Yanka Kupala Grodno State University (YKGSU)

Design of Experiment

Faculty: Mathematics and Informatics	**Amount of student effort (hours):** 120
Department: Advanced Programming Techniques	**Class contact time (hours):** 64
Level: MA, Year 2	**Term period(s):** Sem. 3
Language of instruction: English	**Course status:** Mandatory core
Course leader: Anna Deytseva	**Entry requirements:** At least 30 ECTS studies of the first degree in the field of programming, data processing, linear algebra, calculus been completed.
ECTS: 3	**Contact:** a.deytseva@gmail.com

Objectives:

- acquiring knowledge of how to plan, design, execute and analyze an effective experiment;
- gaining experience in using statistical methods and the principles of experimental design to problems of practical interest and making informed decisions;
- developing skills in the use of statistical analysis software tools for processing experimental data.

Learning Outcomes:

Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Learning outcome	**Assessment criteria**	
The student will be able to:	*The student can:*	
1. **design** an experiment	1. **name** the Experiment design steps;	(Remembering)
	2. **distinguish** Observational Study and Experimental Study;	(Analysing)

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	3. **know** the basic vocabulary of experiments (experimental units, treatments, factors, factor level);	
	4. **explain** Three principles of Experimental Design;	
	5. **describe** the main types of Experimental Design;	
	6. **choose** appropriate type of Experimental Design;	
	6. **specify** some of the pitfalls of conducting experiments.	
2. **perform** exploratory data analysis	1. **explain** the difference between Population and Sample, parameter and statistic;	
	2. **identify** the types of variables (experimental variables and statistical variables);	
	3. **organize** data using frequency distributions;	
	4. **represent** data using histograms, dot plots, scatter plots, time series charts and a stem-and-leaf plot;	
	5. **compare** and **interpret** different graphical representations;	
	6. **compute** descriptive statistics;	
	7. **assess** data quality using measures of central tendency, variation and position;	
	8. **make a conclusion** about population distribution.	
3. **apply** basic concepts and methods of Probability Theory and Statistics of experimental data	1. **understand** and **describe** sample spaces and events for random experiments with tables or tree diagrams;	
	2. **use** permutation and combinations to count the number of outcomes in both an event and the sample space;	
	3. **describe** three ways to assign probabilities to events;	
	4. **describe** main properties and rules of probability;	
	5. **calculate** probability of a random event via definition and rules;	
	6. **describe** the difference between discrete and continuous random variables;	

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	7. **make** a probability distribution and d**etermine means and variances for** e discrete random;	
	8. **describe** important probability distributions (binomial, normal);	
	9. **use** the table for the cumulative distribution function of a standard normal distribution to calculate probabilities.	
4**. use** statistical inference techniques	1. **name** types of statistical inference;	
	2. **understand** the Central Limit Theorem;	
	3. **explain** important properties of point estimators;	
	4. **construct** confidence intervals on the mean, variance and standard deviation of a normal distribution;	
	5. **evaluate** if the data has normal distribution;	
	6. **know** General Procedure for Hypothesis Tests;	
	7. **apply** General Procedure for Hypothesis Tests;	
	8. **assess** sample quality using point estimators and confidence intervals and produce the ideas to improve its quality.	
5. **perform** Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) ;	1. **describe** the relationship between analysis of variance, the design of experiments, and the types of applications to which the experiments are applied;	
	2. **distinguish** between one and two factor analysis of variance tests;	
	3. **perform** analysis of variance by hand;	
	4. appropriately **interpret** results of analysis of variance tests;	
	5. **name** the assumptions of ANCOVA;	
	6. **explain** how to construct and analyze an ANCOVA model;	
	7. **implement** ANCOVA to analyze experiments with factor levels that are quantitative (numerical).	
6. **conduct** a regression analysis	1. **describe** example problems for Regression Analysis;	

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	2. **apply** simple linear regression for building empirical models to engineering and scientific data;	
	3. **evaluate** the adequacy of the Regression Model;	
	4. **use** the regression model to make a prediction of a future observation and construct an appropriate prediction interval on the future observation;	
	5. **apply** the correlation model.	
7. **design** factorial experiment	1. **identify** and describe three types of factorial designs;	
	2. **distinguish** between a main effect and an interaction;	
	3. **identify** main effects and interactions in a summary table and in a graph;	
	4. **demonstrate** the implications of using a quasi-independent factor in a factorial design;	
	5. **illustrate** the higher-order factorial design and fractional factorial design;	
	6. **design** and **conduct** a factorial experiment.	
8. **use** languages and environment for designing experiments, statistical computing and graphics	1. **name** languages and environment for designing experiments, statistical computing and graphics;	
	2. **perform** exploratory data analysis via appropriate software;	
	3. **perform** the most common statistical analyses via appropriate software;	
	4. **compare** the results obtained with different software tools.	
9. **perform** an effective experiment	1. **state** the problem and the questions to be addressed;	
	2 **determine** factors and response;	
	3. **discuss** the choices that can be made and their competing positive and negative effects on the quality and feasibility of the experiment;	
	4. **choose** the type of experimental design and collect data;	
	5. **choose** the type of statistical analysis and **perform** it;	

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	6. **assess** whether the assumptions of the analysis are appropriate for the given data;	
	7. **consider** and **compare** alternative models;	
	8. **conclude** and report their results;	
	9. **distribute** responsibilities among team members	

Course content:

No	Sections and topics	Content of topics
1	Introduction to Experimental Design	Scientific learning. Study designs. Observational study. Experimental study. Principles of experimental designs.
2	The Basic Concepts of Experimental Design	Steps of designing an experiment. Population. Sample. Sampling. Experimental unit. Types of variables. Treatment structure. Design structure.
3	The Basic of Probability Theory	Basic Concepts of Probability and Counting. Random Experiments. Events. Counting Techniques. Assigning Probabilities. Basic Rules of Probability. Conditional probability. Bayes' Theorem.
4	Random Variables and Important Probability Distributions	Types of Random Variables. Probability distribution. Cumulative distribution function. Mean and variance. Binomial, Poisson, Uniform, Normal, Exponential, Student's and Chi-Square Distributions.
5	Exploratory Data Analysis (EDA)	Descriptive Statistics (non-graphical EDA). Central tendency. Variation. Quartiles. Graphical Presentation of Data (graphical EDA) Bar Chart. Histogram. Dotplot. Stem-and-Leaf Plot. Box-and-Whisker Plot. Scatter Plot. Multi-Vari Charts.
6	Statistical analysis software tools	An introduction to R. Excel's Analysis ToolPak Add-In. Data and EDA in R and MS Excel.
7	Inferential Statistics	Estimation. Point estimator. Interval estimator. Confidence intervals. Hypothesis testing. Statistical hypothesis. Statistical model and test statistic. Decision errors. One and two tailed tests. P-value.

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8	One-Way ANOVA	The model and statistical hypotheses. The F statistic (ratio). Inference: hypothesis testing, confidence intervals. Reading the ANOVA table. One-way ANOVA in R and MS Excel.
9	Linear Regression	Regression analysis. Simple linear regression. Method of least squares. Interpreting regression coefficients. Residual analysis. Transformations. Simple linear regression in R and MS Excel.
10	Analysis of Covariance (ANCOVA)	Multiple regression. Interaction. Assumptions for ANCOVA. ANCOVA in R and MS Excel.
11	Two-Way ANOVA	Assumptions for two-way ANOVA. The hypotheses of a Two-Way ANOVA. Differences Between One-Way and Two-Way ANOVA. Interpreting the two-way ANOVA results. Two-way ANOVA in R and MS Excel.
12	Factorial Experiments	2^k factorial design. General procedure for analysis of 2^k design. Fractional factorial experiments. Factorial Experiments in R.
13	Response-Surface Experiments	Multiple responses. Response surface designs. Mixture experiments. Experiments with computer models.

Student workload. Form of student activity.

Lectures: 34 hours

Laboratory classes: 30 hours

Reading literature: 12 hours

Preparation for classes: 28 hours (doing homework, preliminary reading theoretical material, self-assessment)

Working on a team project: 16 hours

Teaching/Learning Methodology:

The variety of formats used in the class includes project work, discussion, presentations and lectures. The teaching methodology is concerned with ingraining theoretical knowledge through practical experience. Teaching methods and delivery will include a combination of lectures, demonstrations, critiques, individual and group tasks, student presentations and in-class work.

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The lectures are aimed at providing students with the integrated knowledge required to hone expertise and master procedures necessary to perform, evaluate, and arrive at decisions using designed experiments.

The tutorials are aimed at enhancing design and analysis techniques. Tutorials and case studies are based on real-world applications of experimental design and are drawn from a number of different fields of engineering. The software tools are introduced in lectures and are used in tutorials and cases studies to handle the analysis of experiments.

Teaching Methods	Implementation
Problem-based learning	Complex, real-life problems are used as a means of helping students learn concepts and principles, rather than directly presenting facts and concepts.
Service learning	Service learning offers direct application of theoretical models. Community-based service activities are paired with structured preparation and student reflection.
Group learning	Working in small groups provides learners with opportunities to articulate ideas and understandings, uncover assumptions and misconceptions, and negotiate with others to create products or reach consensus. Group activities enable students to discover deeper meaning in the content and improve thinking skills.
Just-in-time teaching	Just-in-time teaching actively involves students in the learning process through a two-step series of learning activities. In the first step, students complete a focused set of activities outside of class and submit their work to the instructor. In the second step, the lecturer collects the students' responses and identifies areas of understanding and misunderstanding to adjust the next lesson so that students can receive specific "just-in-time" feedback on those particular areas.

Repetition. A practical working knowledge requires understanding many concepts and their relationships. There is no ideal logical order for learning what student need to know, because everything relates to, and in some ways depends on, everything else. Therefore, the same concepts will be considered several times throughout the course.

Teamwork. During the semester, students will work on a team's project. The purpose of the project is to carry out and demonstrate the results of the experimental design process. Under the project, students will

- define some real problem;
- determine objectives;
- determine factors and response;
- design experiment, conduct experiment and collect data;
- analyze data;
- interpret results;

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- verify predicted results;
- perform additional experiment as required.

The project will not only allow students to apply theoretical knowledge in practice, but will also allow you to see a holistic picture of the problem being studied, look at it from different angles. In addition, project will help to create "conceptual maps" in the learning process, which are especially useful for a course for which the main goal is to study the relationship between many concepts.

Progress of students' project will also be discussed during the laboratory lessons.

The lecture is available for consultation during office hours or by appointment.

Assessment Process:

Formative assessment (*Assessment for Learning*)	**Summative assessment (*Assessment of Learning*)**
1. Performance of classroom tasks, one-minute papers. 2. Think-Pair-Share. 3. Puzzle exercises (conducting individual research on a subset of a given subject area). 4. Concept Mapping.	1. Attendance and participation 10% 2. Homework 20% 3. Tests and Unit Quizzes 30% 4. Teams Project 40%

Assessment Criteria:

To pass, students must achieve at least 70% in total.

Thus we will use the RASE pedagogical model[1])

[1] Churchill, D., King, M., Webster, B., & Fox, B. (2013). Integrating learning design, interactivity, and technology. In H. Carter, M. Gosper, J. Hedberg (Eds.), *Electric Dreams. Proceedings ACILITE 2013 Sydney.* (pp. 139-143 http://www.ascilite.org/conferences/sydney13/program/papers/Churchill.pdf

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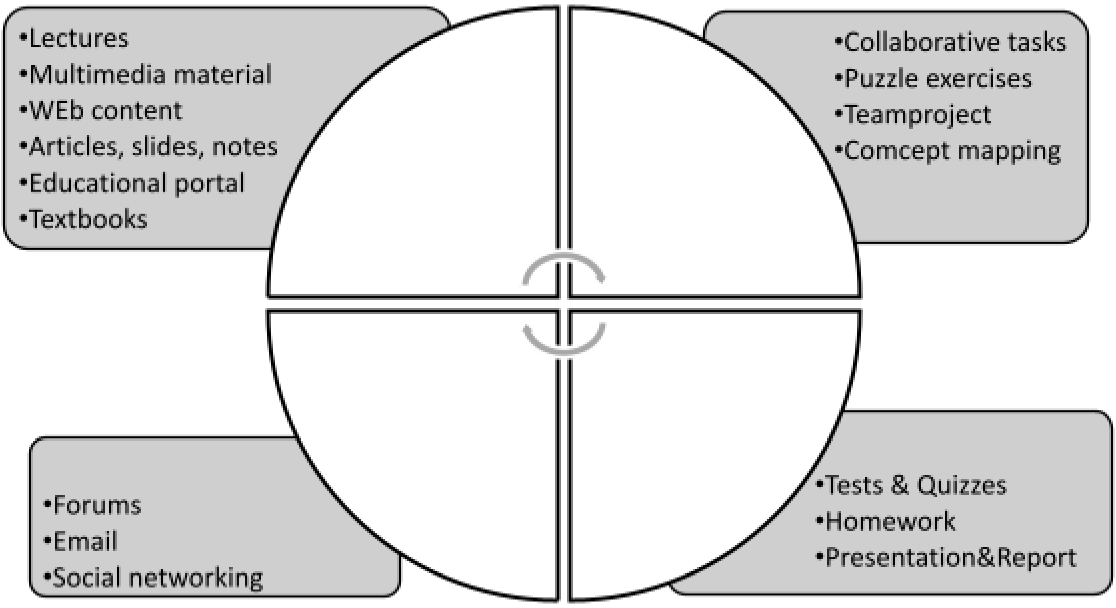

Reflection:

Student reflection	Self-reflection
– Writing exit slips (before students leave class, they quickly jot down what they've learned on a sticky note or answer another reflection question). – Create Mind Map (individually or in group). – Taking videos (creating videos of assignments or recording presentations allows students to look at themselves from the side). – Do regular sprint retrospectives (every few weeks allotted time to encourage students to reflect on where they've been and where they're going).	– Teacher diary. – Peer observation. – Recording lessons. – Student feedback.

Course Resources and References:

1. Montgomery, D., (2001), **Design and Analysis of Experiments**, 5th Edition, John Wiley & sons, Inc.
2. Montgomery D., and Runger C., (2007) **Applied Statistics and Probability for Engineers**, 4th ed. John Wiley & sons, Inc. http://meteo.edu.vn/GiaoTrinhXS/e-book/
3. Mathews, Paul G., (2005) **Design of experiments with MINITAB**
4. Seltman, Howard J. ,(2015) **Experimental Design and Analysis** http://www.stat.cmu.edu/~hseltman/309/Book/Book.pdf

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5. Navarro, Danielle **Learning statistics with R: A tutorial for psychology students and other beginners** https://learningstatisticswithr.com/lsr-0.6.pdf

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