Even in the first subjects of the course, but mainly when we begin inferential statistics “the analysis involves breaking down the material into its constituent parts and determining how the parts relate to each other and to the general structure of the information.” (Silva & Lopes, 2015). Next, the “evaluation is the highest level of the cognitive domain. It involves issuing judgments based on

¹ European Credit Transfer System, ECTS, measures and compares learning achievements and students easily transfer their credits from one institution to another, Adapted in 15.07.2020 from <https://www.mastersportal.com/articles/388/all-you-need-to-know-about-the-european-credit-system-ects.html>

Teaching load / contact hours / ECTS						
Autonomous work (hours)		Distribution of contact hours			Total (hours)	ECTS
100.01	OT	PL	T		162	6.00
	2	30.00	30.00			

Figure 1: Excerpt from FUC of one of the engineering degrees.

1. Probability Theory (Review): Basic definitions; Definitions of probability and its properties; Conditional probability; Independence of events (new).
2. Real random variables: Discrete and continuous random variables; Distribution function; Mass probability function and density function, cumulative probabilities functions; Localization and dispersion parameters; Discrete and continuous laws; Central limit theorem and approximations of probability distributions.
3. Descriptive Statistics: Types of variables and scales, graphics, measures of central tendency, dispersion, symmetry.
4. Inferential Statistics: Samples and sampling distributions. Point estimation and confidence intervals.
5. Parametric and non-parametric hypotheses testing.
6. Introduction to ANOVA and simple linear regression.

Figure 2: Subjects in the engineering degrees statistical courses.

Figure 3: Learning outcomes (LO) in statistical courses.

Figure 4: Theoretical classes' schema.

criteria and standards. The student evaluates or criticizes something based on specific rules and criteria" (Silva & Lopes, 2015).

When we detail these major learning outcomes in our weekly planning, we will explicitly give emphasis to these learning outcomes in order to make students know what kind of subject appropriation is required of them. We will also include the critical thinking skills (interpretation, analysis, inference, evaluation, explanation, and self-

regulation) and dispositions (truth-seeking, open mindedness, analyticity, systematicity, self-confidence, inquisitiveness, and cognitive maturity) from the Faccione framework (Dominguez et al, 2018).

3.3 Theoretical classes

In Figure 4 the main ideas for the planning of theoretical classes (T) are presented. We intend to have some theoretical notes from a book, some slides notes, to give before the T in order for students to prepare for those classes' activities.

We intend to give the students "reading quizzes (...) before the beginning of the class period" (Wilson, 2013) in the institutional Moodle platform. In that way, students will have to look, study and may discuss the answers of the quiz immediately before the class. To begin the class, we will give the students an item of a newspaper news, a small video (2/3 minutes) or another source of statistical information in order to have a brief and directed debate about the class subject. Next, students will have a written task – with the learning outcomes explicitly highlighted – to be done using the "think-pair-share" strategy in pairs or groups of three (Lopes, Silva, Dominguez & Nascimento, 2019, p. 92) or other strategies such as jigsaw (Lopes et al., 2019, p. 39). In a pandemic situation, simultaneous rooms of group work may be used, e.g., in Zoom, as was already done in the 2nd semester of 2019/2020. The teacher will be available to discuss and help the students. After T classes, several pair or group activities may be required of the students (Figure 5) either for assessment or to reflect in a different way on the contents of the T classes.

The plan we have is to give almost immediate feedback after completion of the tasks in order to review the subject or even to interconnect them. For instance, if students are able to do a concept map or any type of schema that summarizes how to connect probability main topics and random variables and their distributions topics, clearly, they are able to deal with the difficulties of probability distributions. Despite the high number of students in those courses, it is possible to choose one work per T class and discuss it over some minutes of the class using questioning in order that all students achieve the outcome

Figure 5: T classes strategies.

Figure 6: PL or TP classes strategies.

of the task by improving that particular work. In the next subject or task, another group will be chosen. Despite the fact that we are in a remote education, students usually give feedback and involve themselves in more dynamic T classes.

3.4 Practical-laboratory classes

In Figure 6 the main ideas behind Practical-laboratory (PL or called in other courses theoretical-practical, TP) is presented. Usually, those classes come after the T class in the week, so it is possible to ask a pair/group of students (e.g., in a rotatory way) to summarize the previous T class in a few main topics. Next semester – 2020/2021 – if classes are either face-to-face, remote or both.

Next, tasks with problems are provided to students that they should complete in pairs or groups of three. Although the teacher is available to support them, the group must use the materials provided and the use of technological resources for statistical calculations is encouraged. For example, instead of the paper tables we invite students to use calculators or to look for mobile apps (Figure 7), to search for answers online in order to discuss if they are good or if students are able to improve them writing their own reasons about the issues raised.

From the middle of the semester till the end of it, some of the classes will be used to structure the project work and to learn how to work with the statistical software adopted. In the last 5 or 6 years, we have used a survey on a topic and students have analysed the data of a group of selected questions/variables in order to answer the aim that the work group (no more than three students) established. The final product has been a statistical poster and students had to present it during the last class of the semester and had to answer other groups' and the teachers' questions.

In this academic year of 2019/2020, we used the Padlet as a mural to schedule and follow the pairs/group peer-review activity cycle (Figure 8). Students did a digital presentation about the variable types and central tendency measures and the Padlet had the teacher's guidelines and schedules in one column and each group of group-student author and group-student reviewer had a column to present each other documents along the cycle stages (1 to 4). For example, in the guidelines we delivered a document with good feedback (based on Lopes et al., 2019, pp. 101-102). This semester the feedback between the groups was not anonymous, nevertheless students did it rather well. Since next year we are going to have engineering students, maybe we will try a different and challenging activity cycle task (Dominguez et al., 2015) with student written problems or texts about a newspaper news with a statistical subject. Next semester from the next academic year – 2020/2021 – we will use these tasks, since the students did like to use the online platform, and we will propose the analysis of a paper about the pandemic effect from a newspaper that presents some statistical data.

3.5 Assessment

Assessment has the function of regulating the teaching and learning process. It makes it possible to check if the students are making the desired progress and finding the necessary paths to reach the established goals (Lopes et al., 2019, p. 245).

The presented ideas gave rise to a series of elements in order to diversify the assessment elements, and in Figure 9 we present the different weights that we will discuss with the students (during the two first weeks of the semester) in order to complete the continuous assessment to be included in the FUC. Usually, we have three written tests, but, as we added so many other components to the assessment, in and out of class, in the next school year two tests will be enough and, if students are involved in

Figure 7: Probability distributions computations using mobile apps.

Figure 8: Pairs/group peer-review activity cycle (Lopes et al., 2019, p. 114).

the learning process, the autonomous working hours will be totally accomplished.

The weights and the parallel feedback from the teacher will allow the students to review and improve their own knowledge and their other skills and dispositions as already mentioned.

4 Final remarks

“Just because someone quotes you a statistic or shows you a graph, it doesn’t mean it’s relevant to the point they’re trying to make. It’s the job of all of us to make sure

Element considered	Suggested weight
“Reading quizzes”	10%
In-class activities	10%
Out-class activities	10%
Project work	20%
1 st test	25%
2 nd test	25%

Figure 9: Suggested weights to the assessment elements.

we get the information that matters, and to ignore the information that doesn’t.” (Levitin, 2016)

If the students are devoted and involved in the planned activities, at the end of the Statistics course they

should be able to select statistical concepts and data analysis methods to apply in their engineering fields (Figure 2), thus fulfilling the main outcome of the course. In summary, in the next academic year, 2020/2021, at the end of the 1st semester using either face-to-face, remote education or both, we will not expect to have statisticians, but, given the importance of the covered subjects, in probability and statistics the students should have learnt to assess correctly and critically:

- to collect the data
- to overview the potential problems and analytical errors that can affect their own analysis (e.g., biased samples, violating the assumptions for an analysis, overgeneralization, causality)
- to select the correct method during a statistical analysis
- to present results
- to evaluate the quality of other analysis presented to them
- to find help from a statistician if they cannot manage the problem they were required to solve.

The ideas presented will be developed in the 1st semester of the next school year – 2020/2021 – with engineering students using a weekly detailed planning, including the choice of the adequate strategies (and feedbacks between students, students-teacher and groups-teacher) in order to obtain the elements – as significantly as possible – for the students' assessment. If we follow the educators' suggestion of Bozkurt and his colleagues (2020) we will try to be empathic, human, simple, curricular agents and we will promote collaboration. We will maintain close contact with our students and will stimulate the contacts between students, we will try to do a feedback follow up in order to keep them engaged and involved. We will try not to "lose" students along the way.

References

- Biggs, J. B., & Tang, C. (2011). *Teaching for quality learning at university: What the student does*. UK: McGraw-Hill Education.
- Bozkurt, A., Jung, I., Xiao, J., Vladimirsch, V., Schuer, R., Egorov, G., ... & Rodes, V. (2020). A global outlook to the interruption of education due to COVID-19 Pandemic: Navigating in a time of uncertainty and crisis. *Asian Journal of Distance Education*, 15(1), 1-126.
- Dominguez, C., Dumitr, D., Bigu, D., Elen, J., Ahern, A., McNally, C., ... & O'Sullivan, J. (2018). *A European collection of the Critical Thinking skills and dispositions needed in different professional fields for the 21st century*. UTAD.
- Dominguez, C., Nascimento, M., Payan-Carreira, R., Cruz, G., Silva, H., Lopes, J., Morais, M. F., & Morais, E., (2015). Adding value to the learning process by online peer review activities: towards the elaboration of a methodology to promote critical thinking in future engineers, *European Journal of Engineering Education*, 40(5), 573-591, DOI: 10.1080/03043797.2014.987649
- Elen, J., Jiang, L., Huyghe, S., Evers, M., Verburgh, A., ..., & Palaigeorgiou, G. (2019). *Promoting Critical Thinking in European Higher Education Institutions: towards an educational protocol*. Vila Real: UTAD.
- Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE*, 100 (Special Centennial Issue), 1344-1360.
- Hubbard, R. (2013). *The really useful e-learning instruction manual*. United Kingdom: John Wiley & Sons Ltd.
- Kedra, K., & Kaltsidis, C. (2020). Effects of the COVID-19 Pandemic on University Pedagogy: Students' Experiences and Considerations. *European Journal of Education Studies*, 7(8), 17-30.
- Levitin, D. J. (2016). *A field guide to lies: Critical thinking in the information age*. Penguin. The quote was retrieved in 22-06-2020 from <https://www.goodreads.com/quotes/>
- Lopes, J., Silva, H., Dominguez, C., & Nascimento, M. (2019). *Educar para o Pensamento Crítico na Sala de Aula - Planificação, Estratégias e Avaliação* [Educating for Critical Thinking in the Classroom - Planning, Strategies and Evaluation]. Lisbon: Pactor.
- Silva, H. & Lopes, J., (2015) *Eu, Professor, Pergunto* [I, Teacher, Do Ask]. Vol. I. Lisbon: Pactor.
- van Merriënboer, J. J., Clark, R. E., & De Croock, M., (2002). Blueprints for complex learning: The 4C/ID-model. *Educational technology research and development*, 50(2), 39-61.
- Wilson, S. G. (2013). The flipped class: A method to address the challenges of an undergraduate statistics course. *Teaching of psychology*, 40(3), 193-199.