Collaborative projects for engineering students

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Abstract. This paper presents the ongoing experience related to the implementation of collaborative projects for Ukrainian engineering students. Engineering students realize these projects during the preparation of bachelor's thesis. Collaborative projects include the students' teamwork on the development of technical equipment and related software for data acquisition systems. In the article, the learning outcomes the engineering students were expected to acquire are considered. The description of the example of students' collaborative project is presented.

Keywords: *engineering education, teamwork, project-based learning.*

Introduction. Many publications of last years, which relates to the issues of modernization of engineering education, point to the importance of the development of skills of collaborative work of engineering students. It should be noted that despite of the diversity of educational ideas and approaches, which are actively used at the modern universities, there is the common point of view concerning the significant role of competences related to work in the multidisciplinary teams and project management [1]. In our opinion, the changing of the essence of modern engineering activity causes the increasing of the role of the competences mentioned above. Analysing the demands, which the engineering education meets during last years, Heitmann [2] points to "additional social demands regarding engineering education range from environmental and sustainability issues to the request for contributions to regional economic developments and to entrepreneurship education and also ethical dimensions". Implementation of mentioned requirements is impossible without the preparation of future engineers to the collaboration with experts from different branches of engineering and science. Now, the lot of universities treat the collaborative students' projects, in particular, during the preparation of bachelor's thesis, as one of the most effective way of such goal achievement [3], [4], [5], [6].

The main purpose of this article is the review of the methodological and organization aspects related to the implementation of collaborative students' projects. The ways of the choosing and assessment of learning objectives are discussed. In addition, the ongoing experience related to implementation of collaborative projects of engineering students at Bohdan Khmelnytsky National University of Cherkasy is presented.

Literature review. Modernization of engineering educational programs is the complex task, which requires of the taking into account the modern demands to engineering professional activity as well as using of the innovation pedagogical approaches. Now, Ukrainian system of higher education is in the state of transformation in order to approach our system of education to the requirements of Bologna process, whose goals are following [2]:

- facilitate mobility of students and staff and professional mobility of graduates;
- promote internationalization and global competitiveness;
- raise quality and contribute to economic development and growth;
- enhance the European Integration.

In order to achieve the mentioned goals as well as standards and recommendations of the European Higher Educational Area (EHEA) concerning the adapting of curricula in terms of content, structure, learning objectives, pedagogical approaches and methods of assessments the Tuning (EC-financed project "Tuning Educational Structures in Europe") was initiated [7], [8].

The Tuning approach is aimed to the development of the methodology of design or redesign study programmes for each of the Bologna cycles. Tuning was successfully tested on several continents, and now it is considered legitimate internationally. Furthermore, Tuning is used as a tool for developing reference points within different subject areas. Concerning the engineering education Tuning-AHELO (Assessment of Higher Education Learning Outcomes) project called "Conceptual framework of expected/desired learning outcomes in engineering" is worthy of notice [9]. Following the Tuning approach the group of experts defined the list of general learning outcomes, which are valid for all engineering programmes. Learning outcomes are statements of what a learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning. According to Tuning, learning outcomes are expressed in terms of the level of competence to be obtained by the learner. Competencies represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values [7], [9].

It should be noted that there are many lists of needed skills, which were proposed by international boards and organizations. Among them, EC2000 criteria, which was prepared by Engineering Accreditation Commission of Accreditation Board for engineering and Technology (ABET, USA) [10], UK standard for professional engineering competence by Engineering Council (UK) [11], EUR-ACE Framework Standards and Guidelines by European Network for Engineering Accreditation [12]. All analysed lists include the communication skills, ability to function effectively on multidisciplinary teams, projects management as obligatory elements of modern engineer training.

One of the way to encourage students to learning and, respectively, to the development of subject-specific and general competences is the using of active learning methods such as problem-based learning and project-based learning (for both of approaches the abbreviation PBL is used) [13]. As mentioned in [14] both approaches are student centred and share the common learning principles. Learning is organized around problems and projects is

used as way to organize the students' activity. Barrows [15] defines the concept of PBL through six core characteristics, which are following:

1. Learning is student-centred.
2. Learning occurs in small student groups.
3. Teachers acts as a facilitators or guides.
4. Problems form the organizing focus for learning.
5. Problems are used in order to develop the problem-solving skills.
6. Self-directed learning is necessary element for acquisition of new information.

With taking into account the hierarchical nature of engineering curriculum, which means the existing of some demands to basic prerequisite knowledge (for example, in mathematics and physics), seems reasonable to use the hybrid PBL approach [14]. Such approach allows to combine the traditional disciplinary approach with students' projects. Also, it's a way of the introducing the collaborative projects of engineering students during the preparation of bachelor's thesis.

Methodology. Preparation of bachelor's thesis is the compulsory part of engineering curriculum for the specialty 151 Automation and Computer Integrated Technologies at Bohdan Khmelnytsky National University of Cherkasy. Writing of bachelor's thesis continues during the fourth year of study (7 and 8 semesters). Collaborative students' projects were organized as the element of hybrid PBL, because our students combined the traditional lessons with the design of projects.

Typically, each member of the Department of Automation and Computer-Integrated Technologies fulfils the duties of the scientific advisor of three or four students, which allows to unite these students into unite team. In the future, students work together concentrating on the solution of mutual engineering problem. In some cases, the team that includes larger number of students can be organized under the mutual guidance of two or three teachers, which are experts in the different engineering branches. The role of teacher is changing from supervisor to the facilitator that are responsible for the organization of the learning process with taking into account the peculiarities of each team.

Choosing of learning objectives is the important element of the design of the requirements to collaborative students' project. In case of our projects, we chose and adapted the list of learning objectives described in the report of Tuning-AHELO project [16]. It was made for several reasons. At first, it corresponds to the general tendencies of the modernization of Ukrainian system of higher education with taking into account the recommendations of Bologna process. In addition, Tuning-AHELO project is the part of complex approach, which includes not only the list of learning objectives (competences) but also the set of practical recommendation concerning the curriculum design.

Table 1 provides the list of learning objectives adapted from [9] and divided in few categories. Some of learning objectives are considered as prerequisites (skills and competencies acquired during previous years of study). It is expected that these acquired skills and competences will be improved to higher levels of proficiency.

Table 1. Learning objectives and proficiency levels

Category	Learning objective	Type	Expected proficiency level
Basic and Engineering Sciences	The ability to demonstrate comprehensive knowledge and understanding of the scientific and mathematical principles and key aspects of physics (thermodynamics, fluid mechanics etc.), higher mathematics, automation (programming, metrology, theory of measurements, microprocessor based systems etc.)	Prerequisite	Expert
Engineering Analysis	The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods as well as to analyse the engineering products, processes and methods	Prerequisite/ Being developed	Advanced
	The ability to conduct searches of literature, and to use data bases and other sources of information		
Engineering Design	The ability to apply their knowledge and understanding to the development of designs of data acquisition systems to meet defined and specified requirements	Being developed	Advanced
	The ability to demonstrate an understanding of design methodologies and to use these methodologies		
Engineering practice	The ability to select and use appropriate equipment, tools and methods and demonstrate understanding of applicable techniques and methods and their limitations	Prerequisite/ Being developed	Intermediate
	The ability to combine theory and practice to solve engineering problems		
	The ability to demonstrate understanding of the non-technical implications of engineering practice The ability to demonstrate understanding of the health, safety and legal issues and responsibilities of engineering practice; impact of engineering solutions	Being developed	Basic
	The ability to demonstrate knowledge of project management		
General skills	The ability to function effectively as an individual and as a member of a team	Being developed	Basic
	The ability to use diverse methods to communicate effectively with the engineering community		
	The ability to recognize the need for and engage in independent life-long learning		
	The ability to demonstrate awareness of the wider multidisciplinary context of engineering		

It should be noted that such list of learning objectives must be revised every academic year before the collaborative projects start. It means that the actual level of students preparation must be taken into account in order to choose the appropriate level of expected level of proficiency.

Assessment of achieved project objectives included the evaluation of students' logbooks, mid-term reports, final reports, oral presentations (see Table 2). The special attention of teachers, who acts as guides for students' teams, was paid to the issue how students work in teams. The regular meeting with students' teams as well as students' logbooks checking were among the duties of scientific advisors.

Description of students' projects. The idea of collaborative students' projects was connected with the following real-world problem: How to build the data acquisition system? Defining such task for the students, we take into account the budget limitation, which unfortunately is typical for the Ukrainian universities. In addition, it was pointed to the fact that created by senior students DAQ systems will also be used as laboratory equipment by other students during laboratory works from physics, microelectronics etc. These systems can be designed with using different technical equipment and software. Therefore, students meet the open-ended problems with different ways of solution.

Table 2. Structure of the assessment

Type of activity	Percentage of scores
Process	**35%**
Log book and activity	20%
Mid-term report	15%
Results	**40%**
Peer review of final report	30%
Text style and structure of bachelor's thesis	10%
Presentation	**25%**
Oral presentation	15%
Answers for questions	10%

The students' PBL activity include the design of DAQ system, which consists of the sensor, programmable microcontroller board, and driver and application software. In 2015-2017 academic years, the main accent was made on the possibility to manage the process of data acquisition as well as data processing by using the well-known engineering software – LabVIEW [17]. Virtual instruments developed with the using of LabVIEW are widely used as part of educational process during the lectures and laboratory works. Fig. 1 shows the schematic representation of designed DAQ system.

Fig. 1. Schematic representation of DAQ system

Since 2015 few different DAQ systems were design. Among them the DAQ system for temperature and humidity measurement in which the DHT11 Digital Temperature Humidity Sensor was used. The designed system also contains Arduino, which is the popular and low-cost programmable microcontroller board. Arduino has a USB interface and can be used for reading acquired data. In order to connect Arduino and LabVIEW, students used the LabVIEW Interface for Arduino, which is the API based on the conception of virtual instruments. After installation of this package, the additional elements of LabVIEW Functions and Controls Pallets will become available. These elements can be used in order to design of required virtual instruments. The Arduino based examples of virtual instruments are also added to LabVIEW library. In addition, the special sketch for Arduino (LIFA_BASE) must be downloaded to the Arduino Uno to allow you to interface with LabVIEW.

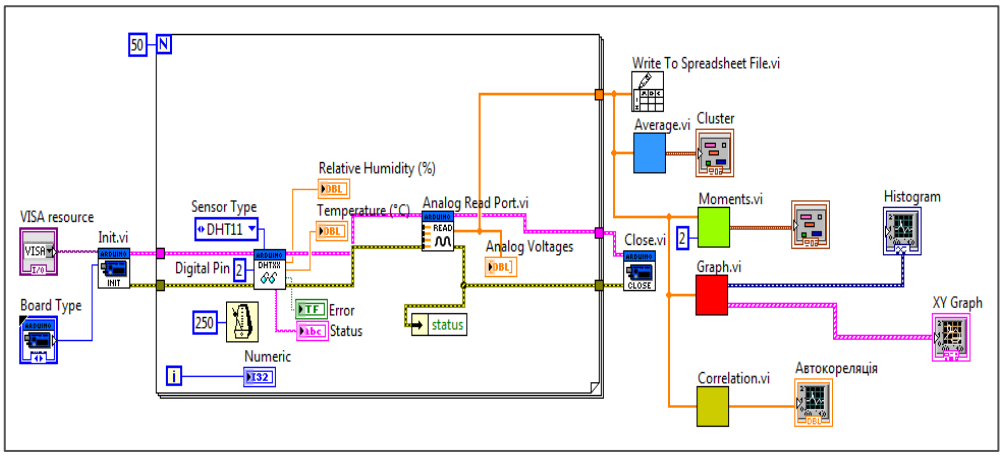

Fig. 1. Example of LabVIEW block-diagram of DAQ system

Fig. 2. Example of LabVIEW front panel of DAQ system

Fig. 1 and Fig. 2 shows the examples of the LabVIEW program, which was written by students to manage the data acquisition system and process the acquired data.

Conclusions. The paper presents the design of students' collaborative projects, which are realized by engineering students during the bachelors' thesis preparation. The described collaborative projects were developed by using the PBL methodology. The paper also focuses on the importance of the development of collaboration skills and competences for engineering students. It was found, that applying of PBL have a positive impact on the achievement of general competences as well as positive students' perception of engineering design.

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Совместные проекты для студентов инженерных специальностей

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Аннотация. В статье представлены результаты поточного опыта по внедрению совместных проектов для украинских студентов инженерных специальностей. Такие проекты были реализованы в рамках подготовки студентами выпускных работ на образовательном уровне "бакалавр". Совместные проекты включали работу студентов в командах над созданием технического оснащения и соответственного программного обеспечения для систем сбора данных. В статье представлены программные результаты обучения, используемые при подготовке методических материалов к проектам.

Ключевые слова: *инженерное образование, работа в команде, проблемно ориентированное обучение.*