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APPLICATION OF STOCHASTIC METHODS IN PROFESSIONALLY ORIENTED TEACHING STUDENTS OF TECHNICAL SPECIALTIES

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Abstract. The rapid digitalisation of engineering and the industry and the increasing technical uncertainty and complexity necessitate strengthening mathematical training among students of technical specialties. Probability theory and mathematical statistics develop analytical thinking competencies, including skills in mathematical modeling, interpretation of data, decision making under uncertainty during the design of models, components of devices and networks, evaluation reliability, safety, etc. This study develops and evaluates the professionally oriented approach to teaching stochastic methods integrating the theoretical mathematical knowledge with practical applications in engineering and information technologies. The proposed methodology incorporates the professionally oriented tasks considering the concepts of: reliability of electrical systems, probability of overload of transformer, diagnose of equipment using Bayes formula, electrical circuits using random processes, etc. Those tasks make students reflect on random phenomena, define probability models, carry out mathematical calculation, interpret results and justify decisions in professional contexts. To investigate the effectiveness of the proposed approach a 2 months quasi-experimental study with (n=23) a control group which studied the

probability content and additional traditional and calculation tasks and ($n=23$) an experimental group which studied probability and performed additional contextual and professionally oriented tasks was conducted. Students completed pre-test and post-test assessment questionnaires, comparative statistical analysis and observation about learning engagement and common types of students' errors followed the experiment. We found results improving in both groups but the experimental group resulted in a greater change in test scores, mean changing from 56.5% to 75.1% while in the control group the mean changed from 58.5% to 67.9%. Embedding stochastic methods into teaching through professionally oriented tasks appears to strengthen the connection between mathematical theory and its practical applications in system modelling while preparing students for their future professional careers.

Keywords: stochastic methods, professionally oriented education, technical specialties, applied problems

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ТЕХНИКАЛЫҚ МАМАНДЫҚТАҒЫ СТУДЕНТТЕРДІ КӘСІБИ БАҒДАРЛЫ ОҚЫТУДА СТОХАСТИКАЛЫҚ ӘДІСТЕРДІ ҚОЛДАНУ

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Аннотация. Техника мен өнеркәсіптің жылдам цифрлануы және техникалық белгісіздік пен күрделіліктің артуы техникалық мамандықтар студенттері арасында математикалық дайындықты күшейтуді қажет етеді. Ықтималдықтар теориясы және математикалық статистика аналитикалық

ойлау құзыреттерін дамытады, соның ішінде математикалық модельдеу, деректерді интерпретациялау, модельдерді, құрылғылар мен желілердің құрамдастарын жобалау кезінде белгісіздік жағдайында шешім қабылдау, бағалау сенімділігі, қауіпсіздік және т.б. технологиялар. Ұсынылған әдістеме келесі ұғымдарды ескере отырып, кәсіби бағытталған тапсырмаларды қамтиды: электр жүйелерінің сенімділігі, трансформатордың шамадан тыс жүктелу ықтималдығы, Байес формуласы бойынша жабдықтың диагностикасы, кездейсоқ процестерді қолданатын электр тізбектері және т.б. Бұл тапсырмалар студенттерді кездейсоқ құбылыстар туралы ойлануға, ықтималдық модельдерін анықтауға, математикалық контексте шешімдерді орындауға және нақты контекстте шешім қабылдауға мәжбүр етеді. Ұсынылған тәсілдің тиімділігін зерттеу үшін ықтималдық мазмұнын және қосымша дәстүрлі және есептеу тапсырмаларын зерттеген бақылау тобымен ($n=23$) және ықтималдықты зерттеген және қосымша контекстік және кәсіби бағытталған тапсырмаларды орындаған ($n=23$) эксперименталды топпен 2 айлық квазиэксперименттік зерттеу жүргізілді. Студенттер тестілеуге дейінгі және тесттен кейінгі бағалау сауалнамасын, салыстырмалы статистикалық талдауды және оқуға деген қызығушылықты және эксперименттен кейін жиі кездесетін студенттер қателіктерін бақылауды орындады. Нәтижелердің екі топта да жақсарғанын байқадық, бірақ эксперименттік топ сынақ ұпайларының үлкен өзгеруіне әкелді, орташа 56,5%-дан 75,1%-ға дейін өзгерді, ал бақылау тобында орташа мән 58,5%-дан 67,9%-ға өзгерді. Кәсіби бағытталған тапсырмалар арқылы оқытуға стохастикалық әдістерді енгізу студенттерді болашақ кәсіби мансабына дайындау кезінде математикалық теория мен оның жүйелік модельдеудегі практикалық қолданылуы арасындағы байланысты нығайтады.

Түйін сөздер: стохастикалық әдістер, қолданбалы есептер, кәсіби-бағдарлы оқыту, техникалық мамандықтар

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ПРИМЕНЕНИЕ СТОХАСТИЧЕСКИХ МЕТОДОВ В ПРОФЕССИОНАЛЬНО ОРИЕНТИРОВАННОМ ОБУЧЕНИИ СТУДЕНТОВ ТЕХНИЧЕСКИХ СПЕЦИАЛЬНОСТЕЙ

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Аннотация. Быстрая цифровизация инженерных и промышленных процессов, а также растущая техническая неопределенность и сложность требуют усиления математической подготовки студентов технических специальностей. Теория вероятностей и математическая статистика развивают аналитическое мышление, включая навыки математического моделирования, интерпретации данных, принятия решений в условиях неопределенности при проектировании моделей, компонентов устройств и сетей, оценке надежности, безопасности и т. д. В данном исследовании разработан и оценен профессионально ориентированный подход к преподаванию стохастических методов, интегрирующий теоретические математические знания с практическими приложениями в инженерии и информационных технологиях. Предложенная методология включает в себя профессионально ориентированные задачи, учитывающие такие понятия, как надежность электрических систем, вероятность перегрузки трансформатора, диагностика оборудования с использованием формулы Байеса, электрические цепи с использованием случайных процессов и т. д. Эти задачи побуждают студентов размышлять о случайных явлениях, определять вероятностные модели, проводить математические расчеты, интерпретировать результаты и обосновывать решения в профессиональном контексте. Для исследования эффективности предложенного подхода было проведено двухмесячное квазиэкспериментальное исследование с участием контрольной группы ($n = 23$), изучавшей теорию вероятностей и выполнявшей дополнительные традиционные и вычислительные задания, и экспериментальной группы ($n = 23$), изучавшей теорию вероятностей и выполнявшей дополнительные контекстные и профессионально ориентированные задания. Студенты заполнили анкеты предварительной и итоговой оценки. После эксперимента были проведены сравнительный статистический анализ и наблюдение за вовлеченностью студентов в обучение и распространенными типами их ошибок. Было выявлено улучшение результатов в обеих группах, однако в экспериментальной группе наблюдалось более значительное повышение результатов тестирования: средний балл увеличился с 56,5% до 75,1%, в то время как в контрольной группе средний балл повысился с 58,5% до 67,9%. Включение стохастических методов в обучение посредством профессионально ориентированных заданий укрепляет связь между математической теорией и ее практическим применением в системном моделировании, одновременно подготавливая студентов к будущей профессиональной деятельности.

Ключевые слова: стохастические методы, прикладные задачи, профессионально ориентированное обучение, технические специальности

Introduction. Digital transformation, increasing technological complexity and uncertainty of industrial processes in the quickly developing technical education require engineers capable to use theoretical mathematical knowledge combined with competences in data analysis, modelling, forecasting, stochastic analysis and decision making under uncertainty. Therefore Probability theory and Mathematical statistics get particular importance at training the students in technical specialties as they provide mathematical basis for describing random phenomena, assessing uncertainty and analysing behaviour of complex systems. At the same time, conventional approaches to mathematical training in higher education often remain focused on algorithms, formula application and standard math problems, which is necessary to mastering the formal apparatus of math, but on its own it may provide limited opportunities to recognize when and how to apply these methods in different professional situations. As a result, the gap between abstract mathematical knowledge and its practical usage in engineering and information technologies may arise.

Stochastic methods are especially relevant because engineering systems often operate under conditions of random variation, incomplete information and uncertainty. Their educational value is not only in calculation. Connecting stochastic concepts to the applied professional situations students must be able identify the problem parameters, chosen an appropriate probabilistic model, perform calculating, interpreting a result and justifying a decision to applied problems. Stochastic methods appear to be a mathematical content and professionally oriented approach to studies at the same time.

Literature Review. Recent research in probability and engineering education pays particular attention to meaningful contexts related to the real world, student-centred learning, technologies and mathematical modelling. Batanero and Álvarez-Arroyo (Batanero et al., 2024) point to emphasis on meaningful applications to reinforce the development of probabilistic reasoning. This point of view seems important to technical education as probability takes a professionally meaningful context to students when they analyse situations connected to uncertainty as opposed to merely reproducing formal solution procedures.

Related tendency is a shift from content orientation to more recent student-centred and outcome-based methods of teaching and learning of probability. Discussing development of stochastic modelling skills in learning of engineering mathematics is Sipos et al. (Sipos et al., 2024) In turn Hsu et al (Hsu et al., 2025) pay specific attention on the importance of technologies and applications in the learning of engineering. These studies support the viewpoint that learning of mathematics of today students is likely expected to be of a modelling, interpreting and application nature than of a context separated from professional contexts.

Importance of stochastic modelling on profession grounds is also evidenced

by research coming from the field of engineering education. The use of stochastic approaches for the uncertainty quantification in engineering structures is illustrated by Yazdani et al (Yazdani et al., 2020), whereas Walrand (Walrand, 2021) introduces probability through problems from electrical engineering and computer science, showing that a close relationship exists between probabilistic concepts and technical applications. Further discussion of the use of modelling and simulation activities to encourage students to become an integral part of the computational engineering workforce is offered by Magana and Silva Coutinho (Magana et al., 2017).

From Mathematics Education standpoint, mathematical modelling can be viewed as an activity connecting professional task with the representation of mathematics. Frejd and Bergsten (Frejd et al., 2016) discuss mathematical modelling as a professional activity. Abylkasymova et al (Abylkassymova et al., 2024) stress the use of professionally oriented problem situations about methodological features of teaching higher mathematics to students from engineering. Collectively this research forms grounds for use of professional oriented tasks in reinforcing of the relationship of theory of mathematics with the future professional activity of students.

A second body of related literature for professionally oriented teaching comes from research on statistical reasoning. Garfield, (Garfield et al., 2008) link research in statistics education with classroom practise and also provide insights on reasoning about models, reasoning about distributions, reasoning about variability and reasoning about inference. This literature provides a case for a shift in emphasis when the students learn statistics, from statistical techniques to relationship between concepts, relationships between probability and statistics and other parts of engineering and IT mathematics.

The proposed teaching model additionally bases upon research about active learning approach to teaching process. Prince (Prince, 2004) points on wide, yet uneven, support for the use of active, collaborate, cooperative and problem-based teaching in engineering education. These and other findings, for instance improved achievement test scores and decreases in faculty rates (Freeman et al., 2014) provide sufficient evidence to support involving the students into work with mathematical equations and discussion, yet they leave the question about the efficiency of a certain sequence of (e.g. professionally oriented) task unanswered, as the efficiency of particular professionally oriented teaching model need to be shown empirically.

Examples of tasks with sufficient mathematical content can be found a textbooks on probability theory, for example, Ross (Ross, 2019) links probability modeling, reliability and stochastic processes with the engineering problems and Blitzstein and Hwang (Blitzstein et al., 2019) illustrate conditional probability, dependence, independence and both discrete and continuous distributions. The former approach would enrich the professionally oriented content part of the course. Moreover, both and Ross and Blitzstein and Hwang (Ross, 2019, Blitzstein

et al., 2019) may be treated as foundational. Examples from these textbooks will serve as professionally-oriented links from topics to actual maths equations and definitions.

Although this literature offers sufficient theoretical base for introducing a professionally oriented curriculum yet such a structured arrangement of stochastic concepts, professionally-oriented examples and sequence of instructions were never introduced during the course on Probability Theory and Mathematical Statistics. The model for professionally oriented approach suggested in the paper organizes students learning about probability theory about the choosing models and solving exercises that allow the student to make sense of theoretical material into professionally oriented and practically valuable solutions together with subsequent evaluation of the outcome.

Specifically, the aim of the current study is to develop and experimentally investigate professionally oriented model of probability theory and mathematical models teaching aimed for students of technical specialisms, paying attention to the application of stochastics method onto solution of practical problems. An originality of work consists of structuring into the coherent unity of these parts: firstly, stochastics concepts studied in the course; secondly, professionally oriented problems of engineers and IT staff and thirdly a staged instructional procedures involving students in the diagnostics of problems and solution of models to these problems by method of analysis and construction followed by interpreting the solution to evaluate the practical and theoretical solution found of the problems of IT staff and managers of production plants.

Materials and Main Methods. The methodology underlying This analysis of the connection between stochastic content and random variation between such of uncertainty occurring problems of engineering and information technologies forms the basis. Theories and models involving probability theory are able to analyze complex and uncertainty-prone systems using stochastic methods, which consist of stochastic approaches, mathematical and computational methods to solve problems that consider the randomness of phenomenon and decision-making on unsure circumstances employing probabilistic models (i.e (Frejd, 2016; Walrand, 2021). methods of modelling, prediction and optimization, as well as that for analysis of complex data).

The role of and what in effect is interpreted to be as a professionally oriented task in This instructionally guided teaching framework is when in which a task which not only contains the role of a problem and its technical vocabulary used for problem but it is a condition that in when a condition is given for students in relation with the solution of a situation and applying the relationship of a mathematical relationship in relevance which creates an opportunity for students to not limit their ability and be more innovative in the use of more complex topics. Given it students get an occasion during which we learn about professional situation, identify random component use some appropriate probabilistic method that can determine quantitative result then give the result relevance to the problems given.

The importance that these things have made and that they play is crucial in making a difference compared to standard problems that give focus to substitution in specified given formula.

The professionally oriented tasks intended to use in the experimental group are designed mostly based on use of problem-orienting examples provided in the study of Walrand (Walrand, 2021) and adapted toward the perspective and approach of engineering and IT disciplines. The tasks included modeling of network load, analysis of user activity and forecasting of system performance. These specific are chosen given that under such cases it tends to make up meaningful events that, to certain extent could give the students of technical field an understanding and hence they will see how various principles of Probability and Mathematical Statistics can be taken into advantage effectively in these situations using mathematical content as a model for making use on things and giving explanation upon random situations being experienced.

There exists instructional procedure which links these two aspects that is application with theoretical knowledge. So with the student not going out of his role it's been decided that student will provide detailed explanation on for using stochastic method, on where probability or model goes well, how the outcome is interpreted in line with relevant technology and on the probability of getting relevant responses, as expected from a student than an automaton for the numerical calculations. Therefore students guided research were engaged for getting acquainted with independent analysis of solutions and giving justification on such as well.

Given the first three examples illustrated for engineering, Ross (Ross, 2019) provides a relevant reference in applied probability and reliability and Blitzstein and Hwang (Blitzstein, 2019) refers more about the models of that kind which are conditional, probabilistic and distributional among similar for which and to refer as a model to apply the reference is the first three examples which are just used to illustrate a simple example than reproducing the questions from these books with that to be the context of all the content that they feature which is based only on numerical, descriptive information with relevance only provided to the type of information presented in example given here. But to be the case example is provided, is the last task which will bring and put everything to one place. In the study as provided and published in the Journal Science Education and Technology, Example 6 provides more detail in the given text; the diagram it shows was redrawn and based on some probability rules, a solution in accordance with the diagrams and figures it demonstrates was shown. Furthermore, two examples about such things which assumes no interference and general case success will show with due process such that their reliability does not allow further probability. As an example the distribution of an hour for hourly load, which is supposed to be normal without any additional variables being considered should be the one to exemplify using the solution given and the probability of defect without needing to be conditional in nature but only for illustrating its difference from diagnostic-type sensitivity

without necessarily the use of those mentioned tools in previous contexts where only an illustrating explanation has been provided than full comprehensive knowledge. The independence and constant success probability that should refer in components reliability example must be discussed as well as the distinction between the assumed normality for the hourly load distribution and diagnostic tests sensitivity as well as that of the posterior probability for an existence of the actual defect.

The teaching process presented, following and expanding upon, turns these into a learning activity during the process and within this educational practice students describe, justifying it later, the reason they chose for such variable and thereby show how it justifies the model and interpretation of this, just like Garfield et al, Gainsburg J. propose to integrate it as follows (Garfield, 2008, Gainsburg, 2006). The usage of samples to make more explicit of and thereby clarify some areas to students must refer a solution in which some reasoning could also exist with similar but slightly varied reasoning within them with some parts included into discussions. But the problem should consist a question like whether or not a model should be selected and in some cases the context and purpose used are instructional and, than being mere claim, constitute a recommendation for an illustrative task, which refers to both cases in questions about whether they apply.

Illustrative Professionally Oriented Tasks for Power Engineering

Example 1. Reliability of Power-System Components

A section of an electric power system with 10 independent components of the same type. Probability that one component runs without failure the given period = 0.98. Find the probability that 9 of 10 or more components run without failure.

Analysis and mathematical model. Each component operates (or fails to operate) as a Bernoulli experiment. We are told, the failure-free operation in the given period, $(p)=0.98$ for one component. Let X be number of components not failure. Then, X has a binomial distribution with $n=10$ and the probability that the system runs over the specified period is: $p=0.98$. The required probability is

$$P(X \geq 9) = P(X=9) + P(X=10)$$

Solution. The Bernoulli formula gives to determine the probability that the system functions:

$$P(X=k) = C_n^k p^k (1-p)^{n-k}$$

Therefore:

$$P(X \geq 9) = C_{10}^9 (0.98)^9 (0.02) + (0.98)^{10} \approx 0.9838$$

Professional interpretation. Based on the given probabilistic model and parameters set for calculations the outcome is such that it would mean that

the probability of at least 9 or 10 power system components operating failure free in a randomly picked operational period should be close to 0.9838. In this example particular emphasis to be placed is, not just on correct calculation or estimation results but more towards determining and justifying that the use of Bernoulli method (binomial model), is suitable tool for this type of problem and how interpreted results can prove useful factor for system reliability monitoring.

Example 2. Probability of Transformer Overload

The 1-hour electrical load at a power transformer sub-station can be modelled as a Gaussian (normal) random variable X with the mean load 420 kW and standard deviation 40 kW. If the power threshold for the transformer is set to 500kW then what can be the probability that power load that could pass over the load threshold of 500kW?

Analysis and mathematical model. The task requires estimating the upper-tail probability for the assumed normal load model:

$$X \sim N(420, 40^2)$$

Standardization gives:

$$z = \frac{500 - 420}{40} = 2$$

Solution. For the standard normal distribution:

$$\Phi(2) \approx 0.9772$$

Hence:

$$P(X > 500) = 1 - 0.9772 = 0.0228$$

The exceedance probability is approximately 2.28%.

Professional interpretation. The output represents the probability and this can be interpreted as the probability that the 1-hour electrical load at the sub-station exceeds the specified 500 kW threshold is close to 2.28%. Then as a training part for students would be an attempt to discuss whether such small probability can be simply neglected in system operation and to describe what kind of additional data would be required to help drawing definite engineering conclusion/decision. Also, questions like what would be potential costs and benefits related to the reduction of such probability. This is also connecting the probability exercise to practical risks interpretation based on it.

Example 3. Bayesian Assessment of Equipment Failure

What if in a real-world example: only 3% of electrical appliances are produced and discovered as defective ones. The probability of correctly signalling a defect to an appliance that actually has a defect is 95%. But at the same time, wrongly

signalling a defect for an appliance without one is 4%. So what is the probability that a device is actually defective, given that the symptom of a defect has already been signalled?

Analysis and mathematical model. Let A denote the event that the equipment is defective and B the event that the diagnostic system signals a defect. Then $P(A) = 0.03$, $P(\neg A) = 0.97$, $P(B|A) = 0.95$, and $P(B|\neg A) = 0.04$. Bayes' theorem is used to update the probability of a defect after receiving the diagnostic signal.

Solution. Bayes' theorem gives:

$$P(A | B) = \frac{P(A)P(B | A)}{P(A)P(B | A) + P(\neg A)P(B | \neg A)}$$

Substitution of the given probabilities yields:

$$P(A | B) = \frac{0.03 \times 0.95}{0.03 \times 0.95 + 0.97 \times 0.04} \approx 0.4235$$

Professional interpretation. A interesting finding is that despite the probability indicating the correctly signal defect being 95%, of and for 3% rate. The probability that an item actually is defective given after having received and confirming defect is found approximately 42.35%. This is the explanation as part what lesson this exercise provides which includes base rate bias to be taken into account when receiving information from a signal in a real situation or diagnosis of patient outcome that a 95% reliable tool, produces only 42% correct results for detecting disease. As part of a task for students following solving it would an asking question, such has for example, whether still one should go under the additional diagnostic testing before taking decision of whether it's an operational appliance or not. Thus risk understanding can be combined alongside probability and data distribution and its uses.

Example 4. Reliability of an Electrical Circuit

The electrical circuit MN is constructed according to diagram and this is in a Figure 1. Electrical components have their numbers showing: 1, 2, 3, 4 and 5 and they all work independently with their given probabilities of failure on specified time period such of:

$$p_1 = 0.1, p_2 = 0.2, p_3 = 0.5, p_4 = 0.3, p_5 = 0.1.$$

Find the probability that the circuit operates normally throughout this time interval.

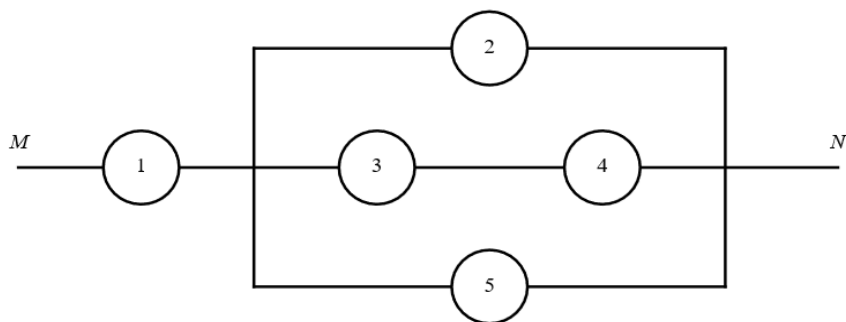


Figure 1 — Electrical circuit MN with five independent components

Solution. Let A_i , $i = 1, \dots, 5$, denote the event that component i operates normally during the specified time interval, and let A denote normal operation of the entire circuit. Component 1 is connected in series with a parallel section. This section contains three branches: component 2, components 3 and 4 connected in series, and component 5. Therefore, the circuit operates normally if component 1 functions and at least one of these three branches functions:

$$A = A_1 \cap (A_2 \cup A_5 \cup (A_3 \cap A_4)).$$

Let B denote the event that the middle branch, consisting of components 3 and 4, functions. Its complement is the event that at least one of these two components fails. By independence,

$$B = A_3 \cap A_4, \overline{B} = \overline{A_3} \cup \overline{A_4}, P(\overline{B}) = 1 - P(A_3)P(A_4).$$

The parallel section fails only if component 2 fails, component 5 fails, and the middle branch fails. Applying the multiplication rule for independent events and the complement rule gives

$$P(A) = P(A_1)[1 - P(\overline{A_2})P(\overline{A_5})P(\overline{B})].$$

Consequently, substituting the given failure probabilities yields

$$P(A) = P(A_1)[1 - P(\overline{A_2})P(\overline{A_5})(1 - P(A_3)P(A_4))].$$

$$P(A) = 0.9[1 - 0.2 \times 0.1(1 - 0.5 \times 0.7)] = 0.8883.$$

Answer. The probability of normal circuit operation during the specified time interval is 0.8883, or 88.83%.

Professional interpretation. The example connects the rules for independent events and complementary events with reliability assessment of a circuit containing series and parallel connections. Students identify the paths between M and N, translate the circuit topology into events, and explain why the simultaneous failure of all parallel branches is easier to calculate than their overlapping success events.

The set of four examples, shown above, represent the proposed methodology, where one common sequence is described briefly here, 'situation of professional relevance - identification of the random component - selection of an adequate stochastic model - mathematical solution interpretation of the result - scientifically motivated decision or justification'. Examples shown above are taken or generated as illustrations/tasks to the power-engineering contest. The methodological functions of the illustrative power-engineering tasks are shown in Table 1.

Table 1— Methodological Functions of the Illustrative Power-Engineering Tasks

Professional situation	Probability concept	Mathematical action	Professional learning focus
Reliability of power-system components	Bernoulli scheme / binomial distribution	Calculate the probability of failure-free operation	Reliability assessment and model selection
Transformer load	Normal distribution	Estimate the probability of exceeding a load threshold	Risk interpretation and forecasting
Equipment diagnostics	Bayes' theorem	Update failure probability after a diagnostic signal	Decision-making under uncertainty
Electrical circuit MN	Independent and complementary events	Calculate reliability of a circuit with series and parallel connections	Circuit topology and reliability assessment

Organization of the Pedagogical Experiment

A quasi-experimental study with a pre-test-post-test design and a comparison (control) group and an experimental group was used. Two already existing academic groups (CG; EEk-24-1; (with similar readiness levels) were engaged in the pedagogical experiment: the control group (CG; EEk-24-1;), using the traditional teaching of the subject, and the experimental group (EG; EEk-24-2;), studying the subject under conditions of a proposed approach oriented on the use of stochastic methods based on professionally oriented tasks. Since the groups were already pre-existing, students were not directly assigned to either the control or the experimental conditions in a random manner.

The groups were evaluated for baseline comparison at the onset of the pedagogical experimenting with equal diagnostic tasks related to probability theory and with a diagnostic task on the application aspect of the use of stochastic methods. Based upon summary statistics of group levels, baseline independent-samples comparison was approximately $t(44) = 0.69$, $p = 0.496$. Therefore, during the baseline conditions, no strong statistical significant difference was reached between the groups. All the same time was allotted as input for learning, and all had followed a common curriculum. Curriculum content, duration and timing

of instruction, assessment conditions, forms of knowledge control, evaluation criteria, task difficulty, and pace of implementation were ensured to be equal for both groups.

Stage 1. Diagnostic Stage

The diagnostic stage was used to determine the initial level of students' knowledge and skills before moving to the stage of the pedagogical experiment after which they would take. The assessment included problems about theoretical comprehension of the stochastic methods and comprehension of the probabilistic models, as well as problems from the relevant applied field of stochastic methods. The tasks for both (control and experimental) groups were of similar content and difficulty. Stochastic method problems had situations involving probability theory for engineering and computer sciences. The baseline result supported the study groups being comparable at the onset of the intervention.

Stage 2. Formative Stage

The traditional methodological order was followed with the Control group following explanation of Theoretical material and usage of formulas for solution of typical problems. The experimental group followed the same course with the stochastic methods and relevant situations to real problems in engineering and computer science. The learning activities here were set up in a manner that had them interpreting data and justifying results and engaging in research activities. Learning activities in the experimental group were organized around the following principles such as a focus on the needs of professionally-oriented tasks that required interpretation and justification of the students' work and a balance of guided and independent students' research activity during study of stochastic methods. The organisation was set in a manner; the professional problem was used as context for the probabilistic model while math was used to acquire and substantiate the result. Aim was to strengthen the transition effect from knowledge to thought i.e. learning to apply stochastic methods for applied problems for it was the methodological intention.

Stage 3. Control Stage

This stage was set to be the control stage. It was the concluding stage and was designed for studying the dynamics of the development of students' knowledge and skills throughout the learning activity. The assessment in the form of a final test in stochastic methods along with test in solving of relevant applied problems was set to test. A final test in stochastic methods was organised for them, with tasks covering theoretical and applied aspects of the material. The same assessment principles and evaluation criteria applied for both the group were kept same in this stage, for students took the diagnostic and formative sections alike. Five tasks were given, a 0-100 percentage scale was followed. A similar method about the assessment principle for both diagnostic and control stages of evaluation were held to account with the changes in the mean value result in percentage points. Quantitative approach of analysis including the group-based result in terms of mean and statistical difference has thus been given as part of mean value in a

percentage difference; and a qualitative perspective showing how students in experimental and control groups solved them along with students interest being shown for the same and typical mistakes made by them have been included.

Statistical Data Analysis

The raw group means, standard deviations and numbers are used to recalculate the between-group comparisons on pre-test and post-test values. A 2-sided Independent-samples Student's *t*-test with pooled variance and 44 degrees of freedom was used for both. The direction of comparisons is Control Group (CG) - Experimental Group (EG). Pooled standard deviation is used to compute between-group Cohen's, its absolute value is noted. Within group paired-samples *t* values are stated in the table with *p* thresholds these are adopted. Within-group Cohen's *d^z* is computed for comparison via $t/\sqrt{n}$ with *n* = 23. This is based on preserved *t* values and should verify when the revised paired individual is done. Tests for significance are evaluated at the 0.05 level. Recalculation from rounded results is only approximate.

Results. Table 2 shows changes in the means in a positive direction, with the Experimental Group having changed more. The CG mean has changed from $58.5 \pm 10.5\%$ to $67.9 \pm 7.3\%$, change of 9.4 percentage points. The EG mean has changed from $56.5 \pm 9.2\%$ to 75.1 ± 8.1 change of 18.6 percentage points. Over all there is an advantage of the EG by 9.2 percentage points difference. Within group results that are preserved are *t* = 5.21 with *p* < 0.01 for CG and *t* = 9.14 with *p* < 0.001 for EG. Calculated Cohen's *d^z* through *t* is for CG *t* = 1.09 and EG *t* = 1.91. This is still assuming preserved values are accurate with revised paired individual data yet again awaiting confirmation.

Pre-Test difference between the cohorts is not significant, *t*(44) = 0.69, *p* = 0.496, Cohen's *d* = 0.20 when value was made absolute. EG scores at 7.2 percentage points above the CG, after post-Test completion. There are comparison between cohorts, *t*(23+23-2) = -3.17, *p* = 0.003 and a value equal to Cohen's *d* = 0.93 when the value was made absolute. These show there is a significant difference with large size.

Table 2 — Outcomes of the pedagogical experiment

Group / comparison	n	Pre-test (%) M ± SD	Post-test (%) M ± SD	Gain (pp)	t	p	Cohen's d / <i>d^z</i>
CG (Control Group)	23	58.5 ± 10.5	67.9 ± 7.3	+9.4	5.21	<0.01	1.09
EG (Experimental Group)	23	56.5 ± 9.2	75.1 ± 8.1	+18.6	9.14	<0.001	1.91
Baseline between-group comparison	46	58.5 ± 10.5 vs 56.5 ± 9.2	—	—	<i>t</i> (44) ≈ 0.69	0.496	0.20
Post-test between-group comparison	46	—	67.9 ± 7.3 vs 75.1 ± 8.1	—	<i>t</i> (44) ≈ -3.17	0.003	0.93

Note: Scores are reported on a 0–100 scale; gain is in percentage points (pp). Between-group *t* values use CG minus EG and 44 degrees of freedom; Cohen's *d* is the absolute effect size using the pooled SD.

The qualitative analysis of performance on the problem-tasks was that in the initial pattern of errors in both groups was similar, consisting mainly of selecting an appropriate method to model the problem probabilistically and understanding random processes, while the other type of difficulty was that of students finding problems hard to justify for. With the introduction of the formative component, the proportion of observed errors reduced from the range between [CG at 40%] and [EG 42%] to the [CG of 27%] to [EG of 15%] (Figure 2.). According to this descriptive shift, it shows the experimental group has a larger scale of errors.

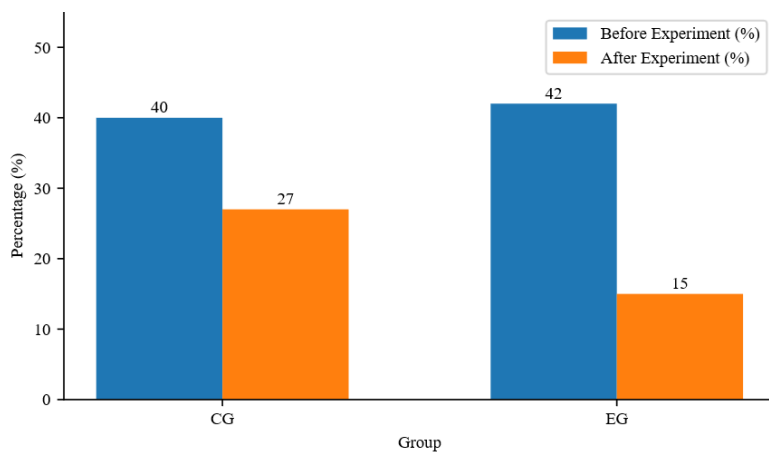


Figure 2 — Dynamics of Typical Errors

Indicators of involvement also changed. In CG group, it increased from 48% to 57%; in EG the percentage raised from 46% to 68% (Figure 3.). Students in the experimental group would likely be more engaged in discussions over work, solutions justifying and analysing problems without help.

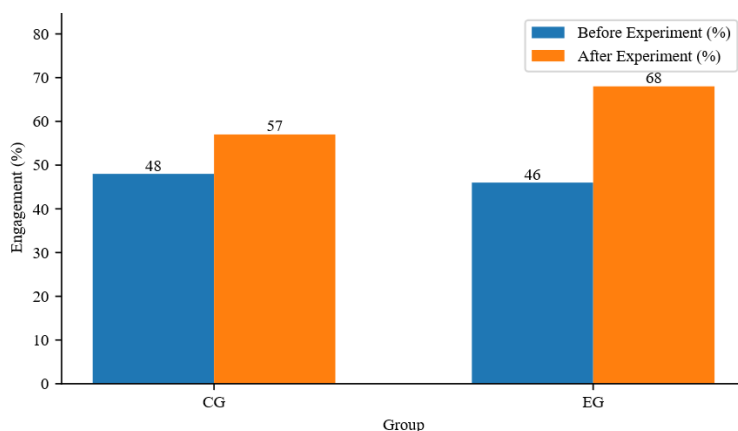


Figure 3 — Level of Students' Learning Engagement

In total, development of probability reasoning, data-interpretation, modelling and forecasting and decision-making skills in situations with uncertainty joined observed gains in the experimental group. The quantitative results combined together suggest that the proposed instructional approach was associated with improved performance. Stronger post-test performance demonstrated by the experimental group, as well as large between-group effect size, supported possible utility of the combination of techniques. Results and possible utility about the usage of stochastic methodology combined with professionally oriented tasks for training students in technical specialties is worth being considered in further planning work for course content redesign.

Discussion. Stochastic methods are important in training specialists for work in the area of technology as engineering systems often involve uncertainty, randomness and incomplete information. The authors add a new layer to this point of view and treat stochastic methods not only as a mathematical technique but also as elements of professionally oriented learning activities.

Batanero and Carver R. (Batanero et al., 2024, Carver R. et al. 2016) stress the importance of a meaningful context that could provide an impetus for students' probabilistic reasoning. From this perspective, the current study grounded the concepts of probability in engineering and IT; students worked under real and ambiguous conditions and were able to see the engineering interpretations of their findings. Magana and Silva Coutinho (Magana et al., 2017) highlight the importance of mathematical and simulation modeling for teaching engineering related topics, while Hsu et al. (Hsu et al., 2025), stress the integration of digital technologies and engineering tasks in mathematics. These arguments are aligned with the findings: students in the experimental group experienced more growth on assessments than students using the conventional approach and the difference on the post-test proved to be significant ($p = 0.003$) and had the large effect size (absolute $d = 0.93$).

Professionally oriented tasks based on stochastic methods fostered students' capability of interpreting data, creating models and dealing with decision making given uncertainty. Frejd and Bergsten (Frejd et al., 2016) discuss the issue of mathematical modeling as a professional activity. Additionally, the argument of professionally oriented problem situations and active learning to train future engineers stressed by Abylkassymova et al. (Abylkassymova et al., 2024), appears to be consistent with presented findings.

The results specify the conceptual role of professional context. It does not offer a replacement for mathematical theory, but is a creating of a situation, where one has to choose, use and interpret from what she has learned for mathematical theory. The experimental group's larger leap in achievement as well as changes in numbers and engagement, is a numerical translation of the relationship proposed above. However, the last two changes were neither part nor focus (both mentioned were only examined through numbers or descriptions without any kind of inferential

test) of the study, thus, can be considered as additional information than any kind of proof for their contribution to effectiveness.

The finding about experimental group's greater gain achievement is certainly aligned by direction with Prince and Freeman et al. (Prince, 2004, Freeman, S. et al., 2019) findings from their review of the evidence for the use of active learning. Nevertheless, none of these findings show how successful the specific version that is discussed was due to other factors such as assessment (the experiment in question was a multiple-choice while the other two were discussion-based and group-activity type, in addition, there might be some other discrepancies between these), implementation or experimental design were (this experiment used already assembled groups instead of individually and randomly allocating them). Hence, all presented here is just context specific evidence and cannot be used to derive any general cause effect relationships.

To describe what the experimental contribution in the current study was, Garfield et al. (Garfield et al., 2008), usefully argue how students should have experiences not only calculating, but reasoning about statistical concepts and solutions. Although here, the former might be compatible with better performance on evaluation, the overall test performance lacks detail on specific conceptual changes involved in this reasoning. Thus for the future, the test should also draw a distinction between model choice, computation, interpretation and justification aspects to be able to examine above argument than only assuming it from a higher test score.

Furthermore, the examples specify how Ross (Ross, 2019) applied modeling scope and Probability foundations presented by Blitzstein and Hwang (Blitzstein et al., 2019) could inspire the design of professionally oriented instruction. Reliability, load exceedance and diagnostic signals are responsible to provide the maths results with an engineering interpretation. These books assist as the basis behind the maths of the examples, they do not show their effectiveness for instruction yet. All four examples were illustrative and thus their instructional effectiveness would require to be examined by a separate experiment in classroom.

One should acknowledge the limitations which the here provided findings are confined. The subject in the experimental were students (46 in total) of one of the institutions, while curriculum taught was the same for one course. Both groups, experimental and control, were already pre-existing; students were never assigned to any group. Thus the results provide a confirmation for the presented claim only as much as it pertains to this experiment, it cannot be generalized to all the students of the technical specialties until additional research is carried out.

Conclusion. The article considered, developed and realized a professionally oriented approach to teaching students of technical specialties stochastic methods within the course Probability Theory and Mathematical Statistics. The approach combined probabilistic concepts with applied engineering and IT tasks. It contained diagnostic, formative and control stages.

Methodologically the presented combination links stochastic concepts to real-

life situations where undergraduates are suggested to search for uncertainty cases, determine necessary method to study stochastic aspects of the situation, perform mathematical analysis and interpret result. Thus professionally-oriented tasks create connection between theoretical mathematical preparation of students and applied engineering reasoning.

The pedagogical experiment showed positive learning dynamics in both groups though with a larger descriptive gain in the experimental group. In the range from 0 to 100 scale, CG gained from 58.5% up to 67.9% of points from the possible while EG gained from 56.5% up to 75.1%. Thus CG learned 9,4% while EG learned 18,6% of the content. The difference of post-tests of 7.2% appeared to be not casual while the calculated Cohen d was $|d|=0,93$. Such evidence enables discussion of a different improvement trajectory in the tested study in the context described but does not indicate causal effects or statistically significant differences in the observed learning trajectories yet.

Results show that professionally oriented system approach to teaching stochastic methods described and realized by authors might help acquisition of probabilistic reasoning, interpretation of data, modeling, forecasting of developments and decision-making when affected by uncertainty. Its applied significance is caused by the opportunity of embedding to existing standard curriculum of course Probability Theory and Mathematical Statistics elements, which include professionally-oriented stochastic tasks while curriculum itself and amount of class hours keeps the same.

However, the study also suffered from certain limitations. There were 46 respondents coming from a university where the study took place while experiment covered a single course of studying stochastic methods. For the future it is needed to expand the sample size, recruit students from other universities, broaden course content. Future research should cover enlargement of the system of professionally oriented tasks and extending areas of IT-engineering and engineering using stochastic methods.

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