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Research article

Teaching English as a Language for Mechanical Engineering

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Abstract
Engineering education usually includes the acquisition of a foreign language for a transnational professional discourse. Engineering education also involves the acquisition of competencies to compose functional technical systems from component parts. This paper provides a conceptual and empirical exploration of a synergistic effect between these two learning processes. It proposes that engineering education draw upon and incorporates this synergy. A pilot training course confirms that this leads to a faster development of the overall engineering knowledge system. This training course implements the conceptual finding according to which the process can be integrated on the model of language learning: to learn mechanics. i.e. kinematics, is like learning English as a foreign language. The grammar of sentence formation and the grammar for the effective technical placement of things teach engineers about symbolic and conceptual order, what the language of mechanics is and how it differs from the language of electronics, and how, for example, this difference needs to be accommodated in the field of mechatronics.

Keywords: Philosophy of engineering education; Foreign languages; Language of kinematics; Integration

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Научная статья

Преподавание английского как языка машиностроения

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Аннотация
Инженерное образование включает обучение иностранному языку для освоения транснационального профессионального дискурса. Обучение инженеров также предполагает приобретение навыков синтеза технических систем из составляющих их элементов. В статье предлагается концептуальный и эмпирический анализ синергического эффекта, возникающего при взаимосвязанной реализации этих двух процессов обучения. Инженерное образование может плодотворно использовать этот синергизм. Реализация экспериментального учебного курса, подтверждает, что взаимосвязанное обучение способствует более быстрому формированию у обучающихся системы общетехнических знаний. В основе курса лежит концепция, согласно которой изучение механики, в частности кинематики, имеет сходные черты с изучением английского языка как иностранного. Сравнение грамматики построения предложений и «грамматики» эффективного соединения частей технических систем способствует научению будущих инженеров символическому и концептуальному порядку, специфическому языку механики, а также показывает как он отличается от языка электроники, и как эта разница должна быть учтена, например, в области мехатроники.

Ключевые слова: Философия инженерного образования; Иностранные языки; Язык кинематики; Интеграция

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BACKGROUND: ONE PROFESSIONAL LANGUAGE AMONG OTHERS

Foreign language as an academic subject is present in the curricula of many technical universities around the world. Unlike the General English course which is studied at school, higher education courses are mostly related to business English, language for special purposes, professional or academic communication. In the case of General English, students have a particularly strong interest in linguistic facts and a motivation to learn through them the language of culture, the way of thinking and the way of life of native English speakers. At the university, the motivation of students in the course of their professional development shifts to more practical motives. A foreign language becomes a tool for obtaining professional knowledge and a tool for self-expression in a specialty. We are no longer talking exclusively about the culture of native speakers; language comes to the fore as a means of mediation and socialization in the international professional community.

Very often poor English becomes a big problem. According to Rudolf Jaenisch (2010) from the Massachusetts Institute of Technology, "some papers from Asia are so badly written that they are difficult to assess." Therefore, "poor language quality which cannot be understood by readers" is one of the main editorial reasons for the rejection of research papers (Phani Kumar & Rao, 2018). Moreover, as noted by Adrian Wallwork (2011), "native referees tend to be more interested in how the paper flows and how easy it is to read. Non-native referees seem to focus more on grammatical and vocabulary mistakes, so very accurate English is important". A number of frequent and typical grammatical, logical and conceptual errors that non-native English writers make indicate the need for improving general English skills (Wallwork, 2011). A large number of recommendations on various aspects of composition and of writing English-language texts have been published (Kallestinova, 2011; Bhakar & Tarika, 2014).

In order to write correctly, one needs to read a lot and comprehend, extracting relevant information. One can improve English considerably by reading lots of papers and books in the field of interest. That will help revealing the typical phrases to express various language functions (e.g. outlining the aims, reviewing the literature, highlighting one's findings) (Wallwork, 2011). In fact, foreign-language reading of professional literature (domain-specific texts) performs a much more important function than just identifying service language concepts. It is inextricably connected with writing and speaking and represents a complex activity that is carried out by the mental operations of selection, categorization, analysis, generalization, synthesis. As a result of these operations, the reader comes to comprehend what has been written, recreating semantic connections (Serova, & Sabitova, 2020).

Informative reading contributes greatly to forming a professional discourse and a professional lexicon as a means of capturing the elementary units of discourse. The problem of lexico-grammatical features of domain-specific discourses requires consideration of the relationship between vocabulary and semantics (C. Orna-Montesinos), vocabulary and syntax (N. Zhinkin, T. Serova). In addition to syntax and semantics, academic discourse as applied to the English language as the lingua franca is studied in other aspects; the examples are the rhetorical structure of research articles, and hedging and cohesion in academic discourse across cultures (Lakić et al., 2015). A whole area of teaching is developing – discourse-based teaching.

There is no doubt that English-language written and oral engineering texts, and more broadly English-language engineering discourse, have specific features at the levels of paradigmatics (genus – species, whole – part), at the syntagmatic level (subjective, objective, temporal, spatial relationships, relations of quality and others), as well as at the levels of rhetoric and cohesion. The success of professional communication, both written and oral, is also significantly influenced by knowledge and the ability to actively use the system of professional concepts, terms, acronyms accepted in the international community – everything that can be included in the thesaurus of the scientific field.

In a broader sense, the languages of the individual sciences are sometimes discussed. The beginning of this tradition was probably laid by Galileo, who believed that mathematics was the language in which the book of nature was written. In the case of the engineering sciences, the description of the properties, states, movements of objects is possible using the combination of words, diagrams, numbers, graphs, and equations. In particular, the concept of the language of kinematics is known (Bodo et al., 2000), which includes the concepts necessary to describe the motion of objects. Consideration of the phenomenon of the language of kinematics (it is also called the language of mechanics) as a special case of a specialized language allows us to clarify two issues that are important from a pedagogical point of view.

The first one concerns the relation between the language of kinematics (as a synthetic means of accumulation, knowledge transfer, and communication) and a natural language, in particular English as the lingua franca of engineering education.

The second question is whether teaching the language of kinematics can be integrated with teaching a foreign language within one pedagogical system.

THE LANGUAGE OF KINEMATICS IN ENGINEERING EDUCATION

Formal engineering education has existed for more than 200 years; its foundation is associated with the opening by Napoleon in 1794 of the Grande Ecole Polytechnique (Barbieri & Fitzgibbon, 2009). Pretty soon, the training of future mechanical engineers moved from an apprenticeship on the shop floor to a combination of the acquisition of practical skills with the acquisition of solid knowledge in mathematics and physics (classrooms on scientific theory or mathematical analysis), as well as theoretical knowledge in area of the device and functioning of mechanisms and machines. The process of rapid accumulation of a huge amount of knowledge in this area required comprehension and generalization.

Efforts to classify mechanisms were undertaken throughout the 19th century and were based on tables and abstract symbolic notations (Moon, 2003), just as was done in biology and chemistry. Based on the analysis of the composition and purpose of machines, the designations of their typical parts appeared (F. Reuleaux, R. Willis, others).

Franz Reuleaux introduced in the last decades of the 19th century the concept of kinematic pairs into the kinematics of a rigid body. He did so by considering the mechanism as a part of a machine and thus a movable system of bodies that are connected in a special way, with each body imposing restrictions on the movements of others. Reuleaux classified kinematic pairs and proposed symbolic designations. For example, the symbol '*C*' was used to denote a cylindrical kinematic pair, '*P*' was used for a prismatic kinematic pair, and '*S*' was used for a screw pair. The features of parts of the mechanism (parallel to the axes, fixed link, teeth in gear wheels), and even the working medium (λ – liquid, γ – gas) were specially designated. Reuleaux created a whole collection of mechanisms in which all types of kinematic pairs were materialized.

This made it possible to designate simple mechanisms with a combination of letters and numbers, in particular, the crank-slider mechanism, in which the '*d*' link was fixedly designated as $(C_3^{''}P^T)^d$. This designation indicates that the links of the mechanism are connected by three cylindrical pairs, the axes of which are parallel, in addition, the mechanism includes one translational pair; link 'd' (one of the four links '*abcd*') is fixed.

The importance of the problem of designating and classifying mechanisms, and the degree of success with which it was possible to solve it, gave reason to say that Reuleaux created a kind of "symbolic language ... to classify a machine, a syntax for kinematic devices which he proposed as a tool to address the problem of synthesis, a language for machine invention" (Moon, 2003). Indeed, using symbolic notation and the concept of kinematic chains, Reuleaux was able to identify six ways of synthesis of mechanisms: inversions, expansion of elements, redefining from plane to conic chains, reduction of kinematic chain elements, augmentation of kinematic chains, generation of compound chains. And it really resembles syntax in linguistics, like the synthesis of various sentences from a set of words. Moreover, the language of kinematics actually anticipated topology, a branch of mathematics that only appeared in the 20th century. Currently, the kinematic topology of mechanisms is widely used in the science of mechanisms (Amirinezhad & Donelan, 2019; Mueller, 2015) including such methods of organizing connections of elements as graphs.

In the second half of the 19th century and in the 20th century, work on the analysis and synthesis of mechanisms based on symbolic designations was continued by Pafnuty Chebyshev, Leonid Assur, Franz Grashof, Ivan Artobolevsky, Jacques Denavit, Richard Hartenberg and other scientists. It is not finished even today, the issues of analysis and synthesis of structures of mechanisms from a set of elements is of significant theoretical and applied interest and continues to attract scientists (Pozhbelko, 2019).

Recognizing the importance of the problem of designating and classifying mechanisms, Reuleaux had created a "scientific symbolic language of kinematics (*wissenschaftliche Zeichensprache der Kinematik*)" (Reuleaux, 1875). He was careful to ensure that his kinematic language could be usefully integrated with the ordinary languages of culture. Just as one can use chemical notation to write chemical reactions, so he develops a syntax and semantics for "writing mechanisms (*Schreibung einfacher Mechanismen*)." And just like the language of logic, his symbolic notation could enable engineers to become aware of equivalences, allowing them to see that two seemingly different mechanisms are really the same (Nordmann, 2002). Since the language allows engineers to conceive hitherto unrealized compositions from the alphabet of machine elements, his is also “a language for machine invention” (Moon, 2003).

The powerful idea of a language of kinematics as an alphabet and syntax of moving devices, the multivariance of the resulting structures and the dependence of the meaning of the parts on their place and role in the mechanism, influenced philosophy. Since one physical state of a machine deductively implies the next, Ernst Kapp (1877) drew on Reuleaux when he interpreted machines as material projections of the human brain (Kapp, 1877/1978). Lewis Mumford (1970) used Reuleaux’s definition of a machine for his theory of non-material socially organized “mega-machines.” When Ernst Cassirer (1985) argued for technology as culture, he followed Reuleaux who showed that natural motion becomes civilized and organized by the mechanical movement of a machine. Most importantly for the present discussion, however, is Reuleaux’s influence on Ludwig Wittgenstein’s *Tractatus Logico-Philosophicus*, Wittgenstein’s engineering education in Berlin was shaped by Reuleaux. As Kelly Hamilton (2001) has pointed out, Wittgenstein’s conception of a proposition is modeled on Reuleaux’s notion of machine elements that can be combined only in specific ways to form a mechanism. Wittgenstein says that the ontological structure of the world is reflected in the logical structure of language – and vice versa (Wittgenstein, 1922; Talalaeva, 2018). The key idea of the philosopher is to understand the structure of sentences as the "logical scaffolding" of the world (Wittgenstein, 1922, 3.42; Borisov et al., 2010), that is, in order to establish the real state of affairs in the world, it is enough to consider the structure of sentences, which together make up language. To know the object *X* means to know which sentences with the name "*X*" are meaningful, and which are meaningless (Wittgenstein, 1922, 2.01231, 3.311; Borisov et al., 2010).

In Wittgenstein's logic, two types of knowledge about an object are distinguished. Semantic – knowledge of the meaning of a name, which does not imply empirical knowledge, this is knowledge about the possibility of facts, the structure of which is a given object. Factual – knowledge about the actual facts that include a given object.

Contextuality is also a characteristic feature of the language of kinematics. For example, if I know the meaning of the object (phrase) rotational kinematic pair R, then I also know that the fact "*a link included in a rotational kinematic pair is capable of turning*" is possible, and a fact “*a link included in a rotational kinematic pair, can translate* " – is impossible. However, the object (name) ‘*R*’ acquires full meaning only in the context of the sentence (in this case, the mechanism). If the mechanism is flat, it can include an unlimited number of objects *R*, about the internal properties of which we have complete a priori information. At the same time, in the case of a three-dimensional spatial mechanism, the presence of even one rotational pair *R* (restricting translational motion along its axis) gives a new quality to the others, since the limitation of translational motion is no longer relevant, it is unnecessary. Therefore, all other kinematic pairs impose excessive constraints (redundant constraints) on motion links, that is, they lose their former internal properties. The way out of this situation is that rotational pairs *R* (except for one) should be replaced by cylindrical *C*, which in the semantic sense is equivalent to making a sentence based on other objects.

As for teaching and learning kinematics as a professionally oriented foreign language, it is necessary to find out to what extent the presence of a specific notation system, the logical construction of scientific theses and thematic educational material affect the teaching of the language as a means of professional communication. In other words, is the language of kinematics something unique, or are there general patterns in the formation of languages of professional communication?

Generally speaking, engineering education presupposes fluency in the language of the specialty, some generalized technological language necessary to obtain, accumulate and generate information of a professional nature, expressed both by means of verbal and non-linguistic signs (formulas, pictures, graphs, diagrams, pictograms and other symbols). An important component of such a language, which develops on the basis of the native natural language, is the transnational component, which captures in a symbolic form the experience accumulated by the (global/international) scientific community in the process of studying nature and objects of the technosphere. In addition, in the technological language of professional communication, a synthesis of the native natural language and the language of logic takes place, in which the basic rules for including objects into structures that have semantic and factual meaning are formulated.

In our opinion, the language of kinematics should be considered as a system of communication and fixation of information, which has specific formal and material properties, develops in conditions of social interaction, is characterized by a close connection of speech activity with thinking, has a special system of signs. This language is formed by means of native and foreign languages simultaneously. Thus, it becomes possible to think about the phenomena of mechanics and other branches of engineering science as a foreign language in which to formulate meaningful technological propositions.

It seems that the most important functions of the language of specialty are *naming* and *predication*. In the context of this research, *naming* refers to the methods of generalized description of the component composition, material performance, principles of operation, limits of applicability, characteristics of various types – for devices, machines, mechanisms, structures and other objects of the technosphere. A generalized description is understood as a method of generating information in a form most suitable for its use both in the individual thought process and in the exchange of information between the subjects of engineering labor in the process of face-to-face or space and time-separated communication. *Predication* includes generalized methods of operation, performing actions with objects of the technosphere.

Obviously, the number of languages of professional communication, due to their generalized nature, cannot be infinitely large. The set of these languages corresponds to the enlarged list of specialties, excluding specializations. So, obviously, there is a professional language of a mechanical engineer, electrical engineer, electronic engineer, programmer, etc. At the intersection of specialties, technological languages interact, as, for example, the language of mechatronics integrates the languages of mechanics and electronics.

TOWARDS THE INTEGRATION OF ENGINEERING AND LINGUISTIC TEACHING

In the process of studying at the university, students become familiar with various aspects of objects of professional interest, while due to the differentiation of scientific knowledge, each academic discipline offers its own ways of learning. Objective factors accompanying the formation and content of training courses in combination with inevitable subjective factors lead to a variety of ways to describe objects of the technosphere. The latter fact, combined with the complexity of such objects, as well as the well-known difficulties that junior students experience in the process of adapting to an academic situation that is fundamentally different from the way of acquiring knowledge in school, leads to difficulties in the formation of an engineering picture of the world that would allow for the productive integration of new information with existing knowledge, and create an information base for engineering creativity (Krylov et al., 2016).

The integration of teaching foreign languages and teaching the language of a specialty has a pronounced synergistic effect (Khalyapina, Almazova et al., 2017; Khalyapina, Popova et al., 2017). Today, there are a large number of definitions of integrated learning. According to some researchers, there are at least forty of them. David Marsh gives the following definition of content and language integrate learning (CLIL), which was later adopted and supplemented by other authors: “content-language integrated learning refers to any educational context focused on two subjects, in which an additional language, i.e. not the main language, in which the entire course of study is conducted, is used as a means of teaching a non-linguistic subject” (Marsh et al., 2001). That is, introducing the acronym "CLIL" into scientific circulation, Marsh implies situations when a foreign language is used in teaching certain disciplines or thematic sections within their framework, pursuing the simultaneous study of the content of the discipline and the foreign language (Marsh et al., 2010). Subsequently, Do Coyle also gives an amended definition of CLIL: “CLIL is an educational approach in which disciplines or their separate sections are taught in a foreign language, thus pursuing a dual purpose: the study of the content of the discipline and the simultaneous study of a foreign language” (Coyle et al., 2010).

The European Commission is considering this approach more broadly, with a view to the use of language as a teaching tool. However, from the point of view of the results of the research carried out by the European agency "Eurydice," it is possible to talk about CLIL when “the dual purpose requires the development of a special, more comprehensive approach, within which a professional discipline is not just taught in a foreign language, but through and through a foreign language" (Eurydice, 2006).

The formation of concepts, categories related to professional activity is effective and personally significant only if there are multiple sources of information about these concepts and categories, as well as multiple ways of updating this information in the process of educational, quasi-professional and professional activities. Comparative analysis of information presented in native and foreign languages objectively contributes to a multiple increase in the efficiency of the noted processes. Here, this kind of informational reinforcement comes from learning on the one hand that any language provides rules for the composition of sentences from words, and learning on the other hand that kinematic provides rules for the composition of devices from component parts. Secondly, multilingual education creates conditions for a strong mastery of students in foreign languages: the professional orientation of training significantly enhances communicative interest and motivation for learning, this training is expected to be much more effective than training in professional discourse within the framework of traditional models of teaching a business foreign language in universities.

Integration is an amalgamation of previously disparate parts which leads to the creation of a new entity that is greater than the sum of its constituent parts. In the context of this research, we can talk about three types (threads) of pedagogical integration: between two academic subjects and within each of them.

Interdisciplinary integration of a foreign language as an academic subject in a technical university and an engineering discipline is possible on the basis of a common subject content, didactic principles and methodological approaches that underlie the respective educational processes. This process creates the conditions for overcoming the subject-centered teaching system and for strengthening its humanistic orientation.

Interdisciplinary integration is represented:

- in relation to the object considered by engineers, which contains thought, information, and which is a unit of consciousness, thinking and at the same time a unit of language and speech;

- in the ways of comprehending reality: theoretical and practical activity-based ways, or semantic (a priori) and factual ways;

- in the direction of comprehending reality: from simple to complex, comprehension of the whole through the study of parts that are in a dialectical connection with each other. It is possible to understand the principle of functioning of a part of the system only if the general plan of the system is clear; dependence of the meaning of the name on the meaning of the sentence; the title should be translated after reading the entire article; the exact meaning of the term becomes clear from the context when the term is included in the denotational structure;

- in the focus on the implementation of various methods of mental activity in the process of solving an educational problem, which leads to the expansion and deepening of professionally significant concepts;

- in the formation of "centers of crystallization" in the professional consciousness, around which, following the logic of training, the growth of the conceptual field occurs;

- in relation to motives (emotional-volitional, motivational-value spheres), which are reinforced by the extreme urgency of the task, which creates tension, which can lead to a synergistic effect.

Integration within the academic discipline "foreign language" is determined by the multidimensionality of the process of teaching a foreign language and is expressed in the integration of:

- units of the external linguistic structure and units of the internal deep semantic structure of texts;

- interrelated development of skills of four types of speech activity – listening, speaking, reading and writing. Various types of speech activity can act as both a goal and a means of learning. So, the teaching of oral speech related to the scientific and professional style is based on written forms of communication, that is, on the analysis of texts. On the other hand, if there is a theme-rhematic interaction between the teacher and the student, the teaching of oral speech can be associated with listening and subsequent dialogical communication. On the basis of dialogical and monologic speech activity, it is possible to generate written texts;

- the process of introducing and activating new vocabulary, starting with listening and reading, and continuing with speaking and writing;

- organization of the learning process including the following stages: joint planning, implementation, assessment and correction;

- the formation of a discourse, including linguistic, non-verbal (pictures, diagrams, formulas), background components.

Integration within engineering disciplines occurs along several threads of integration:

- succession of engineering disciplines, partial intersection of their thesaurus fields, the presence of " genes of information " (Polishchuk, 1993), common to several disciplines;

- the allocation of invariant concepts in the structure of engineering disciplines: mathematics (operations to obtain a numerical result), physics (reflection of objective physical reality in the phenomena, rules, laws under study), philosophy ("how we think", the choice of methods and organization of the solution of the problem) (Polishchuk, 1993);

- when constructing syllabus of educational engineering disciplines, thesauri of which are organized on the basis of the selection of basic concepts, derived concepts, principles, laws, formulas (Semin, 2001). Thus, the concepts of space, time, force, work, energy are common to many, if not all, engineering disciplines;

- in the generality of methods for solving problems (analysis of data, initial / boundary conditions, analysis of dimensions, conversion of units of measurement, construction of a mathematical model, solution of mathematical equations, analysis of the results obtained, planning an experiment, use of methods of the theory of solving inventive problems, etc.), which are common for different disciplines. The language means learned in the framework of the study of one engineering discipline will be transferred, with the necessary correction, to the field of another discipline;

- information message (channel), expressed in the interaction of linguistic and non-linguistic (pictures, diagrams, graphs, formulas) means of communication.

The realization of all the noted opportunities presents significant potential, but at the same time a great challenge for all parties involved in the educational process. Awareness of existing threads of integration and adherence to at least some of them will allow planning and implementing specific pedagogy – integrative teaching / learning. Such pedagogy should provide students with tools for generating and exchanging information necessary for active creative activity in a profession understood in a broad sociocultural sense with all possible connections. The natural basis for the integration of teaching a foreign language and the language of a specialty is the theory of activity (Aleksei Leontiev, Sergei Rubinstein, Lev Vygotsky). Thus, the second question posed in the introduction, concerning integration, should be answered in the affirmative.

RESULT

In the 2018-2019 academic year at a large public technical university in the European part of Russia, a project was carried out on integrative teaching of a foreign language for the specialty of second-year undergraduate students. The experimental group consisted of 13 students in the field of training related to mechanics. The control group included 15 students of the same specialty.

The one-year English course was largely integrated with the course of Theory of Mechanics, the purpose of the training was to form a system of language competencies in students in a wide area (technology) and in a narrow area (theoretical mechanics). The sequence of study courses is shown in Table 1.

Table 1. Time order of study courses

Semester II	Semester III	Semester IV
Theory of Mechanics (part I – Statics, Kinematics), **in Russian**	Theory of Mechanics (part II – Dynamics), **in Russian**	
No	English (part I)	English (part II)

Before the start of training in both groups, an attempt was made to test foreign language knowledge in the subject area of statics. The test material offered a variety of activities: multiple choice questions, open-ended questions, gap filling exercising, reasoning questions. By this time, students successfully studied the statics section, that is, they had formed a system of relevant subject knowledge in their native language. However, testing revealed an almost zero level of perception of the same subject information in English, which is why we are talking about *an attempt of testing*.

The design of the pilot training course was based on two principles noted above:

1) teaching methods of generalized description of technosphere objects and methods of describing actions with them;

2) reliance on mathematics (operations to obtain a numerical result), physics (reflection of objective physical reality in the studied phenomena, rules, laws) and engineering philosophy.

The training was organized in the form of thematic units, see Table. 2. The study of the material of the blocks was not linear, sequential, but was accompanied by repeated returns.

Table 2. Educational blocks

Unit I	Unit II	Unit III	Unit IV	Unit V	Unit VI
Numbers	Objects	Data interpretation	Technology	Elements of Theory of Mechanics	How to read engineering research papers

Unit I: students worked on the skills of foreign language reading, writing and interpreting numbers, fractions, mathematical notations and symbols, formulas, expressions, units of measurement of physical quantities. The content of Unit I corresponded to the structure of the math branches, the knowledge of which is required to a sophomore student. These included algebra, trigonometry, elementary and analytic geometry, elements of statistics, mathematical analysis, and linear algebra. In addition, knowledge of the rules of reading the letters of the Greek alphabet was necessary for the successful use of the numerical material included in the unit. As shown above, the symbolic component is very strong in the language of the specialty, hence the importance of this unit.

The essential factuality of engineering requires knowledge of the ways in which objects enter into facts according to Wittgenstein, that is, the external properties of objects. External properties are dialectically connected with internal properties, which provide the basis for a priori logical constructions and for creativity. That is why the Unit II thematic block for nomination and predication of objects of both physical and mathematical nature is important.

Unit III was devoted to methods of extracting information from pictorial sources. Processing of statistical data is logically connected with reading diagrams, graphs, drawings. Engineering work, like any research that has numerically expressed results, is closely related to the analysis and interpretation (handling, analysis and interpretation) of data, so this block is necessary in the course.

The first three blocks were compiled on the basis of a large collection of authentic materials in accordance with the author's methodology (Krylov, 2020a).

Creative work requires a certain horizon, therefore, in Unit IV, built on the material of the well-known textbooks Oxford English for Electrical and Mechanical Engineering (Glendinning, & Glendinning, 1995) and Professional English in Use. Engineering (Ibbotson, 2009), the principles and features of the functioning of various mechanisms, machines, devices, devices, structures were discussed; lexical-grammatical and syntactic, semantic analysis skills were improved.

Unit V was needed to test the feasibility and usefulness of the interconnected study of a foreign language and engineering disciplines. The material of specially designed lessons (Krylov, 2020b) made it possible to deepen subject knowledge by discussing thematic material in various formats.

Finally, following the notion of the need to prepare students for life-long education and the formation of a culture of extracting relevant information from scientific articles and other sources, Unit VI implemented the methodology of problematic research questions.

Upon completion of training, the students of the experimental and control groups were offered a complex test, consisting of 5 parts: Numbers, Shapes, Data Interpretation, Technology, Statics (Theory of Mechanics = Professional Knowledge). The test results in fractions of 100 are shown in Figure 1.

It can be seen that for all five positions in the experimental group, significantly better results were achieved than in the control group. However, according to the test results, one more important conclusion can be drawn: the growth of foreign language professional knowledge (Statics = Professional Knowledge), which testifies to a relatively deep understanding of the subject area, is much slower than the formation of other knowledge systems presented in Figure 1. However, compared to the near zero entry level, the progress is impressive. Thus, interconnected teaching of a foreign language and special disciplines demonstrates significant potential if certain conditions are satisfied, one of the key is the duration of study, which cannot be less than two semesters.

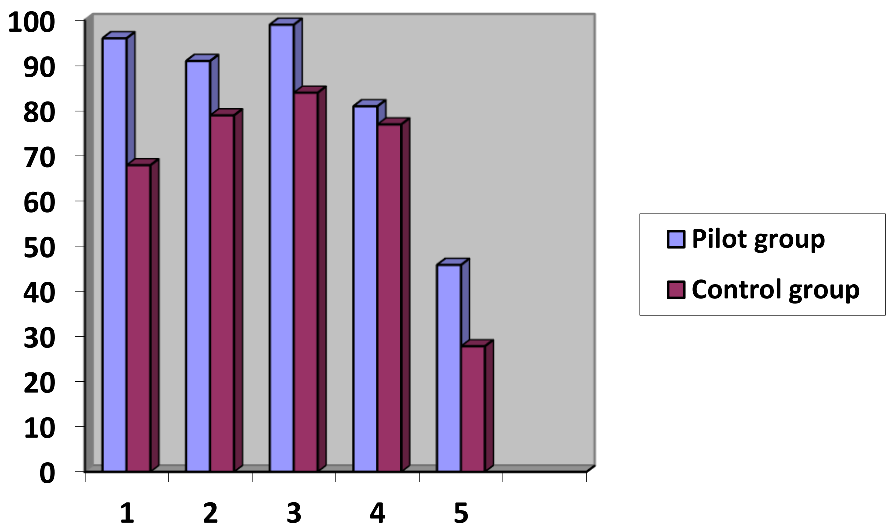

Figure 1 Results of the final testing in the pilot and control groups:1- Numbers, 2 – Shapes, 3 – Data Interpretation, 4 – Technology, 5 – Statics (Theory of Mechanics = Professional Knowledge)

During the project, a survey of students of the pilot group was conducted in September 2018 before the start of training and in May 2019, at the final stage. Table 3 shows the results of survey before and after training.

Table 3. Self-assessment of students in the pilot group

Student	Estimate your ability to carry out written communi-cation (read-ing and writing) in a foreign language,%		Estimate your ability to carry out oral communi-cation (under-standing and speaking) in a foreign language,%		Are you ready to carry out written and oral communi-cation in a foreign language, if necessary,%		Estimate the likelihood that a foreign language may be needed when performing professional duties or in life situations,%	
	before	after	before	after	before	after	before	after
A	30	60	30	60	40	70	100	100
B	65	70	50	50	60	80	80	90
C	40	40	60	60	40	80	99	99
D	40	50	30	50	40	50	90	100
E	40	40	45	50	60	60	80	100
F	70	60	60	60	70	80	70	80
G	20	35	25	40	80	35	100	100
H	30	50	30	59	80	80	100	99
I	51	60	51	50	100	50	90	100
J	50	60	50	60	60	60	100	75
K	40	40	30	30	50	20	100	99
L	40	70	50	60	100	100	100	100
M	85	90	80	90	100	100	100	100

It is noteworthy that in many cases the ability and readiness to carry out foreign language communication show significant positive dynamics. Coupled with an increase in the frequency of using foreign-language internet resources, this can testify to the achievement of personally significant results by students, which may have an impact on their professional trajectory. The reverse dynamics in some cases testifies, in our opinion, to the correction of overestimated self-esteem: training has shown that results can be achieved only in the process of hard work with the expenditure of intellectual and time resources. Not all students are ready for this.

CONCLUSIONS

In the modern world, engineers are looking for local solutions in a globalized world, while engineering problems are solved both in their native language and in the languages of international communication, most often English. For engineers in general and for mechanical engineers, in particular, learning foreign languages is most effective if it occurs simultaneously with their professional education, the development of conceptual thinking. This makes it possible to choose the shortest, most accurate, least redundant and most effective linguistic expression of professional thought, forming what we call the language of mechanics. Hence, the study of the patterns of formation of the language of specialty in the systems of native and foreign languages will be of great importance for increasing the efficiency and effectiveness of engineering education.

Based on the foregoing, it can be concluded that the technology of content-language integrated learning contributes to the activation of the process of mastering foreign competencies based on the active integration of a foreign language with the process of teaching professionally relevant disciplines. For students who have already had an idea of the basic concepts of the subject, since it is part of the curriculum, it is easier to perceive it in a foreign language. This reduces the uncertainty in the use of foreign language resources for the delivery of content and professional opinion. To form the communicative competence of students of non-linguistic specialties and to join together the process of learning of two languages – the language of mechanics (as the language of a specialty) and a foreign language, it is important to give them the opportunity to think in a foreign language, to solve any problems that generate thoughts in a foreign language, which acts in its direct function of forming and formulating these thoughts. The application of the content-language integrated learning approach is advisable in training students in technical and engineering areas, since for them the study of a foreign language is often not a priority. "The purpose of reading for students of non-linguistic specialties is not so much linguistic material, as information contained in them" (Khalyapina, Almazova et al., 2017). That is why the use of the format of the content-language integrated learning of students of non-linguistic directions is one of the factors that increase their motivation and stimulate educational and cognitive activity.

In this way, our study proved the idea that content-language integrated learning at the systematic use contributes greatly to the main mechanism for activating the learning process of foreign language students of non-linguistic specialties of universities, because their attention is inadvertently held at an interesting, new and meaningful language material. They develop the ability to use the language of their specialty in a non-native language on the issues of their competence. This greatly increases the level of knowledge of foreign language of students at non-linguistics departments, which in turn, increases the competitiveness of the future expert in today's highly competitive job market.

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