

## Realization of Project-Based Learning Approach in Engineering Education

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**Abstract:** The paper presents the experience accumulated by National Research Tomsk Polytechnic University and Tomsk State University of Control Systems and Radioelectronics in the area of project-oriented training of engineering specialists, exemplified by TPU Elite Engineering Education Program and TUSUR Project-Based Group Learning. The importance of the experience is justified by the current lack of programs in this area to be available and ready for implementation. Program objectives, their history and relation to traditional learning, as well as expected results, main stages and implementation principles are described.

**Key words:** Project-oriented training • Engineering specialist training • Project-based learning

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### INTRODUCTION

Project-oriented method is widely known and used in the world practical pedagogy. First it was described in 1918 by American psychologist and a teacher William Kilpatrick in his book "The Project Method" [1]. Modern Russian researchers V.V. Guzeev, M.V. Klarin, O.C. Kruglova, D.G. Levites, E.C. Polat, I.D. Chechel realize the project-oriented learning on the absolutely new level: as a holistic training technology, contributing to students' methodological knowledge and skills acquisition necessary for further self-education; and as an effective training system, supporting students to start productive activity just after university graduation. Validity of this thesis is confirmed by introducing of project-oriented learning into new Federal State Educational Standards that regulate the system of higher education in Russia. But the number of project-oriented learning models available and ready for replication and implementation is small enough. The most frequent project-oriented learning models are worked out for separate subjects [2] but they are not suitable enough for system implementation at the university.

The research conducted includes the description and a analyses of two independently developed project-oriented learning models: TPU Elite Engineering

Education Program (EEEP) and TUSUR Project-Based Group Learning (PBGL). They both are unique and have been implemented into university educational curriculum and are still being improved but have particular advantages and disadvantages. As a result of research the generalized group project-oriented model is offered.

### Main Part

**Tpu Project-Oriented Training of Elite Technical Specialists:** The model of project-oriented training of TPU students (POT ETE TPU) is presented on the example of Elite Technical Education program (ETE) having been realized at TPU since 2004. The program of ETE is one of the educational trajectories for students and is a part of the Core Educational Program. After competitive selection the first-year students of engineering faculties with high level of knowledge and motivation enter the ETE program [3]. Thus the model of POT ETE TPU is being tested within bachelor and specialist degree programs.

The model of POT ETE TPU includes 3 stages: introduction, development and results presentation. The planned results of training are presented as the main results: *teamwork and professional competencies*; and interdisciplinary ones: *communication, leadership, creative and system thinking, entrepreneurial and business aspect*.

The main objective of POT ETE is to train students to get ready for engineering activity from the very basic to advanced level of design.

**The Tasks of POT ETE Are the Followings:**

- The integration of training results on independent subjects/modules.
- Basic and complex knowledge acquisition necessary to solve engineering tasks.
- The formation of active position and the ability to work in project designing teams.
- The arrangement of conditions for technical ideas generating and taking the initiative [4, 5].

Project activity in accordance with ETE program involves three successive stages. They are ‘Introduction’ (basic theoretical educational stage), ‘Project development’ (advanced practical educational stage) and ‘Results presentation stage’.

**First Stage (Introduction).**

**‘Teambuilding’ Training Complex (Semester 1):**

- Introduction into teamwork peculiarities;
- Teamwork organization training;
- Personal role determination in a team;
- System analyses of making team decisions [6].

**The Subject ‘Introduction in Project Activity’ (Semester 2):**

- Knowledge acquisition of the project activity background; acquisition of skills for proficient coordination of team members, equipment, materials and finance as well as project scheduling in order to develop a project in a fixed timeframe and within a fixed budget satisfying customer needs;
- Acquisition of project management and realization skills with the use of modern software;
- Development of goal setting, information structuring and goal achievement skills; resources searching for project realization and paper work.

During the lesson students use different interactive forms and techniques to get involved into project developing process. As a result of training students are organized in teams of 3-7 people to develop the own project and to present its results at the ETE conference.

After that students start searching for partners to realize developed project. Financial backing for a project can be sponsored by partners, lending agencies (banking institutions) and interested customers. To find a sponsor the project can be presented at the ETE Project Fair [7].

**Second Stage (Project Development).**

**The Subject ‘Introduction in Inventive Activity’ (Semester 3):**

- Involving of students into research-creative process; activation and stimulation of their creative and inventive activities; development of solving inventive tasks abilities;
- Knowledge acquisition of engineering activity background supported by availability of multifunctional equipment access; development of intellectual tasks setting and solving skills;
- Development of competencies to plan and implement obtained results;
- Preparation for interdisciplinary experimental-research activity in order to solve tasks connected with the development of effective and innovative methods of equipment installation and use;
- Gap elimination between acquired theoretical knowledge and its practical application.

Students are organized into teams of 3-4 people. Each team carries out a project that has to be presented on the last conference-week. The defense of the project includes the presentation and demonstration of how the project works. During the presentation, the team has to illustrate and validate project decisions.

The classes are organized in the TPU Centre “Pilot-(line) Production” (CPP) where ETE “Student Design Office” has all the necessary facilities for creative work:

- Workbenches, locksmith tools;
- Radio-building workplaces and equipment;
- Laser cutter;
- Turn-milling machines with CAM (computer-aided manufacturing) and drilling machine;
- Semi-automatic welder.

**ETE Summer School (Summer Holiday after Semester 2):** School participants are junior students; school moderators are senior students. The Program of Summer School consists of the followings:

- Personality traits and professional skills development trainings: ‘Goal setting’, ‘Creation of successful presentation’, ‘Bastion’, ‘The art of negotiation’, ‘Stress control’, ‘Leadership’;
- Role plays and events aimed at the development of teambuilding skills;
- Competitions on the ‘Theory of Inventive Problems Solving’ (TIPS).

During the Summer School session students are trained to be tutors of students project groups and leaders of pilot projects.

The first-year students get initial leadership qualities, while the second-year students have all the opportunities to test their leadership abilities. All of them are trained to plan personal and professional growth for the next year.

#### **Students’ Initiative Creative Projects:**

**The Museum of Curious Science (Starting from the Second Course):** The project, which combines science and culture, is developed to prove that physics is a science, interesting and accessible for innovation. The exposition of the Museum consists of different models and exhibits made by ETE students and schoolchildren under the students’ supervision.

While inventing and creating exhibits for the Museum, students apply the knowledge and skills, obtained on the subjects ‘Introduction in Project Activity’ and ‘Introduction in Inventive Activity’, as well as develop and improve professional leadership competencies, while coordinating schoolchildren.

**Corporate Culture Development (The Whole Period of Study):** The improvements of students’ independent activity level, as well as stimulation of their creativity and initiative arrange conditions for formation of a responsible, socially and professionally mobile specialist; for developing of corporate competencies in project-creative activity of students.

After Summer School students have active position and become leaders or participants of corporate/intramural/ external initiative projects and events such as ‘ETE Club’, ‘Championship of “What? Where? When?”’, ‘Sentjabrjovka’, ‘Mayovka’, ‘New Year’, ‘23+8’, ‘Cinema Club’, ‘Joining ETE program Party’, ‘ETE Graduation Party’, ‘Photo marathon’ and some others.

**Problem-Oriented Projects (During the Third and Fourth Courses):** In the 3<sup>rd</sup> course students start learning in accordance with the Individual Curriculum that plans

students’ obligatory participation in one of the a problem-oriented projects. Initially only ETE students took part in problem-oriented project realization, but since 2012 all students of TPU have been involved into project activity. The projects to be developed are presented by all administering sub-departments, TPU business-partners that train specialists, since 2013 there has been an opportunity to develop and carry out interuniversity projects (TPU-TUSUR-TSU). Students choose the projects according to their interests and there is no strict connection with projects presented by administering sub-department.

Project work is carried out in accordance with a project datasheet, student’s individual curriculum; project stages and results are controlled by a student in the project diary.

#### **Third Stage (Results Presentation)**

**Ete Projects Fair (The Whole Period of Study):** ‘ETE Projects Fair’ is a complex of events aimed at popularizing and stimulating ETE students’ project activity. It includes the followings:

- Presentation of current projects realized by research-training institutions of TPU.
- Presentation of project realization experience, stories of success and current grant programs.
- Conduction of workshops and business games organized to analyze project problems and resources, group dynamics and failures, as well as value-conscious essence of the project.
- Contest among developed projects as an opportunity to promote project idea to the prototype ready to be realized; and to win initial financial support for project realization.

#### **Ete Students Conference (The Whole Period of Study):**

- An opportunity to estimate intermediate results of problem-oriented projects, their structuring and systematization during the process of preparation for the conference;
- Planning of further lines of project development during collaborative discussion with the participants of the conference;
- Experience exchange between developers of different problem-oriented projects;
- Communication with prospective employers and scientific supervisors in informal situation;
- Public speaking experience.

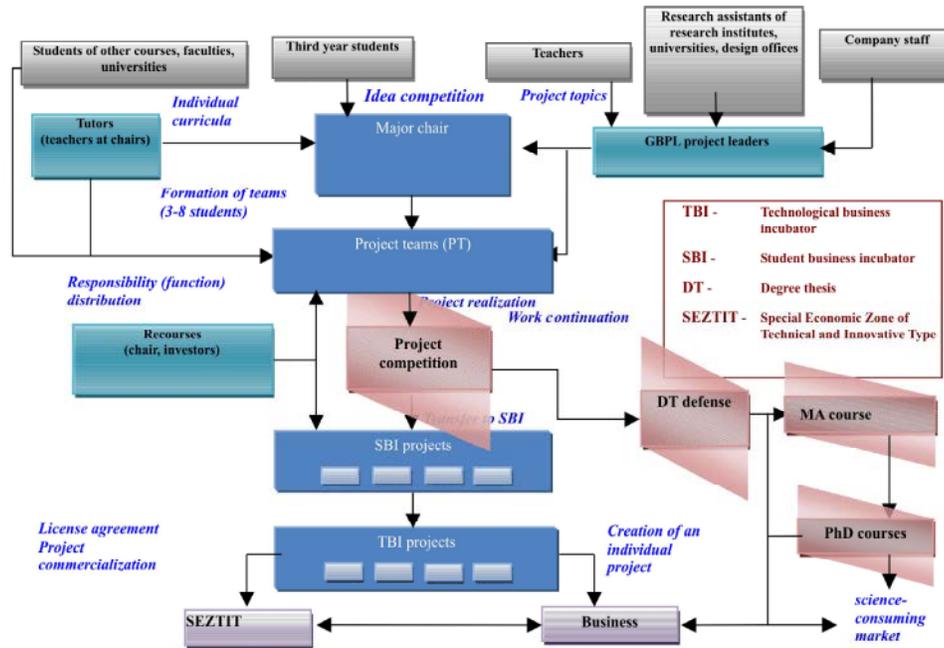


Fig. 1: The block diagram of project-based group learning implementation in TUSUR

Presented ETE TPU model allows students to get professional competencies, teamwork competencies, communication skills, creative and systematized thinking competencies, engineering leadership skills, entrepreneurial and business accent abilities [8].

**Tusur Project-based Group Learning (PBGL):** TUSUR Project-Based Group Learning (PBGL) is a large-scale innovation in the educational process organisation of a technical university. For the first time PBGL method was conducted as an optional experiment in 2004 at the Radio-engineering faculty. The purpose of this course was practical consolidation of knowledge and skills in the project, research and organizational-management activity in development of an innovative project for radio-electronic device or system design. For this purpose, a new discipline has been introduced into the curriculum of all specialities: “Training and scientific design of radio-electronic devices and systems” (TSD REDS). Since 2006 the given method is used at all faculties of university, including on humanitarian and economic ones [9, 10].

Work on the PBGL projects starts with the choice of project subjects through search and competitive selection of ideas and suggestions. The ideas and suggestions can be implemented in the form of construction of new high technology items, technologies, software products and services in demand.

The following categories of participants can take part in the competition without any limitations: teacher; engineering staff of the university; students involved in the innovative activity, who bring up a motion; and also businesses, firms and organisations interested in development and production of new high technology products. As a rule, they are companies – members of the educational and scientific innovative complex of TUSUR. At the present time there exist over a hundred of such companies.

The main requirements to the projects are innovative and/or high technology character of a development and commercialisation prospects of a project.

The block diagram of PBGL implementation in TUSUR is presented on Fig. 1.

First, it is necessary to form creative project teams (PT) of 3 to 8 people. This takes place in the end of the second year. The initial stage is not so simple, as the students of the group should be compatible both professionally and psychologically. There are about 250 groups in TUSUR at the present time. It is necessary to supply all groups with themes of projects, also students - PBGL participants should have individual curricula. This means that more than a thousand students of TUSUR have individual curricula.

Actually, within the framework of PBGL system there is rearrangement of student groups and there appears the new branch of educational

process covering approximately 40 % of the student contingent in the third and fourth year of study.

To make possible that interfaculty groups were involved in the project learning that realises the interdisciplinary approach, weekly uniform PBGL day is established at the university. GPO laboratories are created within each major chair. Laboratories are provided with about a thousand work places equipped with advanced engineering, measuring and info- and the telecommunication equipment.

Teams can include students of different courses, specialities, faculties and even different universities of the city. For each student the role in the project is defined. From among students the executive of the project is assigned. At the stage of preliminary design, students of Economic faculty can take part in the project to elaborate economic aspects of the project. In the same team there can be lawyers, sociologists, ecologists and university students of the required specialities if necessary. Formation of project teams is confirmed by an order of the rector. The requirement specification is developed for work of each team. All data on team participants, project content, stages of fulfilment and results are contained in AIS "Group project", being the constituent of automatic control system of TUSUR.

Project team work is organised as the constituent of educational preparation process of specialists and bachelors.

Educational process is organised on the basis of the individual curriculum for participants of each project team. For the subjects combined by the PBGL cycle, the common working program is made. In the project process if necessary the studying of subjects is carried out, programmes of which correspond to the project content. Also the fulfilment of course works and projects, field experience, laboratory works are possible within the limits of corresponding work on PBGL project.

The report is in the form of defence of a project stage in front of attestation commission with the conferment of a term mark. Materials of projects are used by preparation of degree work. The best projects participate in various competitions, including competitions which award is the continuation of project works the in student's business incubator of TUSUR. The role of PBGL is especially important in giving the real purpose and meaning to the business incubator. A variety of projects carried out by creative students teams are field of our innovator's work. They select the attractive for the market projects, commercialise them and create small businesses

on their basis, also according to the Federal Law of Russian Federation No. 217-FZ of August 2, 2009 on Amending Certain Legislative Acts of the Russian Federation Concerning the Creation by Budgetary Scientific and Educational Institutions of Economic Societies for the Purpose of Practical Application (Introduction) of the Results of Intellectual Activity (with Amendments and Additions).

At the end of each project the working model of a device, system, construction documents or a ready software product possessing competitiveness in the market of high technology products should be presented. The work result of a team can be a realised economic or social project. Projects are not admitted to defence without demonstration of the working model or the program.

## CONCLUSION

**Generalised Model of Project Based Learning of Engineering Specialists:** In comparison we can see that model developed by Tomsk Polytechnic University staff is well worked out and is widely studied on structure and the training contents (development of the demanded competences), in turn, PBGL model of TUSUR represents the technology of team building and leading the projects to commercialisation level.

As the generalised model the model development of TPU Elite Engineering Education Program (EEEP) by implantation of PBGL model in the following blocks is offered: "Design of projects" and "Result presentation of projects"; integration of efforts on search of real innovative technological projects; holding of interuniversity competitive selection of students; realisations of joint project result presentations. It will make possible to train engineering specialists fully and on a high level. The generalised model has following characteristics:

- Completeness of the object domain description: regulations, guidelines, orders.
- description width of an object domain: a set of supporting and supplying actions and quantity of educational modules.
- Depth of the description of an object domain: statistical data on years (quantity of projects, a commercialization degree) and quantity of publications on subjects.
- Usage of group based project learning: module quantity of group projects and quantity of teams.

- Description of requests to resource support of the project based learning process.
- Informational support of process: specialised software, web-interface.

Integration of the two models will allow achieving higher results in preparation of engineering specialists of the new generation capable to both project and innovative activity.

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