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Research article

Convergence of Foreign Language and Engineering Education: Opportunities for Development

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Abstract

Significant changes are taking place in the modern post-industrial world both in the technological sphere and in society. These changes require a review of the professional skills of future engineers. Critical thinking, well-developed communicative skills, creative approaches for professional problem solving, ability to independently set and solve production tasks and interdisciplinary research gained significance. The article analyzes the process of forming professional skills of future engineers to meet the requirements of modern society. Based on our working experience, creativity and critical thinking are quite difficult to form within the framework of teaching/learning one or more engineering disciplines. However, it can be facilitated by a closer interaction of the humanitarian and engineering disciplines in the tertiary educational environment. A blended teaching approach of integrating a foreign language into the engineering study is proposed. The foreign language contribution to stimulating critical thinking skills and maintaining learning motivation is crucial for future engineers' training, which requires detailed consideration. The article highlights the importance of integrating the English language into a technical university curriculum based on the principle of problematization and verbalization of learning, using reflection exercises (reflection in action) and professional vocabulary acquisition. The authors present the results of professional vocabulary acquisition by students during the implementation of a pilot integrative course within one semester for international student competition training in the theory of mechanisms and machines.

Keywords: ESP; Engineering; CLIL; Cognitive Development; Critical Thinking; Motivation

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Научная статья

Иностранный язык и инженерные дисциплины в техническом вузе: Возможности для личностного роста

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Аннотация

В современном постиндустриальном мире происходят значительные изменения как в техносфере, так и в области социальных отношений. Эти изменения требуют пересмотра профессиональных навыков будущих инженерных кадров. К этим навыкам можно отнести критическое мышление, развитые коммуникативные умения, креативность подхода к решению профессиональных задач, способность самостоятельно формулировать и решать производственные задачи, проводить междисциплинарные исследования. В статье анализируется процесс формирования профессиональных навыков будущих инженеров необходимых в современном мире. Исходя из опыта работы, в рамках преподавания/изучения одной или нескольких инженерных дисциплин креативность и критическое мышление сформировать достаточно сложно. Однако этому может способствовать более тесное взаимодействие дисциплин гуманитарного цикла и инженерных дисциплин в учебном процессе. Вклад иностранного языка в стимулирование мышления и поддержания мотивации к обучению будущих инженеров является важным аспектом обучения и требует детального рассмотрения. Целью данной статьи является анализ методических приемов по интеграции иностранного языка и инженерных дисциплин направленных на стимулирование навыков критического мышления и поддержания мотивации к обучению. В статье отмечается важность построения учебного процесса по иностранному языку в техническом вузе с учетом проблемности и вербализация обучения, включения упражнений по размышлению (рефлексия в действии) и освоению профессиональной лексики. Авторы приводят результаты освоения студентами иноязычной профессиональной лексики в ходе реализации интегративного курса в рамках одного семестра по подготовке к международным студенческим соревнованиям по теории механизмов и машин.

Ключевые слова: Профессионально-ориентированное обучение иностранным языкам; Инженерные дисциплины; CLIL; Критическое мышление; Мотивация; Проблемность обучения

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INTRODUCTION

By the beginning of the 21st century, it was clear to educators that engineering students need to develop competences not only in technical matters, but also in humanistic and social concerns. “This doesn't mean that an engineering student would merely take a few extra courses in the humanities or even that he or she would need to take a double major. Rather, it means that educating the next generation of engineers must, at its core, bridge the gap inherent in the reductionist paradigm” (Kastenberg, 2007, p. 1497).

Basically, an engineering education should provide students with the competences of the following specialists:

– analyst (analysis of past ideas and experience, discovery of open problems and challenges),
– researcher (understanding of operation, performance, economics, interaction of systems),
– designer (creation of alternative and innovative solutions),
– computing engineer (simulation, estimation of systems, modeling using relevant software sets).

At the same time, the education program should encourage such qualities as social responsibility, effective communication (both oral and written, in native and foreign language), teamwork (collaborative way of professional activity) and open-mindedness (thinking outside national frame, long-life education) (Balyakin & Krylov, 2019, p. 39; Goldfarb et al., 2016, p. 3).

In recent decades, new social and technological challenges have emerged that have an impact on the economy, industry and education. The challenges such as increasing level of complexity of engineering systems, control systems based on the elements of artificial intelligence, significant human and environmental impacts of manmade disasters, communications revolution, economy globalization, ageing of population demand for a new post-industrial technology possessing three fundamental aspects: complexity, uncertainty and ambiguity. In this context, W.E. Kastenberg, G. Hauser-Kastenberg and D. Norris claim that “complex systems can have one or more of the following characteristics: holistic/emergent – the system has properties that are exhibited only by the whole and hence cannot be described in terms of its parts, chaotic – small changes in input often lead to large changes in output and/or there may be many possible outputs for a given input, and subjective – some aspects of the system may not be describable by any objective means” (Kastenberg et al., 2007, p. 1499).

The challenges mentioned above inevitably lead to a strategic reassessment of the goals of engineering education. One of the biggest questions discussed among the educators and the experts from the industry is how to ensure relevance of the skills and suitable resilience of the personalities developed by university courses to meet increasingly complex, interdependent needs of the society and industry.

Rugarsia et al. note that the volume of information that engineers are called upon to know is increasing far more rapidly than what engineering curricula can cover. One solution proposed is that the focus in engineering education must shift from the simple presentation of knowledge toward the integration of knowledge and the development of critical skills needed to make appropriate use of it (Rugarcia et al., 2020, p. 16).

There is a growing consensus among engineering educators that future engineers will need such skills as creativity and communication, critical thinking and problem-solving, as well as the ability to innovate across disciplines (Benson et al., 2010, p. 1042). Borrego & Newswander (2008) suggest that the way an individual understands and appreciates the nature of knowledge affects the way he or she collaborates with colleagues in different academic disciplines, and suggest ways of successful cross-disciplinary engineering education collaborations (p. 123). A perspective for establishing this collaboration is to provide students tools to read the world around them based on problematization and investigation. Mendes & da Silva (2018) propose "a teaching-learning process of mathematics grounded on the relationships between society, cognition, and culture, in the way of practices that exercise multiple readings of reality and give meaning to mathematical construction as learning of culture, through culture" (p. 41).

Learning a foreign language is an important aspect of a new holistic engineering curriculum. For an engineering graduate, a fluent foreign language opens the door to international databases, publications, provides independent sources of information. It helps the graduate a good deal to be incorporated into the international professional society and get better opportunities for job and carrier.

Thus, the purpose of the research is to identify whether the convergence of teaching foreign language and teaching engineering stimulate students' thinking and contribute into the inspiration for personal development.

METHOD

We consider students' cognitive development, ability to think critically, and awareness both in the subject area and foreign language as the core of holistic engineering study programs. Mina & Moore (2010) note that mental representations, perception, and attention all present great challenges in the learning process. One way to address these challenges is communicating effectively with students during the stages of cognition because self-aware students will be more likely to think critically and operate meaningfully (p. F3G-1).

Very often engineering classes focus on the repetition of examples and solutions. As a result, many students do not distinguish between definitions and concepts, and the examples designed to teach the concepts. Consequently, students memorize methods and steps of particular solutions rather than learn the underlying concepts of problems (Mina & Moore, 2010, p. F3G-2). This mode of teaching/learning is also popular in foreign language classes. A typical general English university course provides grammar and vocabulary drills, texts skimming, scanning tasks and listening comprehension activities. Implemented ESP course focuses on professional needs. In fact, in many cases it is merely a compendium of introductory information related to some basic engineering things followed by professional text reading and translation and maybe how to behave at a conference.

In both cases, these learning-by-example classes contribute very little to students' cognitive development and critical thinking. Learning a foreign language through engineering and learning engineering through a foreign language provides better opportunities.

The basic components of professional competence are knowledge and skills of applying this knowledge in the situations of theoretical analysis and practical activity. Terminology is at the core of engineering knowledge. Concepts are of utmost importance for the language of any profession, since facts, ideas, methods, models are condensed, concentrated and fused into a single unit, which then becomes something we call a concept.

Concepts often seem familiar to students while being just a facade that hides facts, ideas that elude students' consciousness. Being involved in the kaleidoscope of study subjects, overloaded with assignments, projects, and presentations, and limited in time, students try to find the easiest way to solve problems and follow teacher's samples. In order to provide students with a room for thinking, the teacher has to stop and ask them questions about even the simplest ideas, concepts that are relevant to the subject. Questioning and reasoning are in the core of the **problematization**. Students should focus on developing skills for analyzing information and basic concepts.

In particular, students have difficulty discovering the idea of a *constant* as one of the basic engineering notions. The following is a typical dialogue in a class with junior students:

Teacher (T): Time derivative of speed is zero, what about the speed?

Student (S): It does not change (speed).

T: What do you mean by it ***doesn't change****?*

S: Speed is a ***constant****.*

T: What does ***constant*** *mean?*

S: It ***doesn't change****.*

…

(after a few rounds of searching for the right word, the dialogue reaches a new level)

T: What do you mean by the speed ***doesn't change****?*

S: So it keeps ***the same value****.*

T: Which value?

S: The one that it had initially, the ***initial value****. Constant speed at any time keeps its initial value.*

The definition of the *constant speed* concept took time and involved overcoming a difficulty using analysis, comparison, and categorization. The established concept is extremely important both for a particular problem and for many engineering applications in general.

Engineering education is impossible without solving problems; here we find another possibility for problematization in the teaching/learning process if it takes place in a foreign language. Authentic foreign-language texts of problems, questions, and tasks give rise to informational insufficiency, because of two reasons. First, students' foreign-language conceptual field is often poor and does not suggest easy-to-use scaffoldings. Second, the mother tongue and foreign tongue conceptual engineering domains are often not the same; they can be expressed in different words. These reasons lead to the impossibility of using ready-made solutions, approaches, methods as generalized examples and models from experience. Students find themselves in a situation of a permanent choice: they may know elements of a solution, but need to identify them. Difficulties encourage students to compare, generalize, and synthesize, which contributes greatly in developing critical thinking skills.

The blended teaching/learning of a foreign language and engineering provides a number of opportunities for cognitive development via **verbalization**. Verbose speech patterns are not typical in the engineering communication where ideas are presented in concepts, have the form of equations expressed by numbers, diagrams, graphs and drawings. Yet the invasion of language into engineering courses unleashes a high potential of verbalization, since language exists and manifests itself through patterns of speech.

If a teaching mode tends to be very "solve this because" without necessary speculations and discussions, then new concepts are introduced as merely dull words and are memorized as words only. This disrupts the connection between the concept and what students are doing, and ends up with the students' imitating the samples without understanding.

Students will successfully acquire new information if it is presented to them in contrast to their previous knowledge, if the meaning of the information and its practical application are well understood. In many cases, mental operations of **comparison**, **generalization**, **classification**, and **categorization** are valuable for these purposes. This is particularly important for the conceptualization of notions and terms expressed in a foreign language.

Here we will consider only three possible scenarios: an exercise in reasoning, making a formula, and setting up a concept map.

Exercises in reasoning are very useful as a thought-provoking introduction to a topic. For example, *what is the difference between oscillatory motion and any periodic motion?*

Possible reasoning:

Any motion that repeats itself over and over again at regular intervals of time is called periodic motion. For example, the motion of planets around the Sun. If a body moves back and forth repeatedly about its <u>*equilibrium position*</u> *(key word), its motion is said to be oscillatory or vibratory or harmonic motion. The swinging motion of the pendulum of a wall clock is an example. So every oscillatory motion is necessarily periodic but not every periodic motion is oscillatory. For example, the Earth completes one revolution around the Sun in one year but it does not move about a mean position. Therefore, its motion is periodic but not oscillatory*.

Making appropriate formulas on the basis of verbal instructions is sometimes hard for engineering students. Students require repetitive training to develop the appropriate skills.

Example:

The first step: setting the scene, a problem question.

Angle φ for a rotating body is known to be proportional to the cube of time t. What formulas could satisfy the condition?

Students are given time for reflection and argument.

The second step: conclusions, generalization.

If we say that one quantity is proportional to another quantity, does this mean they are equal to each other?

No, $\varphi = kt^3$*, we need a factor between φ and t.*

Another example you will find with weight and mass of a body.

Setting up a concept map captures all mental operations together with the stages of making a conclusion.

For example, consider an object subject to air resistance while falling down in a vertical plane. The concept of *terminal speed* is to be introduced. As a rule, this phrase, *terminal speed*, says nothing to junior students. Necessary speculations and discussions concerning this concept can be organized around a concept map (see Fig. 1).

Cognitive development is also enhanced by the active use of foreign-language textbooks on study subjects. They often present the methods of analysis different from those used in national universities. For example, the *Willis method*, named after the American engineer, is used in Russian course of Machine and Mechanism Science to derive the gear ratio for a planetary gearbox. Most English-language international textbooks refer to it as “*formula method*” and not consider it as a basic methodology. An alternative method is used (essentially the same analysis of the relative motion of the toothed wheels) performed as an algorithmic sequence of operations that is formalized in the table, respectively, and called “*tabular method*”. It is believed that specialists do understand that *formula method*, *tabular method*, and *Willis method* are merely different names for the same reality.

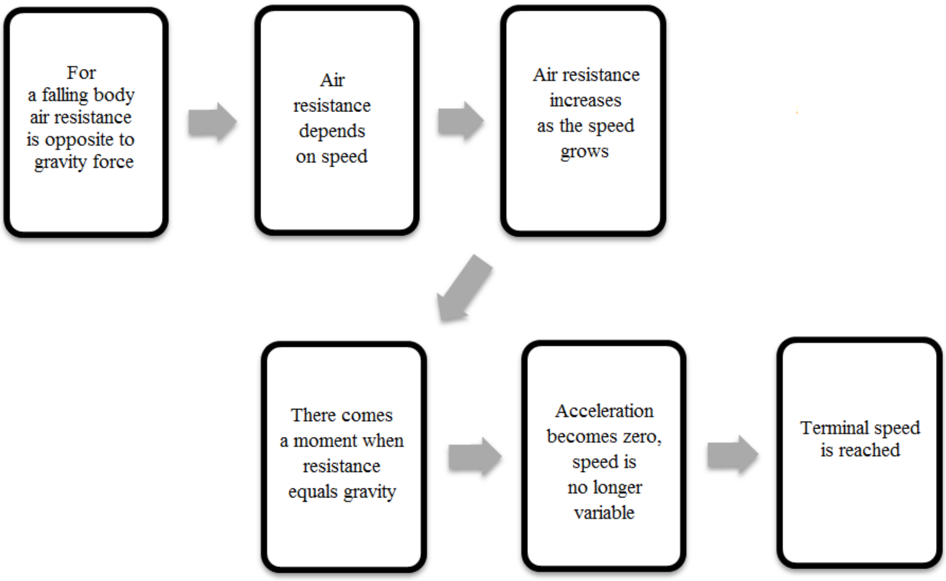

Figure 1. Concept map example

RESULTS

Content and Language Integrated Learning (CLIL) pedagogy is still far from the final stage of development in a worldwide university practice. Various projects explore different aspects of the methodology, such as achieving an optimal balance between language and subject material linking all kinds of speech activities to the thematic material, formation of professional thesaurus, motivation, and others. In a recent paper, the authors of this article discussed the conceptual problems of the language of mechanical engineering as a pedagogical phenomenon and gave an example of a CLIL-type course for undergraduate students (Krylov et al., 2021). The main goal of the two-semester course described in the paper was balanced formation of the components of foreign language and engineering professional competencies. The results of surveys and testing of students of the pilot group and the reference group indicate a significant success (p. 140–141).

However, students' critical thinking and stimulation of their creativity were beyond the project's objectives and, therefore, were not investigated. These issues are rather sophisticated, so piloting is required to reveal what the contours of future methodology should be. Students' high motivation and time limitations are seen as conditions to establish a close connection between intellectual development and the progress in engineering English. The impetus for a pilot course has come from the objective necessity of the mechanical engineering students' to participate in the international Olympiads on the theory of machines. Students under stress due to competition should be able to quickly navigate the thesaurus of the discipline, find solutions to contest problems and think critically about them. Preparation for the Olympiads is not in principle a mainstream training, so, unlike the project noted above, the number of participants of the piloting was limited.

The pilot methodology is based on the following key principles: problematization; verbalization; exercise in reasoning; scaffoldings and repetitive language patterns; setting up a concept map; the use of international textbooks.

One semester a blended course combining teaching English and teaching the elements of theory of machines was run for a pilot group of three sophomore students. In many aspects, this course is in the scope of CLIL pedagogy (Coyle, 1999, Coyle, et al., 2010, Gierlinger, 2017, Khalyapina et al., 2017). The most important aspects include: double focus on Language and Engineering; the use of foreign language as a teaching tool; Cognition, Culture, Content, and Communication as a foundation, impetus and guidance (Dalton-Puffer, 2011; del Pozo, 2016; Marsh, et al, 2005; Meyer, 2011; Pérez Cañado, 2016).

Since the course is focused on students' cognitive development, the "first C" is given special attention based on problematization, categorization, conceptualization, and verbalization. Therefore, this pedagogy is in fact merely a CLIL-like one. English scientific literacy is one of the main goals.

The essentials of the study course of theory of machines are fixed in Russian-English thesaurus, which discloses the structure of the course; provides two-language equivalents of basic concepts, notations, units, conversion factors; demonstrates typical graphical models. The thesaurus is considered as a kind of a guide helping to catch the logic of the course, understand the information, and apply it in the relevant problems.

Table 1. Understanding concepts: before study course (total 129).

Student	Correct interpretation	Incorrect Interpretation	No interpretation
A	20 (15.5%)	5 (3.9%)	104 (80.6%)
B	31 (24.0%)	1 (0.8%)	97 (75.2%)
C	28 (21.7%)	1 (0.8%)	100 (77.5%)

Table 2. Understanding concepts: after one semester course (total 129).

Student	Correct interpretation	Incorrect Interpretation	No interpretation
A	56 (43.4%)	7 (5.4%)	66 (51.2%)
B	73 (56.6%)	6 (4.6%)	50 (38.8%)
C	75 (58.1%)	19 (14.7%)	35 (27.2%)

At the initial stage of the experiment, the students’ acquisition of English concepts was under investigation. A total of 129 basic concepts were selected, and these were included in teaching modules. The students’ acquisition before and after the course are shown in Tables 1, 2.

It can be seen that the degree of acquisition of foreign-language concepts has grown sharply. Interestingly, all students have increased the percentage of misinterpretations and errors in their native language translations. This could indicate a rise of degree of self-confidence, which is essential for foreign-language communication.

The authors understand that the pilot group of only a few students does not allow definitive conclusions and recommendations. Yet, the results of this pilot course confirm the validity of the reasoning given at the beginning of the article and encourage designing the methodology of creative development within CLIL pedagogy.

CONCLUSION

Today the evolution of social life and technology calls for engineers capable of cognitive development, critical thinking and awareness, both in the subject area and in a foreign language. This is a challenge for the traditional ways of higher educational courses. Engineering education should not be reduced to some important facts and ideas shown in a "do as I do" manner. Learning from ready-made samples is not only boring, but often a waste of time.

At the same time, by the beginning of their studies at the university, students already have some linguistic knowledge and foreign language speech skills, and also have an idea of academic disciplines, engineering and technology. Integrative teaching of foreign language and engineering provides excellent opportunities for students' cognitive development. This is not just about the notorious double focus on language and engineering. Similarly, it is a double focus on experience and thoughts within the scope of native and international science expressed by means of native and foreign languages.

A teacher in an integrative CLIL-like course is expected to be able to teach students to reveal the connections between concepts, analyze information, and establish their own logical relationships within the systems of two languages.

In our opinion, problematization, categorization, conceptualization, and verbalization should be at the core of the two-language pedagogy focusing on understanding of engineering information and concepts, which also contributes to a significant improvement in foreign language proficiency.

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