Online Problem-Based Learning: Possibilities for Engineering Vocabulary Acquisition in ESP Course at Technical University

Iryna Lytovchenko, Olena Ogienko, Yelyzaveta Kriukova, Inna Meleshko, Nataliia Yamshinska, Hanna Voronina, and Neonila Kutsenok

***Abstract*—The article aims to examine the effect of the online problem-based learning (PBL) method on engineering-related vocabulary acquisition by ESP students and their satisfaction with the learning experience. The study involved 70 third-year undergraduate students at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine). They were taught with the use of traditional methods (control groups) and PBL method employing different online platforms, such as, Quizlet, LearningApps, Wordwall, and Quizizz (experimental groups). The learning outcomes were assessed using a vocabulary test and compared by means of the Fisher Criterion using online statistical software. The data about the students' attitudes towards online problem-based vocabulary learning was collected with the use of a questionnaire in Google forms application which was automatically processed and analyzed by the authors. The findings of our study showed that the students who were taught with the PBL method online had statistically higher results in vocabulary acquisition than those taught with traditional methods. Students' attitude to problem-based vocabulary learning was positive. Based on our findings we can conclude that the factor of the authenticity of the problems plays a vital role in vocabulary learning, makes it more enjoyable and meaningful for students, promotes their motivation and self-direction. The use of online vocabulary learning tools and videoconferencing technologies provides the students with a considerable degree of flexibility and autonomy and creates an opportunity to study at various locations. The online mode of instruction is appropriate for the context of distance learning, which is especially valuable during the pandemic.**

***Index Terms*—English for specific purposes, online learning, problem-based vocabulary learning, technical university.**

I. Introduction

Vocabulary knowledge is an essential tool necessary for communication between people. The use of words makes it possible for people to express their thoughts and understand others. Thus, it is natural that mastering a foreign language begins with vocabulary learning. This serves as the foundation for the development of other language skills: reading, listening, speaking, writing, and grammar. Learners cannot understand what they read or hear, neither can they speak or write if they do not understand the meaning of words. In this context, it seems highly appropriate to quote Wilkins [1] who wrote, "There is not much value in being able to produce grammatical sentences if one has not got the vocabulary that is needed to convey what one wishes to say ... While without grammar very little can be conveyed, without vocabulary nothing can be conveyed (p. 111-112)".

In view of the importance of vocabulary acquisition for the successful use of a foreign language, the choice of the teaching and learning strategies is essential. Besides the traditional approach defined by Willis and Willis [2] as "form-based" wider acceptance has been gained by the innovative problem-based approach in which students learn about a subject through the experience of searching for a meaningful solution to a problem related to the real-world context. This study proposes an effective method, which can be used in conditions of online learning during the COVID-19 pandemic. Since the epidemiological situation in Ukraine remains very serious and university lockdowns frequently resume, collecting and analyzing feedback from students makes it possible for teachers to introduce necessary improvements to entirely address students' needs.

Based on the background outlined above, we examined the effect of the online problem-based learning (PBL) method on engineering-related vocabulary acquisition by English for Specific Purposes (ESP) students and their satisfaction with the learning experience. Thus, the research questions were as follows:

1) Do the university students involved in online problem-based learning of ESP have better engineering-related vocabulary acquisition outcomes than those who are involved in traditional learning?
2) Does the PBL approach enhance ESP students' satisfaction and motivation to learn during the COVID-19 university lockdown?

II. Literature Review

A comprehensive definition of PBL was given by Woods, Hall, Eyles, and Hrymak [3] who described it as:

one of the most innovative developments in education in the past 30 years. In PBL, the problem drives the learning. Instead of lecturing, we give the students a problem to solve. For that problem, small groups of students identify what they know already and what they need to know, set learning goals, and make learning contracts with the group members (1-4). Each student learns the knowledge independently and then

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Iryna Lytovchenko, Yelyzaveta Kriukova, Inna Meleshko, Nataliia Yamshinska, Hanna Voronina, and Neonila Kutsenok are with the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine (e-mail: irinalyt@ukr.net, lizacru@ukr.net, inameleshko@ukr.net, nyamshinskaya@ukr.net, hannavoronina@ukr.net, engnila@ukr.net).

Olena Ogienko is with the A. S. Makarenko Sumy State Pedagogical University, Ukraine (e-mail: el.ogienko@gmail.com).

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returns to the group to teach others that knowledge. The group uses that knowledge to solve the problem. The group reflects and elaborates on that knowledge. In this way, students work actively and cooperatively (p. 231).

PBL is based on the integration of real-world problem-solving, employment of critical thinking, promotion of self-directed active learning [4]-[6]. In the PBL classroom, students are presented with a real-world problem and should use real-world data to solve it. The learning is accomplished through group discussions and peer collaboration. Students collectively generate objectives for their autonomous learning, explore procedures that might be appropriate for their realization, create new ideas, evaluate, and apply them in practice. The teacher serves as a facilitator, who does not provide ready-made decisions, but in turn encourages students to take responsibility for their own learning and engages them in active enquiry [7]-[10]. In language learning, PBL aligns with other methods in which students learn the language by using it – task-based learning (TBL), content-based learning (CBL) and project-based learning (PBL) [11].

In recent years, similarly to other methods, PBL has been increasingly used online. In this context, as stated by Savin-Baden [12], the teacher's role "is altered and existing skills need to be adapted and new skills adopted to support students in learning in virtual environments" (p. 17). She singles out 10 reasons for using this approach in the online environment:

1) Online PBL offers more flexibility for students.
2) This innovative approach is appropriate for the context of distance learning.
3) Teachers believe that online PBL would enrich both the pedagogical and technological experience of students.
4) Online PBL is an interdisciplinary learning approach.
5) Online facilitation could be more effective than face-to-face facilitation when student numbers are increasing.
6) Integration of diverse learning resources can be provided through this approach.
7) This method promotes and enhances collaborative learning beyond the classroom.
8) In online PBL students are provided with more support, which reduces their isolation.
9) Students have more freedom to decide what, when and how to learn.
10) Students are engaged in learning tasks through social networking tools and mobile learning (p. 17-19).

PBL was first employed in medical education in the 1960s, and in a decade expanded to other fields of learning [4], [7]. Currently, in various parts of the world, the PBL method has been successfully used in the teaching of different areas of knowledge, including medicine, chemistry, engineering, geography, etc. However, social sciences and humanities were among the last disciplines to adopt PBL due to implementation difficulties in these disciplines. Especially, it is easier to define a problem, such as diagnosing an illness in medicine, than to specify a learning problem in history or language education. Therefore, in language learning, this method was introduced only at the beginning of the 21st century, which was almost the latest of all areas of education. Consequently, studies on the use of PBL in language learning are quite scarce [7]. This gap needs to be filled given the relevance of this method for language teaching. It consists of its close relation to the real world, including the professional sphere, and the promotion of students' skills of teamwork, independent learning, communication, problem-solving, interdisciplinary learning, information-mining, higher-order thinking [13], [14].

III. Methods

To compare the effectiveness of teaching vocabulary to ESP students at technical university we chose a mixed research design that utilized quantitative and qualitative research methods. The quantitative method was used to analyze the data of students' academic achievement after the experimental learning. The qualitative method was used to interpret the students' answers to open-ended questions in the questionnaire after the experimental learning and to analyze their behavior in online group discussions based on teachers' observations.

A. Participants

The participants of the study were 70 third-year undergraduate students at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine). They studied ESP during COVID-19 lockdown and mainly had a B1+ English language proficiency level on the CEFR scale. Students voluntarily agreed to take part in the experiment and were divided into two kinds of groups: three control groups (group 1 – 11 students, group 2 – 11 students, group 3 – 12 students, a total – 34 students), who studied using traditional methods, and three experimental groups (group 1 – 12 students, group 2 – 12 students, group 3 – 12 students, total – 36 students), who studied using PBL method in online ESP classes.

B. Materials and Procedure

During the second semester of the 2020-2021 academic year both kinds of groups learned four topics within the ESP course: "Innovations in technology", "Engineering design process", "Technological systems", "Procedures and functions", and used the same learning materials. The control groups studied the vocabulary using the traditional learning activities, such as, gap-filling, matching, multiple-choice, giving definitions, word formation, etc. In the experimental groups, the students were taught with the use of the PBL method in online mode. Studying in these groups was learner centered. Students worked in small groups and performed tasks close to those they are expected to perform in real professional life. Since learning was conducted online, we used the following applications: Zoom – for video conferencing, Quizlet – for creating flashcards and learning vocabulary online, LearningApps, Wordwall, Quizizz – for creating and playing quiz-based vocabulary games.

We presented the plan (two 60 min. sessions) of the PBL lesson on the topic "Engineering design process" conducted in the experimental groups which was designed using creative ideas suggested in the MOOC created by World Learning [15] (Table I).

To check the students' knowledge of relevant vocabulary on the four topics after the experimental learning the same vocabulary test was given in the control and experimental groups. The test included multiple-choice, gap feeling, matching, word formation types of tasks and was assessed using the following grading scale: A – 95-100; B – 85-94; C – 75-84; D – 65-74; E – 60-64; F – 1-59 (which was considered as a failing grade).

TABLE I: SESSIONS 1, 2. TOPIC: ENGINEERING DESIGN PROCESS

Stage	Procedure	Inter-action
Introduction to topic	In a Zoom session, the teacher asks the students: What applications do you have on your smartphone? (The teacher writes down the students' answers and shares the screen with the students).	T-S
	Next, she asks students to brainstorm the words which can be used to talk about each of these smart phone applications, writes down these words and shares the screen again.	T-S
	Then she divides the class into groups of four using the breakout rooms setting in Zoom. She asks each student to choose one of the applications he/she has on the smartphone and describe its main features and capabilities to peers in the group.	S-S
Defining the Problem	In the same groups, students are asked to choose an application that, in their opinion, needs design modification and then to write the design specification for the updated mobile application.	S-S
Planning	Students work in the same groups and have to: - choose an application that all of them have on their smartphones and which, in their opinion, needs design modification; - make a list of the current main features and capabilities of this application; - brainstorm the features and capabilities the application needs to have.	S-S
Realization	Next, out of the classroom, each group prepares a poster presentation with the design specification for the updated mobile application, using the Thinglink application. The teacher acts as a facilitator and helps students to improve their presentations.	S-S
Report	Groups deliver their presentations in front of the whole class in Zoom. Students make comments and ask questions. The teacher provides feedback on content and form.	S-S
Analysis	Language focus: vocabulary on the topic "Engineering design process".	
	The teacher asks students to think of seven new words they learnt while working on the task and, using the Quizlet application, create vocabulary flashcards with these words.	T-S S
	Then, the teacher pairs up the students and asks them to exchange the links to the flashcards.	T-S S-S
Practice	Using the link, each student accesses their partner's set of flashcards and performs vocabulary activities of 5 types (learning, writing, spelling, testing, matching) provided by Quizlet. Finally, the students are asked to close the flashcards and write ten words they remembered from the lesson in the chatbox in Zoom. The teacher monitors the work and provides feedback.	S-S
Evaluation and reflection	The teacher makes notes of what students say and write and gives feedback at the end of the lesson.	T-S
	In the chatbox, students write down one thing they liked and one thing they did not like about the lesson.	S

In order to understand the students' attitudes to online problem-based vocabulary learning, we used a questionnaire created in Google forms application, which included three open- and closed-ended questions:

1) Did you like learning the vocabulary while solving the problem? Why / Why not?
2) Did you have any difficulties with the use of vocabulary in the problem-solving process? If so, what difficulties did you have and how did you deal with them?
3) Do you think it would be appropriate to make more emphasis on vocabulary practice and do additional exercises at the initial stages of the problem-solving tasks?

C. Data Analysis

The results of the post-test in the control and experimental groups were evaluated and compared using the Fisher [16] Criterion with the help of online statistical software (https://www.psychol-ok.ru/statistics/fisher/fisher_02.html). The data obtained through the questionnaire was processed automatically by the Google forms application and interpreted by the authors.

IV. RESULTS

As stated earlier, before the experiment, the language levels in the control and experimental groups were approximately the same – B1+ by CEFR. After the experimental learning, according to the results of the vocabulary test, both groups had higher grades (the majority of students got A, B and C grades, F being absent at all) for vocabulary acquisition (See Tables II and III).

TABLE II: RESULTS OF THE POST-TEST IN THE CONTROL GROUPS

Grades	Group 1	Group 2	Group 3
	Number of students (%)	*Number of students (%)*	*Number of students (%)*
A	1 (9.09%)	3 (27.2%)	2 (16.66%)
B	2 (18.18%)	1 (9.09%)	2 (16.66%)
C	4 (36.36%)	3 (27.27%)	3 (25.00%)
D	2 (18.18%)	3 (27.27%)	3 (25.00%)
E	2 (18.18%)	1 (9.09%)	2 (16.66%)
Total	**11 (100%)**	**11 (100%)**	**12 (100%)**

TABLE III: RESULTS OF THE POST-TEST IN THE EXPERIMENTAL GROUPS

Grades	Group 1	Group 2	Group 3
	Number of students (%)	*Number of students (%)*	*Number of students (%)*
A	3 (25.00%)	4 (33.33%)	3 (25.00%)
B	2 (16.66%)	2 (16.66%)	3 (25.00%)
C	5 (41.66%)	4 (33.33%)	4 (33.33%)
D	2 (16.66%)	1 (8.33%)	1 (8.33%)
E	0 (0.00%)	1 (8.33%)	1 (8.33%)
Total	**12 (100%)**	**12 (100%)**	**12 (100%)**

However, in the experimental groups, the test scores after

the experimental learning were higher than in the control groups. The number of students with high grades – A, B and C – in the experimental groups was higher than in the control groups (A –by 10.13%, B – by 4.74%, C – by 6.7%) (See Table IV). On the contrary, the number of students with low grades – D and E – was lower in the experimental groups than in the control groups (D – by 12.41%, E – by 9.15%).

TABLE IV: COMPARISON OF THE POST-TEST RESULTS IN THE CONTROL AND EXPERIMENTAL GROUPS

Grades	Control groups		Experimental groups		Difference
	Students	%	*Students*	%	%
A	6	17.64	10	27.77	+10.13
B	5	14.70	7	19.44	+4.74
C	10	29.41	13	36.11	+6.7
D	8	23.52	4	11.11	-12.41
E	5	14.70	2	5.55	-9.15
Total	**34**	**100**	**36**	**100**	

We considered that the students who received A, B and C, achieved the learning effect and the students who received D and E, did not achieve the learning effect. Thus, the learning effect was achieved by 21 (61.8%) students in the control groups and 30 (83.3%) students in the experimental groups. At the same time, 13 (38.2%) students in the control groups and 6 (16.7%) students of the experimental groups did not achieve the learning effect.

The Fisher Criterion was applied to define whether the difference in the vocabulary acquisition learning effect between the control and experimental groups was statistically significant.

Using Fisher's [16] method, where φ_1=83.3%, φ_2=61.8% (See Table V), we calculated φ*emp. automatically with the help of the online statistical software (https://www.psychol-ok.ru/statistics/fisher/fisher_02.html) and received 3.471.

TABLE V: LEARNING EFFECT IN VOCABULARY ACQUISITION IN THE CONTROL AND EXPERIMENTAL GROUPS

Groups	Learning effect	No learning effect	Total
	Number of students (%)	Number of students (%)	
Control groups	21 (61.8%)	13 (38.2%)	34 (100%)
Experimental groups	30 (83.3%)	6 (16.7%)	36 (100%)

The value of φ*emp.=3.471 is greater than 2.31. So, 3.471 is in the significance zone, which means that the percentage of students who showed high results in vocabulary acquisition was significantly higher in the experimental groups than in the control groups.

After the problem-based experimental learning, we analyzed the students' answers to the questionnaire. The results showed that the overwhelming majority of students (91.66%) liked learning vocabulary while working out a solution to a problem. The most common reasons were:

- they learnt the words better when they used them to solve a problem (for example, one of the students wrote that "it was easy to remember the new words during problem-solving even without learning them by heart.");
- they had a purpose – to solve the problem, which stimulated them to learn the necessary vocabulary;
- they did not have to do mechanical drilling;
- they were thinking in English and trying to find the proper words when they communicated in groups;
- they worked collaboratively (for example, one student wrote, "*When I did not know how to express something in English, I asked other students in my group to help me*.");
- they were more interested in learning (one student wrote, "*I felt like it was my real business task and I wanted to be successful.*").

Only two students answered that they remembered words better when they learnt them by heart or read them in a text.

When analyzing the students' answers to the question about the difficulties with knowledge of vocabulary and dealing with them during problem-solving, we found that the main hardship was that they did not have any ready-made speech patterns or models to use and had to deal with the language problems spontaneously. The students also wrote that quite often they could not remember all the new words and had to look them up in a dictionary or translator when they did a lot of reading to solve a problem. Also it was often difficult for them to choose a proper word or expression in English for a particular context.

In answer to the question "*Do you think it would be appropriate to make more emphasis on vocabulary practice and do additional exercises at the initial stages of the problem-solving tasks?*" only 4 (11%) students said they did not think it necessary, the rest of them finding it appropriate.

The teachers' observation of students' behavior showed that in online problem solving the students, overall, did not experience any serious barriers to communication and used the online tools with enthusiasm. However, some students were less active while communicating in online groups, i.e., their input into the discussions was considerably less substantial than that of other participants. Also, according to our observation, the online group discussions required additional time and effort on behalf of the students. Unlike face-to-face learning, they could not demonstrate their mobile phones as visual support when they presented an application on their smartphone which, in their opinion, needed design modification and showed the group a list of the current main features and capabilities of this application.

V. DISCUSSION

This study aimed to explore the possibilities of PBL for engineering vocabulary learning in online ESP instruction at university. It showed that the students who were taught with the PBL method had statistically higher results than those taught with traditional methods. In our opinion, this can be explained by the ability of this method to promote interaction between learners motivated by the necessity to find a solution to a problem during group discussions. We completely agree with authors [7], [11], [17]-[20] who argue that a powerful factor that stimulates students to actively learn and cooperate is the authenticity of the problems or tasks which students

should solve. Dealing with real-world issues makes interaction more meaningful, particularly for adult learners who are practice-oriented and willing to transfer the knowledge and skills acquired in the classroom to their real lives.

We would also argue that better learning outcomes in the experimental groups could be achieved due to the encouragement of students' autonomy which was challenging and stimulating at the same time. Students were involved in developing a solution to a problem that was new to them while they were neither given all the information which was necessary to perform the task nor instructed how to do it step by step. Thus, they were required to develop a high degree of self-direction and independence in their learning. The teachers' role in our experimental study was that of a facilitator who organized, guided, moderated, supported and assessed the students' problem-solving activity.

This research supports previous studies devoted to the use of problem-based vocabulary learning. For example, Iswandari, Prayogo and Cahyono [21] concluded that PBL had a positive effect on environment-related vocabulary acquisition by EFL students. In their study, similarly to our research, the students' achievements were statistically more significant in the PBL group than in the traditional learning group. Similar findings were also reported by Nychkalo, Jinba, Lukianova, Paziura and Muranova [22] who revealed a significant positive dynamic in the acquisition of business vocabulary by technical university students that studied ESP using PBL method. Our results are also in line with those obtained by Bicer, Boedeker, Capraro and Capraro [23] who achieved a statistically significant improvement in mathematical, scientific, and environment-related vocabulary acquisition by students in PBL. A considerable improvement in students' vocabulary recall and retention rate in PBL was noted in Shafaei and Rahim's [24] research which showed better retention of new vocabulary of higher difficulty levels. In addition to studies with a primary focus on problem-based vocabulary learning, an increase in students' lexical knowledge was also observed in PBL studies in which teaching English vocabulary was an ancillary purpose [25], [26].

Another important finding of our research is the positive attitude of the engineering students to problem-based vocabulary learning. As shown by their answers to the questionnaire, the majority of students liked learning the vocabulary while working on a problem, which had a decisive role in their motivation and engagement. They were particularly satisfied with the possibility of learning new vocabulary in the context and the process of collaboration without drilling and memorizing. However, the students experienced certain problems in PBL related to difficulties in finding proper words and expressions for communication and at times used the native Ukrainian language instead. The results of our survey also showed that it would be appropriate to make more emphasis on vocabulary practice and additional exercises at the initial stages of the problem-solving tasks. It could facilitate the students' communication and reduce or eliminate the necessity of using the native language.

There are similarities between the attitudes expressed by students in this study and those described by Azman and Shine [27] who found that PBL promotes motivation and self-confidence in university students. Chiou [28] found that hand-on and collaborative learning in the problem-based approach enhances students' motivation as well as their self-assessment and critical thinking skills. The statistically significant relationship between engineering students' motivation and PBL strategy was also fixed in the study of Silva, Mendoza and Chiquillo-Rodelo [29] who emphasized the role of contextualization in this link.

Based on our observations we may argue that the use of online learning tools, particularly videoconferencing technologies such as Zoom, which permit group discussions in breakout rooms, create a favorable PBL environment. That makes learning enjoyable, provides students with opportunities to communicate in real-time and have a considerable degree of mobility and autonomy. These results match those observed by Şendağ and Odabaşi [30] who pointed out that online learning facilitates personalized learning regardless of time and space boundaries. They also found it convenient to implement PBL practices through online learning tools since the online learning environments are flexible, interactive, and attractive for students.

However, certain problems, common for face-to-face and PBL, can only deepen when learning online. For example, in the videoconferencing mode, it is easier for students who are unwilling to work collaboratively to hide behind other, more active members of the group. Especially, when their cameras are switched off (as was in our case) and there is no eye contact which is an important factor in each discussion. The online group discussions were also more time-consuming and required more elaborative explanations from students since they could not demonstrate the applications on their mobile phones in support of their argumentations as in the case of face-to-face learning. The factor of time in PBL was also noted by Dennis [31] who compared the outcomes of problem-based learning between synchronous online groups and face-to-face tutorial groups and found that the groups which studied online spent significantly more time on learning than the groups which studied face-to-face.

VI. Conclusions

Based on the results of our study we can conclude that using the PBL approach in online ESP learning can produce a positive effect on vocabulary acquisition by students, which was evidenced by their test results. According to the data from students' survey and observation, they liked learning the vocabulary while using the language in problem-solving and employed all the online tools with enthusiasm. This gives us ground to believe that the factor of the authenticity of the problems plays a vital role in vocabulary learning, makes it more enjoyable and meaningful for students, promotes their motivation and self-direction. The use of online vocabulary learning tools and videoconferencing technologies provides the students with a considerable degree of flexibility and autonomy and creates an opportunity to study at various locations. The online mode of instruction is appropriate for the context of distance learning, which is especially valuable

during the pandemic.

Although the current study is based on a relatively small sample of participants and its findings do not allow for generalizations on a broader scale of ESP learning at universities and colleges in Ukraine, we assume that this research will provide some insights into the possibilities of using PBL in online mode for ESP vocabulary learning at university.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Iryna Lytovchenko conducted the research and wrote the Methods section; Olena Ogienko wrote the Introduction and Literature Review sections; Yelyzaveta Kriukova conducted the research and wrote the Results section; Inna Meleshko conducted the research and wrote the Discussion and Conclusions sections; Nataliia Yamshinska conducted the research and analyzed the data; Hanna Voronina conducted the research; Neonila Kutsenok conducted the research; all authors had approved the final version.

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Iryna Lytovchenko received the doctor of science in education degree from Ivan Ziaziun Institute of Pedagogical and Adult Education of the National Academy of Educational Sciences of Ukraine (Kyiv, Ukraine) in 2018 and the Ph.D. degree in 2012. She is a professor in the Department of English for Specific Purposes №2 of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine). The main fields of her professional interests are ESP teaching, use of educational technologies, comparative education, andragogy, adult education, and corporate education. She is the author and co-author of scholarly publications published in Ukrainian and English. She is an editorial board member, editor and reviewer of international scientific journals; a member of the International Society for Comparative Adult Education, TESOL Ukraine (Teachers of English to Speakers of Other Languages), UERA (Ukrainian Educational Research Association).

Olena Ogienko received the doctor of science in education degree from Ivan Ziaziun Institute of Pedagogical and Adult Education of the National Academy of Educational Sciences of Ukraine (Kyiv, Ukraine) in 2009 and the Ph.D. degree in 1994. She is a professor in the Department of Pedagogy at A. S. Makarenko Sumy State Pedagogical University (Sumy, Ukraine). Additionally, she is a principal research Scientist of the Foreign Pedagogical Systems and Adult Education Department at Ivan Ziaziun Institute of Pedagogical and Adult Education of the National Academy of Educational Sciences of Ukraine (Kyiv, Ukraine) and a scientific supervisor of Doctoral Researches in Education. The main fields of her professional interests are comparative education, global and European studies, educational technologies, andragogy, and adult education. She is the author and co-author of more than 100 scholarly publications published in Ukrainian, English, Russian and Polish. She is an editorial board member of a number of scientific journals and a member International Society for Comparative Adult Education, Ukrainian Adult Education Association.

Yelyzaveta Kriukova received her Ph.D. degree in pedagogical sciences from the Institute of Higher Education of the National Academy of Pedagogical Sciences of Ukraine in 2015. She is currently working as an associate professor at the Department of English for Specific Purposes №2 of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine). The areas of her scientific interests are gamification of education and the use of digital tools for teaching ESP. She is a member of TESOL-Ukraine.

Inna Meleshko obtained her master's degree in teaching English and German languages from Bohdan Khmelnytsky National University of Cherkasy, Ukraine, in 1992. She has more than 20 years of teaching experience including the design of language courses for undergraduate and graduate students. Currently, she is a senior teacher at the Department of English for Specific Purposes №2 of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine). Her research interests include innovative tools for ESP teaching and techniques for classroom interaction aimed to motivate students to master foreign language skills. Her research results in problems of innovative tools for ESP teaching are presented at national and international conferences.

Nataliia Yamshinska obtained her master's degree in teaching English and foreign literature from Kyiv National Linguistic University, Ukraine, in 2005. Since 2010, she has been an English teacher at the Department of English for Specific Purposes №2 of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Her current research interests include assessment tools and techniques for classroom interaction aimed to help ESL students overcome the language barrier. She has published scientific articles and taken part in scientific conferences in the area of her professional interests.

Hanna Voronina received her PhD in pedagogy from the Institute of Problems of Education of the National Academy of Educational Sciences of Ukraine in 2019. She has more than 20 years of teaching experience including the design of language courses for undergraduate and graduate students and the development of e-courses for distance language learning. Her research results on problems of education are regularly presented at national and international conferences. Currently, she works as a senior teacher at the Department of English for Specific Purposes №2 of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" Her research interests include innovative tools for ESP teaching and building students' foreign language skills by means of technologies.

Neonila Kutsenok is a teacher in the Department of English for Specific Purposes №2 of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine). She got her master's degree from Borys Hrinchenko Kyiv University (Kyiv, Ukraine) in 2002. Her research interests include blended learning, curricula design, and language teaching methodology.