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Implementing project-based learning for students of engineering specialties in the context of the pandemic

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Abstract

The paper is devoted to the problem of students' projects in the context of distance learning in a higher education institution. When educating bachelors of engineering and technical specialties, an important role in competence development is given to the possibility for students to apply theoretical knowledge while performing project tasks in a team with the use of laboratory equipment. Introduced due to the global pandemic COVID-19, the distance learning format has significantly complicated the implementation of educational programs, making it impossible for students to attend the university campus and class laboratories in person. The article discusses the concept of project-based learning for engineering specialties and the approaches of the leading

technical universities to its implementation in the educational process. It also makes an attempt to describe the ways of teachers abroad implement student projects in the context of global lockdown and carries out an analyzsis of the advantages and disadvantages of the considered approaches. Having considered project-based learning in the context of the pandemic, the authors of the article present the experience of project-based learning implementation at Tomsk Polytechnic University and its adaptation to the context of the COVID-19 pandemic, using the discipline "Open-ended Project" for students majoring in physics as an example.

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Keywords

Project-based learning, distance learning, engineer, COVID-19, pandemic.

Introduction

The shift to distance learning during the COVID-19 pandemic was a challenge for teachers and students at universities. Today, students in a number of countries find it difficult to attend classes as usual because of the importance of maintaining social distance. Face-to-face classes have been replaced by online and hybrid learning formats. This has become a necessity that gives students a sense of safety. In the shortest possible time, universities were forced to arrange their work so that it would not affect the educational process. This was realized through online, video courses, various messengers and other units of e-learning. Fortunately, modern technology makes it possible to continue the educational process under quarantine.

Nevertheless, providing classes by distance learning is a significant professional challenge. With the implementation of the distance learning format, it becomes impossible to teach the material in the ways previously used. According to the International Association of Universities report on the impact of COVID-19 on higher education [Marinoni, Van't Land, Jensen, www], the greatest difficulties were found for disciplines based on access to laboratories and equipment.

Project-Based Learning (PBL) is considered a promising approach to improve student learning in higher education. Universities today focus on developing student both hard skills, namely cognitive knowledge and professional skills, and soft skills, such as problem solving and teamwork [Coşkun, Kayıkcı, Gençay, 2019, www; Guo et al., 2020, www]. Quarantine regime makes it difficult to implement PBL and impacts the quality of education and training.

The purpose of this paper was to study the possibility of PBL implementation and improving in the COVID-19 pandemic conditions on the premises of Tomsk Polytechnic University (TPU), taking into account TPU's own experience and international developments.

The Project-Based Learning concept

All over the world, the industry is interested in graduates of engineering educational programs who are ready to start working immediately. Moreover, there is a demand for non-technical skills development beyond the core curriculum. With industry influence, universities are accelerating the

adoption of programs or courses to develop cross-industry career-relevant skills. Public speaking, writing skills, and industry career preparation courses are now offered at leading engineering educational institutions.

In this way, formats of educational activities that integrate the mastery of professional and interdisciplinary competencies are becoming increasingly relevant. Project-based learning is a pedagogical approach that provides students with an opportunity to apply their knowledge in practice by solving real-world problems. More and more engineering projects are being implemented in the world`s leading universities to acquire the skills of applying fundamental disciplines knowledge to practical engineering. In addition, this format of learning activities allows students to develop the oral and written communication skills, defend their ideas and embody them in real projects, develop skills of interaction, teamwork [Coşkun, Kayıkcı, Gençay, 2019, www; Lider, Slesarenko, Solov'ev, 2021]. Thus, from the first days of learning, plunging into the implementation of projects, students acquire the basics of professional and interdisciplinary professionally relevant competencies, as well as skills that will be more deeply acquired in subsequent academic disciplines.

According to the research [Orr et al., 2011, www], students are most willing to perceive information and solve urgent problems if they apply knowledge in a realistic context. As a result, by the end of their course, they have acquired a set of skills and experiences necessary to solve real industrial problems and are capable of making independent decisions, including collaborating with others. These acquired skills and experience are included in the graduate's professional profile as interdisciplinary professionally relevant competencies.

Today, the curricula of technical universities maintain a balance between practical classes and traditional lecture learning. Practical programs are complemented by educational technologies that allow students to apply lecture materials to solve real-world problems from the first year of study (experience of Hong Kong, Singapore, Russell Group UK, MIT, Arizona State universities, KIT, etc.) [Lider, Slesarenko, Solov'ev, 2021]. Students get access to modern research equipment to prove their ideas in practice [Orr et al., 2011, www].

The educational activities concept of the Massachusetts Institute of Technology implies the formation of a knowledge culture among students through participation (learning by doing) [Bruce, Bloch, 2012]. The focus of educational activities is on interdisciplinary programs where students work on projects of social importance to society.

As part of the policy of implementing educational activities, Hong Kong Polytechnic University (PolyU) has formulated and implemented the following principles:

– educational activities are focused on achieving real result (outcome-based learning [Chan, Chan, 2009]);
– the programs of all-round improvement of students contribute to the provision of high-quality education.

PolyU offers students a variety of forms of entrepreneurship implementation. The main principle of this approach is the development of entrepreneurial skills outside the classroom ("out-of-class" entrepreneurship).

Lancaster University formulated the following objectives:

– the development of research-based educational activities (research-stimulated learning);
– the development of a flexible educational environment through the use of distance and open learning technologies;
– the importance of the role of graduates as civic leaders, the development of relationships with industry and employers [Lancaster University…, www].

In October 2011, TPU joined the Global CDIO Initiative (Conceive – Design – Implement – Operate). This is an international project aimed at eliminating the contradictions between theory and practice in engineering education. The approach involves enhancement of the practical part of education, as well as introduction of the system of problem-based and project-based learning [Plotnikova, Red'ko, Yanushevskaya, 2015]. The philosophy of educational programs for complex engineering activities, requirements for the curriculum formation and educational environment, teaching methods, and methods of student learning outcomes assessing and the program as a whole are determined by 12 CDIO standards. Standard 5 provides for two or more projects in the curriculum aimed at obtaining practical experience by project activities (one for basic level, the other for advanced). For ten years, TPU has been implementing the "Creative Project (Open-ended Project)" discipline for the first- and second-year bachelor students, who get experience via project activities starting at the basic level.

The learning strategy during the COVID-19 pandemic

A lot of studies on e-learning focus on valuable tools for the implementation of disciplines.

The study of international experience in the transition to a distance learning format demonstrates the formation of several modes of educational activity:

– asynchronous (students studied materials that teachers posted on university`s e-learning system);
– synchronous (simultaneous participation of students and teacher in the lesson in a webinar format);
– mixed (combination of synchronous and asynchronous) [Lapitan et al., 2021].

As an example of the mixed concept is presented in [Ibidem], describing the experience of the University of Santo Tomas`s transition to a distance learning format in the chemical engineering program during a pandemic. It is a five-part learning strategy called Discover, Learn, Practice, Collaborate and Assess (DLPCA). In the DLPCA, the asynchronous part of the learning was achieved by broadcasting pre-recorded video-lectures on YouTube. The synchronous part of the learning was conducted using video conferencing platforms such as Zoom or Google Meet.

The authors of the publication [Noviyanti, Paristiowati, Moersilah, 2021] demonstrate the experience of applying PBL in the distance education format by the example of the developing a device which measures surface tension. The stages of PBL online learning in this study are:

– planning and defining the idea of creating simple surface tension measurement tools;
– developing tools from improvised items;
– reporting progress on tools formation through Google Classroom, and teacher provides feedback;
– implementing tools through experimentation developed by the students;
– recording videos of tool formation and realization and submitting videos through Google Classroom;
– teacher and groupmates evaluate the project.

The results showed that students could create simple surface tension measurement tools and implement experiments using these tools at home.

More sophisticated idea was described by authors from the University of Madrid [Larriba et al., 2021]. Four laboratory experiments were designed to be conducted by students studying thermal engineering during COVID-19 self-isolation at home. A mixed learning model methodology was used to obtain experimental data and write the laboratory report. To study heat transfer using conductive and convective heat exchangers, thermal engineering units were designed and 3D printed. Samples of

laboratory equipment were delivered for students to their homes. The low cost and reliability of the results obtained demonstrated the validity of this approach.

Laboratory classes, during the lock-in period, at most universities were also implemented using LMS-based simulators. In the absence of simulators, students were engaged in processing data retained from previous semesters. Obviously, the disadvantages of the described approaches could be highlighted, they are inability to develop students' skills with laboratory equipment, and in the case of simulators – ideal conditions for experiments with random variables, without regard to errors. Also, there should be noted the difficulties of developing the teamwork skill – practical implementation of the tasks was performed by students individually.

TPU uses in the educational process:

– learning interaction systems (LMS Moodle e-learning system, Big Blue Button, ZoomUs, Webex videoconferencing systems; virtual laboratory complexes and simulators);
– tools for providing asynchronous and synchronous feedback and assessment (forums, other elements of electronic courses of the LMS Moodle platform, allowing for assessment, mutual assessment, feedback between students, students and teachers, to implement the questionnaire option built into the personal account of TPU employees and students; videoconferencing);
– systems and tools for organizing assessment activities;
– systems for making organizational decisions, planning the educational process (electronic schedule with built-in notification options about the format of the classes and the videoconference system used; online department journals, records; organization of assessment activities taking into account the time zones in which students are located);
– tools for data storage (cloud storage OwnCloud – an analogue of Google disk, working on TPU facilities).

Project-based learning at the Department of experimental physics of TPU

As part of the program 03.03.02 Physics in the 2019-2020 academic year, the discipline "Creative Project (Open-ended Project)" was realized on the premises of the Department of experimental physics. It was supposed that during two semesters students of the first year would be asked to design a model of a car on a hydrogen battery and using 3D-printing.

During the first online classes, teacher prepared reference materials for self-study and provided an explanation of the main stages of the work. The first stage was to design the body and electronic part of the car. After studying theoretical materials students in subgroups of three to four people identified the main tasks - creating drawings of body parts for further printing, determining the electronic elements of the car. Designing was done by students in AutoCAD, KOMPAS, Inventor software environment.

Supervision was conducted via weekly consultations on the projects using Zoom. Assessment of the work done was based on written scientific reports prepared by each of the subgroups. Further stages of work (3D printing, assembly of the body, electronics, and fuel cell) were implemented in TPU laboratories after the end of the lockdown and moved to the hybrid learning format.

Thus, project-based learning at TPU during COVID-19 pandemic was implemented in a mixed concept. The tools of learning interaction systems and assessment (Webex, e-courses on LMS Moodle platform, forum) were used. Drawing was done in the licensed software through setting up remote access to the student's account.

Conclusion

As becoming evident, it was impossible for TPU students to complete a practical project avoiding personal attendance of the laboratory. The development of graphic editors and simulators could solve this problem. However, the skill of working with graphic editors does not cancel the necessity of obtaining skills in working with electronics, materials, and equipment. It should also be noted that it is problematic for the teacher to assess the teamwork skills and personal contribution of each student to the project.

In our reality, the realization of project-based learning in a global pandemic situation requires additional development of IT technologies and material and microelectronic solutions. Distance learning may take the form of a literature review, basic research, project documentation, or modeling.

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Реализация проектного обучения студентов инженерно-технических специальностей в условиях пандемии

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Аннотация

При подготовке бакалавров инженерно-технических специальностей важную роль в развитии компетенций играет возможность применения студентами теоретических знаний при выполнении в команде реальных проектных заданий с использованием лабораторного оборудования. Введенный из-за глобальной пандемии COVID-19 режим дистанционного обучения существенно усложнил реализацию образовательных программ, делая невозможным личное присутствие студентов на территории кампуса и в учебных лабораториях. В статье рассмотрены концепция проектного обучения и подходы к его реализации в образовательных процессах ведущих технических вузов мира. Приводится опыт реализации студенческих проектов в условиях дистанционного обучения.

Проанализированы преимущества и недостатки рассмотренных подходов. Описаны опыт проектного обучения студентов-физиков в Томском политехническом университете и его адаптация к условиям пандемии на примере дисциплины «Творческий проект».

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Проектное обучение, дистанционные образовательные технологии, инженер, COVID-19, пандемия.

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