



## Teaching Guide

| Teaching Guide           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |          |           |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----------|-----------|
| Identifying Data         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |          | 2019/20   |
| Subject (*)              | Design and Analysis of Experiments                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |        | Code     | 614493010 |
| Study programme          | Mestrado Universitario en Técnicas Estadísticas (Plan 2019)                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |          |           |
| Descriptors              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |          |           |
| Cycle                    | Period                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Year   | Type     | Credits   |
| Official Master's Degree | 2nd four-month period                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | First  | Optional | 5         |
| Language                 | Spanish                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |        |          |           |
| Teaching method          | Face-to-face                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |          |           |
| Prerequisites            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |          |           |
| Department               | Matemáticas                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |          |           |
| Coordinador              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | E-mail |          |           |
| Lecturers                | ,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | E-mail |          |           |
| Web                      | <a href="http://dm.udc.es/staff/jose_vilar/">http://dm.udc.es/staff/jose_vilar/</a>                                                                                                                                                                                                                                                                                                                                                                                                                                                 |        |          |           |
| General description      | This subject provides an introduction to the basic principles of the experimental planning process and a broad range of statistical models to deal with data coming from planned designs. Particular emphases is put on: (i) evaluating the pros and cons of various design strategies, and (ii) discussing the applicability of the statistical procedures according to the pursued objectives and the structural assumptions behind data. Statistical software is also used to complement the practical and theoretical learning. |        |          |           |

## Study programme competences

| Code | Study programme competences                                                                                                                                                |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A2   | Capacidade para comprender, formular, formular e resolver aqueles problemas susceptibles de ser abordados a través de modelos da estatística e da investigación operativa. |
| A4   | Coñecer algoritmos de resolución dos problemas e manexar o software axeitado.                                                                                              |
| A6   | Realizar inferencias respecto aos parámetros que aparecen no modelo.                                                                                                       |
| A9   | Obter os coñecementos precisos para unha análise crítica e rigorosa dos resultados.                                                                                        |
| A10  | Complementar a aprendizaxe dos aspectos metodolóxicos con apoio de software.                                                                                               |
| B6   | Capacidade para iniciar a investigación e para participar en proxectos de investigación que poden culminar na elaboración dunha tese doutoral.                             |
| B10  | Capacidade de identificar e resolver problemas                                                                                                                             |
| B11  | Capacidade de integrarse nun equipo multidisciplinar para a análise experimental                                                                                           |
| B12  | Adquirir destreza para o desenvolvemento de software                                                                                                                       |
| B13  | Capacidade de análise estatística crítica das mostras, as formulacións e resultados                                                                                        |
| C1   | Ser capaz de identificar un problema da vida real.                                                                                                                         |
| C2   | Dominar a terminoloxía científica-metodolóxica para comprender e interactuar con outros profesionais.                                                                      |
| C3   | Habilidade para traballar os aspectos metodolóxicos da investigación en colaboración con outros colegas a través do Campus Virtual co foro.                                |
| C4   | Habilidade para realizar a análise estatística con ordenador.                                                                                                              |
| C5   | Escooller o deseño máis axeitado para responder á pregunta de investigación.                                                                                               |
| C6   | Utilizar as técnicas estatísticas máis axeitadas para analizar os datos dunha investigación.                                                                               |
| C7   | Planificar, analizar e interpretar os resultados dunha investigación considerando tanto os aspectos teóricos coma os metodolóxicos.                                        |
| C8   | Habilidade de xestión administrativa do proceso dunha investigación.                                                                                                       |
| C9   | Comunicación e difusión dos resultados das investigacións.                                                                                                                 |
| C10  | Lectura con xuízo crítico de artigos científicos dende unha perspectiva metodolóxica.                                                                                      |

## Learning outcomes

| Learning outcomes | Study programme competences |
|-------------------|-----------------------------|
|                   |                             |



|                                                                                                                                                                                                                                  |                    |                     |                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|---------------------|----------------------------------------|
| To be able of planning experiments following a set of suitable stages, identifying all sources of variation, specifying the experimental procedure and the anticipated difficulties, and formulating proper mathematical models. | AC2<br>AC9         | BJ6<br>BJ10<br>BJ11 | CJ1<br>CJ2<br>CJ3<br>CJ5<br>CJ7<br>CJ8 |
| To use statistical software fluently.                                                                                                                                                                                            | AC4<br>AC10        | BJ12                | CJ4                                    |
| To acquire capability to take part from a multidisciplinary team by working on experimental analysis.                                                                                                                            |                    | BJ11                | CJ8<br>CJ9                             |
| To be able of performing a critical review of the attained results.                                                                                                                                                              | AC9                | BJ10<br>BJ13        | CJ10                                   |
| To obtain knowledge on the basic principles of the design of experiments.                                                                                                                                                        | AC4<br>AC6         | BJ6<br>BJ10<br>BJ11 | CJ1<br>CJ2<br>CJ5<br>CJ6               |
| To manage a broad range of suitable design structures to be able of describing properly the performance of data coming from experimental planning processes.                                                                     | AC2<br>AC6<br>AC10 | BJ11<br>BJ13        | CJ1<br>CJ5<br>CJ6<br>CJ7               |
| To know a range of statistical techniques to analyze data coming from the experimental planning processes. Specifically, knowledge on how performing inference on model parameters.                                              | AC4<br>AC6<br>AC10 | BJ13                | CJ5<br>CJ6                             |
| To know specific procedures to perform a critical and rigorous analysis of the results.                                                                                                                                          | AC2<br>AC9         | BJ13                | CJ2<br>CJ10                            |
| To complete the learning process with the support of statistical software.                                                                                                                                                       | AC4<br>AC10        | BJ12                | CJ4                                    |

| Contents                                      |                                                                                                                                                                                                                                                                                                    |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Topic                                         | Sub-topic                                                                                                                                                                                                                                                                                          |
| 1. Basic principles of experimental design.   | 1.1. Introduction: Advantages of planning an experiment. Variability sources.<br>1.2. Basic principles in experimental design.<br>1.3. Step by step guide to the experimental planing process. A real example.<br>1.4. Some standard experimental designs.                                         |
| 2. Designs with one source of variation.      | 2.1. Introduction.<br>2.2. Randomization. Model for a completely randomized design: Estimation of parameters, one-way analysis of variance, inference on contrasts and means.<br>2.3. Methods of multiple comparisons.<br>2.4. Checking the adequacy of the model.<br>2.5. Alternative approaches. |
| 3. Designs with several sources of variation. | 3.1. Introduction.<br>3.2. Randomization. The meaning of interaction. Complete model. Main effects model.<br><br>3.3. Estimation, analysis of variance, inference on contrasts.<br>3.4. Sample sizes.<br>3.5. Checking the adequacy of the model.                                                  |
| 4. Analysis of covariance.                    | 4.1. Introduction.<br>4.2. Mathematical models.<br>4.3. Estimation, analysis of variance, inference on contrasts.<br>4.3. Checking the adequacy of the model.                                                                                                                                      |



|                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5. Random effects models and mixed models. | <p>5.1. Random effects: variance components. Examples.</p> <p>5.2. Mathematical models for random effects models: Estimation and analysis of variance.</p> <p>5.3. Sample sizes.</p> <p>5.4. Checking the adequacy of the model.</p> <p>5.5. Mixed models: los mixtos: Estimation and analysis of variance.</p>                                                                                                                                                                                                                      |
| 6. Block designs.                          | <p>6.1. Basic concepts.</p> <p>6.2. Complete block designs: Models, estimatin, analysis of variance, inference on contrasts.</p> <p>6.3. Incomplete block designs: Balanced incomplete block designs; group divisible designs; cyclic designs. Models, estimation, analysis of variance, inference on contrasts.</p> <p>6.4. Row-column design: Latin square designs, Youden designs, cyclic and other row-column designs. Models, estimation, analysis of variance, inference on contrasts.</p> <p>6.5. Alternative approaches.</p> |
| 7. Nested designs.                         | <p>7.1. Introduction.</p> <p>7.2. Nested designs in two stages..</p> <p>7.3. Nested designs in m stages.</p> <p>7.4. Models including both nested and crossing sources of variation.</p>                                                                                                                                                                                                                                                                                                                                             |
| 8. Split-plot dsigns.                      | <p>8.1 Introduction: Motivation and examples.</p> <p>8.2. Mathematical modrls.</p> <p>8.3. Estimation and analysis of variance with complete blocks.</p>                                                                                                                                                                                                                                                                                                                                                                             |
| 9. Designs with repeated measures.         | <p>9.1. Introduction: Experimental setup.</p> <p>9.2. Dependence structures for repeated measures.</p> <p>9.3. Mauchly's test of sphericity.</p> <p>9.4. Univariate and multivariate analysis.</p>                                                                                                                                                                                                                                                                                                                                   |
| 10. Factorial designs at two levels.       | <p>10.1. Two levels designs with two factors.</p> <p>10.2. Two levels designs with three factors.</p> <p>10.3. Two levels designs for k factors.</p> <p>10.4. Adding centerpoints in a general design at two levels.</p> <p>10.5. Algorithm of Yates.</p>                                                                                                                                                                                                                                                                            |

| Planning                                                                                                                        |                                                                         |                      |                               |             |
|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------|-------------------------------|-------------|
| Methodologies / tests                                                                                                           | Competencies                                                            | Ordinary class hours | Student?s personal work hours | Total hours |
| Guest lecture / keynote speech                                                                                                  | A2 A4 A6 A9 B6 B10<br>B11 B13 C1 C2 C3<br>C5 C6 C7 C9 C10               | 20                   | 30                            | 50          |
| Problem solving                                                                                                                 | A2 A6 A9 A10 B10<br>B11 B12 B13 C2 C4<br>C5 C6 C7 C9 C10                | 16                   | 24                            | 40          |
| Case study                                                                                                                      | A2 A6 A9 A10 B6 B10<br>B11 B12 B13 C1 C2<br>C3 C4 C5 C6 C7 C8<br>C9 C10 | 0                    | 25                            | 25          |
| Objective test                                                                                                                  | A10 B10 B13 C1 C2<br>C4 C5 C6 C9                                        | 3                    | 0                             | 3           |
| Personalized attention                                                                                                          |                                                                         | 7                    | 0                             | 7           |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. |                                                                         |                      |                               |             |



## Methodologies

| Methodologies                  | Description                                                                                                                                                                                                                                                 |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Guest lecture / keynote speech | Lectures addressed to present the main theoretical and methodological concepts. Additional learning resources will be employed, such as slides showing real study cases and the use of statistical software (mainly R packages).                            |
| Problem solving                | Lectures addressed to solve exercises and practical cases, where students will have an active role and will be gradually introduced in the manage of statistical software. Besides references, lists of exercises and questionnaires will be also provided. |
| Case study                     | Students should develop one or two practical works related to the subject contents.                                                                                                                                                                         |
| Objective test                 | Final exam on the theoretical and practical contents of the subject. This exam consists in answering a list of short questions and/or solving some longer exercises in a reasoned way.                                                                      |

## Personalized attention

| Methodologies                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Problem solving<br>Case study | <p>a) Tutorial sessions where students can receive personalized support to clarify doubts and solve exercises.</p> <p>b) Tutorial sessions during the development of the practical works. In these sessions, students can receive personalized support to solve doubts, correct mistakes and overcome possible difficulties in the application of theoretical concepts to the study case.</p> <p>Personalize advice may be also received via online, by means of e-mail, virtual platform,...</p> <p>Part-time students are not required to defend their works in class, but these works must be provided to the teachers for their assessment. Part-time students can also receive personalized assistance using both face-to-face and virtual approaches.</p> |

## Assessment

| Methodologies  | Competencies                                                            | Description                                                                                                                                                                                                                                                              | Qualification |
|----------------|-------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Case study     | A2 A6 A9 A10 B6 B10<br>B11 B12 B13 C1 C2<br>C3 C4 C5 C6 C7 C8<br>C9 C10 | Assessment of practical cases.                                                                                                                                                                                                                                           | 30            |
| Objective test | A10 B10 B13 C1 C2<br>C4 C5 C6 C9                                        | Exam for assessment of knowledge consisting of two parts: (i) Test of knowledge about key concepts for planning and analyzing an experiment (nearly one hour), and (ii) Solving one or two practical exercises with help of the statistical software (nearly two hours). | 70            |
| Others         |                                                                         |                                                                                                                                                                                                                                                                          |               |

## Assessment comments

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>To attain a satisfactory final assessment is required to pass the two aforementioned evaluations (study case and objective test). These requirements hold for both opportunities (May and July). Whether the practical works are not completed in May, they must be provided in July. This also applies to the part-time students.</p> |
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## Sources of information

|              |                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Basic</b> | <ul style="list-style-type: none"> <li>- Dean, A. y Voss, D. (1999). Design and Analysis of Experiments. Springer Texts in Statistics, Springer-Verlag, New York</li> <li>- Montgomery, D.C. (2009). Design and Analysis of Experiments. 7a Ed.. J. Wiley and Sons.</li> <li>- Kuehl, R.O. (2001). Diseño de Experimentos. Principios estadísticos para el diseño y análisis de investigaciones. 2a Ed.. Thomson Learning.</li> </ul> |
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| Complementary | <p>- Berger, P.D. y Maurier, R.E. (2002). Experimental Design With Applications in Management, Engineering, and the Sciences. Belmont, CA: Duxbury Press</p> <p>- Box, G.E.P., Hunter, W.G. y Hunter, J.S. (2005). Statistics for Experimenters: Design, Innovation, and Discovery. 2a. Ed. Wiley, New York.</p> <p>- Coob, G.W. (1998). Introduction to Design and Analysis of Experiments. Springer-Verlag</p> <p>- Cox, D. y Reid, N. (2000). The Theory of the Design of Experiments. Monographs on Statistics and Applied Probability. Chapman &amp; Hall CRC Press</p> <p>- Gibbons, J.D. y Chakraborti, S. (1992). Nonparametric Statistical Inference, 3a. Ed.. Marcel Dekker, New York</p> <p>- Prat, A., Tort-Martorell, X., Groma, P. y Pozueta, L. (1997). Métodos estadísticos. Control y mejora de la calidad. Edicions UPC (Universitat Politècnica de Catalunya)</p> <p>Vikneswaran (2005) An R companion to "Experimental Design"URL</p> <p><a href="http://CRAN.R-project.org/doc/contrib/Vik-neswaran-ED-companion.pdf">http://CRAN.R-project.org/doc/contrib/Vik-neswaran-ED-companion.pdf</a>.Vikneswaran (2005) An R companion to "Experimental Design"URL <a href="http://CRAN.R-project.org/doc/contrib/Vik-neswaran-ED-companion.pdf">http://CRAN.R-project.org/doc/contrib/Vik-neswaran-ED-companion.pdf</a>.</p> |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

| <b>Recommendations</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  |
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| <b>Subjects that it is recommended to have taken before</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |
| <b>Subjects that are recommended to be taken simultaneously</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |
| Modelos de Regresión/614427105<br>Control Estatístico da Qualidade/614427121                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |  |
| <b>Subjects that continue the syllabus</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |
| <b>Other comments</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |  |
| To obtain a satisfactory assessment of this subject is highly recommended regular attendance and active participation at lectures. It is also important to complete exercises and practical applications proposed in the development of the classes, in particular when lectures cannot be regularly attended.   Previous knowledge of the basic principles of statistical inference and of the R package eases the learning of the subject. Also, solving questionnaires and list of exercises and taking advantage of the personalized tutorial sessions will be particularly helpful. |  |

(\*)The teaching guide is the document in which the URV publishes the information about all its courses. It is a public document and cannot be modified. Only in exceptional cases can it be revised by the competent agent or duly revised so that it is in line with current legislation.