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Research article

On the Non-Universality in Mathematical Language

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Abstract

The authors analyze examples of the manifestation of non-universality in mathematical language. The identified inconsistencies are due to both cultural differences between national mathematical schools and differences in approaches in different scientific schools, regardless of their cultural background. Currently, university teachers of math pay insufficient attention to analysis of inconsistencies. At the same time, the formation of students' competencies in this area will ensure their successful professional communication in international environment in future. Authors split the analysis results into four groups. The first group includes discrepancies in Russian and English concepts describing various mathematical categories. Knowledge of these inconsistencies greatly simplifies the professional communication of mathematicians in the international aspect. The second group includes differences in the designation of "nominal" mathematical objects in Russian, English, French and German. These discrepancies are not critical in intercultural communication, because the correspondence is easily established based on graphs and formulas. The authors form the third group of inconsistencies between Russian and English mathematical terminology arising due to cultural differences in the development of math sections in scientific schools in different countries. In this case, establishing correspondences requires a lot of effort, since there are no equivalents for a number of terms, while others differ due to differences in approaches to their justification. Accordingly, teachers should pay special attention to the formation of intercultural competencies of students in this area. Finally, the fourth group includes inconsistencies in the interpretation of some mathematical phenomena, both in Russian and in English, resulting from variations in the approaches of various scientific schools. The authors give two striking examples from Probability Theory. Students' awareness of these differences undoubtedly contributes to the development of their critical thinking and cognitive abilities in general.

Keywords: Language of mathematics; Intercultural communication; Probability theory; Mathematical statistics; Terminology mismatch

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Научная статья

О неуниверсальности языка математики

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Аннотация
Авторы анализируют примеры проявления неуниверсальности математического языка. Выявленные несоответствия обуславливаются как культурными различиями национальных математических школ, так и различиями в подходах в разных научных школах вне зависимости от их этнической принадлежности. В настоящее время университетские преподаватели математических дисциплин уделяют анализу несоответствий недостаточное внимание. В тоже время формирование компетенций студентов в этой области обеспечит в будущем их успешное профессиональное общение в международной среде. Результаты анализа можно разделить на четыре группы. К первой группе относятся расхождения в русских и английских понятиях, описывающих различные математические категории. Знание об этих несоответствиях существенно упрощают профессиональную коммуникацию математиков в международном аспекте. Ко второй группе относятся различия в обозначении “именных” математических объектов в русском, английском, французском и немецком языках. Эти расхождения не являются критичными при межкультурной коммуникации, потому что соответствие легко устанавливается с опорой на графики и формулы. Третью группу составляют несоответствия русской и английской математической терминологии, обусловленные культурными различиями путей развития разделов математики в научных школах разных стран. Для установления соответствий в этом случае требуется затрачивать большие усилия, поскольку эквиваленты ряда терминов отсутствуют, а другие различаются в сиу различия подходов к их обоснованию. Соответственно, преподаватели должны обращать особое внимание на формирование межкультурных компетенций студентов в этой области. Наконец, в четвертую группу выделены несоответствия в трактовках некоторых математических феноменов, как в русском, так и в английском языках, происходящие от вариации в подходах различных научных школ. Авторы приводят два ярких примера из Теории Вероятностей. Осознание студентами этих различий, несомненно, способствует развитие их критического мышления и когнитивных способностей в целом.

Ключевые слова: Язык математики; Межкультурная коммуникация; Теория вероятностей; Математическая статистика; Терминологическое несоответствие

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INTRODUCTION

We know the statement of Galileo Galilei (1623/1960) who claimed that our Universe “cannot be understood without first learning to comprehend the language and know the characters as it is written. It is written in mathematical language, and its characters are triangles, circles and other geometric figures, without which it is impossible to humanly understand a word; without these one is wandering in a dark labyrinth.” The language of mathematics is a language consisting of words, symbols, tokens, as well as graphic schemes. Mohan Ganesalingam (2013) considers the most striking feature of mathematical language is the way in which it mixes material that looks as if it is drawn from a natural language with material built up out of idiosyncratically mathematical symbols (p. 17). At all times, experts in various scientific fields extolled the language of mathematics as the most accurate and devoid of the shortcomings of natural languages, such as fuzzy definitions. Burt Williams Horatio noted that “mathematics is both a body of truth and a special language, a language more carefully defined and more highly abstracted than our ordinary medium of thought and expression” (Horatio, 1927). It means that a natural language, becoming a part of a mathematical language, automatically becomes a part of a formalized system. Mathematics serves as a model for the discussion of linguists about the construction of a metalanguage.

When people talk about the exact sciences, they mean, first, mathematics. Indeed, mathematics reflects the fundamental patterns of the world order. Therefore, it should be least dependent on the socio-psychological, including cultural, context. Thus, in simple terms, mathematicians from different communities who have reached a similar level of education are simply obliged to understand each other without question. This is true, since the basis of mathematics – numbers as well as the formulas and abstract representations connecting them – bear a clear imprint of universality.

There are quite a few studies devoted to the language of mathematics, the authors of which consider the language, first, in the aspect of teaching mathematical disciplines. Researchers study the use of words in the language of mathematics, and some of them assign an important role to the linguistic features of the vocabulary (Dobie & Sherin, 2021; Moschkovich et al., 2018; Wilkinson, 2018). Other researchers focus on sentence construction (Ganesalingam, 2013; Morgan, 1996) and on challenging students' language skills in learning mathematics, including bilingual ones (Clarkson, 1992; Jenlink, 2020; Jorgensen & Graven, 2021; Riccomini et al., 2015). However, researchers practically ignore the multilingual aspect of mathematical language, and this study represents the beginning of discussion about the specific features of the language of mathematics in a multilingual world.

Mathematics teachers reproduce the mathematical knowledge based on the traditions of the scientific schools to which they belong. While analyzing mathematical courses in colleges and universities the authors found numerous manifestations of the phenomenon of the non-universality of the language of mathematics. There are several stereotypes about mathematics and its teaching that support the myth of the universality of the mathematical language. Below, the authors show how these stereotypes are blurring through detailed analysis supported by examples.

First, whatever the ways of teaching mathematics, the results in the form of mathematical competencies of kindergarten, university or high school graduates turn out to be comparable to some degree of approximation. Perhaps this is true for arithmetic and elementary geometry. But there are significant discrepancies even in mathematical analysis, differential equations and probability theory (Adoniou, 2014). Mathematical disciplines that are in their infancy, such as graph theory, discrete mathematics, mathematical statistics, and others, allow discrepancies both in language and in meaning.

Secondly, the universal nature of mathematical competencies also requires a universal, maximally abstracted approach to the presentation of mathematical ideas. At the same time, researchers say that the language of mathematics itself is difficult for students (Bulaon, 2018). Visual images can aid understanding of theoretical positions. However, the abundance of examples and graphs is considered not a virtue, but a vice of “theoretical” math courses. Moreover, many teachers, especially at universities, give examples in lectures, but do not include them in printed or electronic manuals to avoid condemnation of colleagues. There are also works criticizing the “excessive” enthusiasm for practice-oriented tasks related to the professional activities of graduates. As a result, currently one of the problems of engineering and economic training at universities is the low level of competencies in the field of mathematical modeling in the professional field. With regard to the problems of this work, this means that in professional intercultural communication, graduates will be deprived of the most important auxiliary means of establishing mutual understanding with their foreign colleagues.

Thirdly, the orientation towards rigor in teaching makes mathematicians adhere to the approach underlying this or that course, determined, as a rule, by the scientific school in the womb of which these mathematicians received their professional education. The study of various variant concepts is usually discouraged. In secondary school, all mathematical operations are strictly prescribed, and deviation from them is punished (Lucas et al., 2014). The university environment is quite loyal to the differentiation of techniques, however, theoretical excursions into “parallel mathematical worlds” are absent simply due to lack of time, or they are masked by this lack. As a result, the study of mathematical courses in this manner does not contribute to the formation of critical thinking, which is one of the components of the fundamental training.

In connection with the development of globalization of world processes, both education and professional realization of university graduates have a steady tendency towards internationalization. Namely, getting an education in one country and absorbing its mathematical culture, a graduate could work in another country or in an international company. In this case, successful professional communication requires broader ideas, in particular, about mathematics, than those that can be given by a certain, albeit a very strong, scientific school.

The above reasoning leads to the purpose of this study, which is to identify inconsistencies in the definition and description of mathematical objects in various scientific schools, primarily national ones. The presented examples of the non-universality of the mathematical language, integrated by teachers into mathematical courses, will help university graduates in successful professionalization in an international environment.

RESEARCH METHODS

The main research method is the analysis of a large scope of teaching materials for university mathematical courses in Russian and English, both in the form of printed manuals and in the form of electronic educational resources. In materials of this kind, the authors reveal elements of inconsistency between the formulations of concepts and statements. The authors consider both Russian and English texts separately and in comparison. If necessary, terminology typical of German and French mathematical sources is also used.

Based on a preliminary analysis, the authors found that a significant number of inconsistencies are observed in the courses of probability theory and mathematical statistics, which the authors focus on. These discrepancies are largely due to the fact that the development of statistics from the beginning to the second half of the 20th century in Russia and Western countries proceeded in isolation. Thus, in the Soviet Union, it was customary to distinguish between “bourgeois statistics” as the basis for manipulating public consciousness, and “Soviet statistics” as the basis for a planned socialist economy (Dumnov, 2019). At present, it is obvious that neither the elements of the free market, nor the strict regulation of economic mechanisms provide ways for optimal development (Eliseeva, 2011). The globalization of world processes subjected to storms indicates the need for the development of critical thinking of specialists who will have to build constantly transforming models that reflect the ever-changing reality.

Usually, the authors of educational materials adhere to a certain point of view when presenting controversial statements in the spirit of the mathematical school that formed them or in the spirit of the existing mathematical environment. This is probably correct for constructing a coherent mathematical theory within a certain mathematical school. However, the professional activities of graduates are likely to proceed in conditions of communication with representatives of other schools. Therefore, acquaintance with other variants of debatable mathematical statements will undoubtedly contribute to the development of their critical thinking, as one of the most important soft skills.

The authors focus on a number of identified contradictory phenomena, the awareness of which will allow students to have tools for a more flexible approach to the construction and analysis of mathematical models.

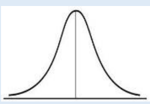
FINDINGS AND DISCUSSION

The authors divided the results of the analysis into four groups. The first group includes the most common discrepancies in the English and Russian languages of mathematics. The authors have collected in the second group terms in different languages, which are named after prominent mathematicians. The third group consists of terms that have essentially different names in Russian and English, which cannot be “guessed” in intercultural communication without knowing the correct correspondences. The fourth group focuses on examples of different interpretations of the same mathematical objects in different scientific schools.

The examples of the first group concern several general facts noted when comparing Russian and English languages of mathematics. These remarks belong to the category of the metalanguage of mathematics, i.e. describe the primary constructions that precede the actual mathematical content. They are significantly related to their own cultural context, and therefore are not perceived by native speakers as something that presents difficulties in intercultural contact. The authors give two examples of terms, the direct translation of which in mathematical context can cause mutual misunderstanding between the parties. The notion of “attributes” (“properties”), beloved by Russian mathematicians, in English sources can most often be compared with “rules,” for example, “rules of addition,” “rules of integration.” Teachers should pay some attention to these constructions in lectures. Further, the concept of “characteristics,” depending on the context, can mean either “parameters,” “attributes” or something else. For example, “numerical parameters” in the English version of Probability Theory more accurately reflect the essence of the object than “numerical characteristics” in its Russian version. Typically, characteristics in the English mathematical and natural science context are associated with processes, for example, “volt-ampere characteristic.” In general, to avoid misunderstandings, the term “characteristics” should be avoided in mathematical reasoning. Once again, it will be quite difficult to reach the correct interpretation of the meaning of communication, especially if English is not the native language for both communicators.

The second group of examples of inconsistencies includes the use of proper names to denote equations, conditions, theorems, formulas, etc., for example, “Navier–Stokes equations,” “Moivre–Laplace formula,” “Cauchy theorem.” In most cases, the nominal designations of objects are the same in mathematical courses in different languages. In some cases, categories acquire mobility, for example, “Cauchy–Riemann conditions” and “Cauchy–Riemann equations” refer to the same object of the Theory of Functions of Complex Variable. It is possible to state the phenomenon of “avoidance of names,” as well as “avoidance of “foreign” names,” which is illustrated in Table 1 by some examples in Russian, English, French and German. The most frequent names in each of the languages are given.

Table 1. Examples of avoidance and transformation of nominal designations of mathematical objects.

Object	Russian	English	French	German
$\iint \vec{f}\cdot\vec{ds} = \iiint div\vec{f}dv$	Theorem of Ostrogradski–Gauss (Dubik, 2015)	Divergence theorem (Silhavy, 2009) / Gauss theorem (Xiaolan, 2011) / Gauss divergence theorem (Benci & Baglini, 2014)	Théorème de Green–Ostrogradski (Robbes et al, 2010)	Gaußsche Gesetz (Scheibenzuber & Schwarz, 2011)
$\int_a^b f(x)dx = F(b) - F(a)$	Theorem of Newton–Leibniz (Trefilova, 2018)	Fundamental theorem of calculus (Sobczyk & Leon Sanchez, 2008)	Théorème fondamental de l'analyse (Bahra, 2020)	Fundamentalsatz der Analysis (Weitz, 2018)
	Gauss curve (Ter-Martirosian et al., 2021)	Bell curve (Klinck & Swanepoel, 2019)	Courbe de Gauss (Bru, 2006) / Courbe en cloche (Catin et al., 2008)	Gauß-Kurve (Schreven & Hammer, 2019) / Gaußsche Glockenkurve (Mossig, 2012)

From the examples given in Table 1, we can see that in mathematics in Russian, names in denominations are used more widely than in the main European languages. It should be noted that in intercultural communication these discrepancies are established quite easily. Communicators simply write a formula or draw a sketch of the corresponding graph.

The third group combines examples of Russian mathematical terms that either lack direct analogies in English, or their equivalents are not obvious, which is difficult for professional intercultural communication. The identified terminological discrepancies in Russian and English sources with a conditional breakdown by sections of mathematics are shown in Table 2. The terms of the “Russian version” of mathematics are given in equivalents or transliterations in English. We write the transliteration in <broken brackets>.

Table 2. Comparison of Russian and English mathematical terms

Term or concept in Russian	Term or concept in	Remarks
Pre-Calculus		
Elementary functions (x^n, e^x, logarithm, trigonometric and inverse trigonometric functions)	The term is not available in English	When it is necessary to refer to an indication of such functions, English-speaking authors use descriptive constructions such as “the easiest functions.”
$tg\ x, ctg\ x, arctg\ x, arcctg\ x$	$\tan x$, $cot\ x$, $\arctan x\ (tan^{-1}x)$, $arccot\ (cotan^{-1}x)$	In connection with the development of computer systems focused on English, English equivalents began to appear in Russian sources, but you cannot find them in textbooks on “classical” mathematics.
<Pokazatel’naya> function a^x	Exponential function a^x	In Russian sources, the English term is applicable only for a particular case e^x.
<Pokazatel’no> power function / Power <pokazatel’naya> function $a(x)^{b(x)}$	The term is not available in English	If necessary, in English sources, the function is defined through the exponent $a(x)^{b(x)} = e^{b(x)\ln(a(x))}$.
Complex function / Function superposition / Function composition	Function composition	In English sources, the term does not appear in the “Pre-Calculus” section, but you can find it in the “Calculus” section and more complex sections, such as “Theory of Operations,” “Discrete Mathematics.”
Calculus		
Replacing infinitesimal values / functions with equivalent ones	Chain rule for infinitesimal quantities / functions	
Complex Function Differentiation	Chain rule for derivatives	
Necessary extremum condition	First derivative test	In English sources, the terms “necessity” and “sufficiency” are mainly used in the “Mathematical Logic” section
Sufficient extremum condition	Second derivative test / higher-order derivative test	

Differential Equations		
Total differentials equation	Exact equation	$P(x,y)dx + Q(x,y)dy = 0,$ $\partial P/\partial y = \partial Q/\partial x$
Probability and Statistics		
Quadratic mean deviation	Standard deviation	In connection with the internationalization of education and the spread of computer statistical products of American origin, the term “Standard deviation” began to appear in Russian-language sources (Narkevich et al., 2016).
Absolute deviation $\boldsymbol{\frac{1}{n}\sum_{i=1}^{n}\lvert x_i - Med_x\rvert}$	Median absolute deviation $\frac{1}{n}\sum_{i=1}^{n}\lvert x_i - Med_x\rvert$ Mean absolute deviation $\frac{1}{n}\sum_{i=1}^{n}\lvert x_i - M_x\rvert$ Mode absolute deviation $\frac{1}{n}\sum_{i=1}^{n}\lvert x_i - Mod_x\rvert$	Russian-language sources mainly use the absolute deviation from the median. Some authors introduce other types of absolute deviations without defining them as separate point estimates.
Variation series / Ordered statistics	Ordered sample	You can meet the term “Series” in English-language sources in relation to statistics only in the “Time series” section. From the point of view of the authors, the Russian-language terms are arbitrary and archaic; if possible, they should be replaced with equivalents of English-language terms, which is already being done in many sources (Savchenko, 2011).
Statistical series	Distribution / Statistical distribution	
Correlation moment / Covariance	Covariance	Recently, the term “correlation moment” has been ousted from Russian-language sources (Zheleznyak et al., 2014) due to the depreciation of the moment approach, which has not been developed in American statistics. From the point of view of the authors, the term “Covariance” is more consistent with the essence of the concept.

Significance level	Significance
General totality	Population
Sample volume	Sample size
Mechanical sampling	Systematic sapling
Full group of events	Collectively exhaustive events
Dispersion	Variance
Statistical hypotheses verification	Hypotheses test

The information given in Table 2 shows the greatest discrepancies between Russian and English terms in the statistical sections of mathematics. The authors can explain this by the fact that modern statistics has received a powerful development in the United States. In the 1920s, 1930s and 1940s, statistics was predominantly applied science. It served as a tool of analysis in psychology and genetics. However, these areas of science were not recognized in the USSR, which is why even the terminology of “Soviet” statistics differs from the terminology adopted in the countries of the Western world (Krasnoshchekov & Semenova, 2020). Statistics is of great importance in medicine, demography, and economics. At the same time, during the Soviet period, most of the statistical data was not in the public domain, which also did not contribute to the development of statistics as a science in the USSR. In this case, the authors believe that it is necessary to bring the Russian statistical terminology in line with the generally accepted in world science, since the discrepancies are explained not by national tradition, but by the subjective circumstances of the development of statistics in Russia.

The last group of examples concerns inconsistencies in the fundamental concepts of probability theory, generated by various approaches cultivated by scientific schools. The authors obtained these materials from the analysis of open educational sources, both in Russian and in English, such as Wikipedia, DPVA.net, Math Help Planet, exponent.ru, TeorVer-online, SlidePlayer.com, StackExchange, Academic and others.

The first example concerns the distribution function of a discrete random variable. By definition, the value of the distribution function of a random variable X at the point x is equal to the probability that the variable takes a value less than x: $F(x)=P(X<x)$. The plot of the distribution function of a discrete random variable is a step function that experiences a jump at each isolated value. According to modern views, interval estimates are more important than point estimates, so it is necessary to know whether the end point belongs to a given interval or not. If the end point does not belong to the interval, then this is indicated by an arrow on the graph. This means that the boundary value of the probability is not taken into account in the total value of the probability in this interval. The graphs presented on mathematical sites do not give an unambiguous answer about whether the end points belong to one or another interval (Fig. 1).

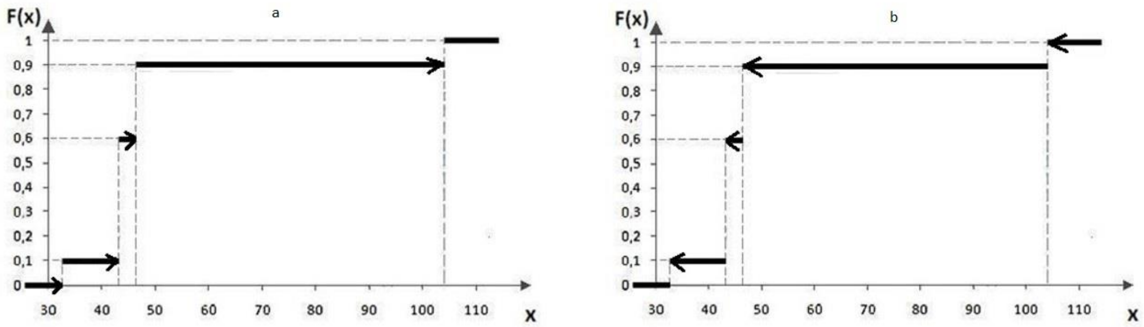


Figure 1. Variants of graphs of the distribution function of a discrete random variable.

The left and right graphs in Fig. 1 differ in the direction of the arrows, which means the inclusion or exclusion of the end of the interval. What causes such inconsistency? For example, the probabilities in the range of x from 45 to 47 in the left and right graphs differ by 30%, which is quite a lot, for example, when predicting financial risks or emergencies.

The second example considers the uniform distribution mode. The graph of the uniform probability density is shown in Fig. 2.

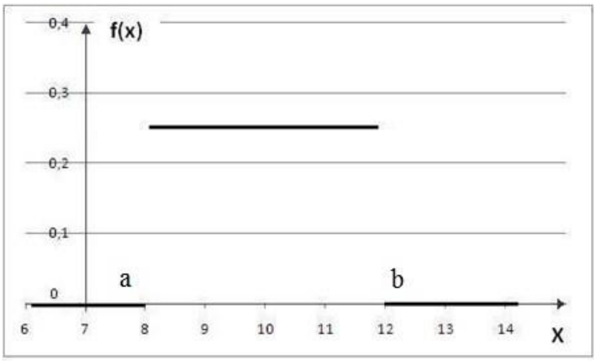


Figure 2. The probability density of a continuous uniform distribution.

The mode of a continuous distribution is the maximum of its probability density. This is one of the main parameters of the location of a random variable. According to the theory of extrema, if all points of the interval (a; b) are maximum points, such a maximum is called non-strict one. However, 80% of the sites claim that there is no mode of uniform distribution, and only 20% claim that each point of the interval (a; b) is the mode. Moreover, some scientific schools introduce the concept of antimodal distribution, but not all of them classify the uniform distribution as the antimodal one.

The authors recommend teachers to acquaint students with similar inconsistencies found in probability theory. However, the teacher should not insist on the fairness of one of the alternatives. The fact is that graduates in their professional activity can fall into the orbit of a scientific school that adheres to a different alternative. In this case, their tough position could lead to a conflict in which both sides would have arguments based on authoritative opinions.

CONCLUSION

The authors analyzed some of the phenomena associated with the non-universality of the mathematical language. One part of these inconsistencies in the names and descriptions of concepts reflects the cultural characteristics of mathematical schools in different countries. Differences in the approaches of scientific schools within the same culture explain the other part of inconsistencies. In connection with the internationalization of education and the globalization of the labor market, university graduates are more likely to work in international communities. The authors divide examples of discrepancies into several groups. The authors analyzed the grounds for the discrepancies found, as well as proposed mechanisms for facilitating mutual understanding in intercultural communication in the professional field.

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