DESIGN OF STEM – PBL MODEL WITH APPLICATION IN HIGHER EDUCATION

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Abstract

Modern theoretical concepts of higher education pedagogy and student learning outline the framework of methodological innovations in the academic environment. According to a number of researchers, the concept of self-regulated learning is now becoming the focus of educational theory. The leading goal of bringing educational objectives closer to those of business brings to the fore one more direction for development and these are the goals for a larger share of Science – Technology – Engineering – Mathematics (STEM) skills of students as a result of training at all levels. Students studying in the modern, rapidly and dynamically changing learning and business environment have to make independent choices between possible different solutions to a problem and to learn to take on responsibilities on which their academic and professional development depends. To develop these specific skills, a variety of interactive and personal engagement programs can be developed.

Herein we report a design of project-based learning (PBL) model, which implements the concepts of student-centered learning (SCL) and is oriented towards achieving specific learning outcomes in various disciplines of higher education programs. The created model of PBL is applied in a real learning environment, as part of exercises and extracurricular activities, with topics including applied versions of project tasks on the curriculum of major disciplines, which are studied in medicine and by students of biotechnology and biomedical engineering.

Keywords: *Project-Based Learning, Higher education; STEM – PBL; Student-Centred Learning*

I. Introduction

In 1984 The World Federation of Medical Education in collaboration with the World Health Organization has initiated its ongoing program for global reforms in preclinical medical education. In the debate that has arisen about how this can be achieved, the concept that problem-based learning has an important role is widely supported. [1], [2], [3] The influence is expressed in the development of both the content and the educational principles in a number of countries, the most significant being the recognition that the doctor must be qualified in autonomous or independent training related to clinical practice throughout his life. [4], [5]

At the same time, the American Society for Engineering Education (ASEE) argues that engineering education should not focus only on theory and experiment, there should be appropriate, attractive, and connected programs to prepare students for lifelong learning. Undoubtedly, in the knowledge society of the new millennium, the profile of a good engineer must be based on the ability and will to learn, in a solid knowledge of the basic natural sciences and in a good command of certain technological areas, in addition to general human values. In addition, modern engineers must be prepared for continuous training and must also have communication skills and attitude to work in a team. The CDIO project (Conceive, Design, Implement and Operate) is based on the belief that the job of higher education is to train students to be modern engineers, able not only to participate, but also to become leaders in the concept, in the design, implementation and operation of the cycles they work with. The competences are organized on four levels: technical knowledge and critical thinking, professional and personal skills, interpersonal skills and CDIO (highest level: concept-design-introduction-implementation). The modern dynamic development of the professions requires reforms in higher education so that the education adapts to the challenges of society.

Since the last decade of the twentieth century, the academic community has been trying to reformulate the goals of higher education in all its directions. The new methodology of an educational model based on the development of certain competences - European Qualifications Framework (EQF), allows students to find new ways to acquire knowledge and solve problems. Achieving this is related to the development of technical competence, understanding of engineering practice as a social enterprise, gaining clinical experience in practice, preparation for managerial and leadership role in society and building a background for lifelong learning.

Society change requires professionals with appropriate professional competence, more than experts in specific fields. Although much of the teaching of science, medicine, and engineering is relatively conventional, the application of new approaches is key to achieving the modern learning goals set in various international frameworks. Among them, project-based learning (PBL) is established as an appropriate educational methodology for the development of competences, linking education with the professional sphere, which will enrich the study repertoire of students and ensure the formation of significant professional and academic skills. Project-based learning is a modern educational method that implements the key concept of student-centered learning (SCL).

The novelty in the idea of PBL is the emphasis on education STEM (Science Technology Engineering Mathematics Education) and the connection of secondary education with the educational practices after it. STEM-PBL is a challenge because it requires students to have a number of skills that are built gradually in the process of their learning in secondary education: critical and analytical thinking; cooperation and partnership communication; problem solving and self-directed learning; ability to explain and defend certain decisions. [6]

STEM PBL is both a challenge and a motivating approach, as it supports self-regulated learning (SRL) by highlighting STEM skills. It largely ensures the development of key competencies under the EQF, forms competences for lifelong learning while including rigor and fairness for all participants in the project. Last but not least, PBL develops key skills for teamwork and partnership, mutual assistance in the learning process and the development of the ability to reach agreement through dialogue in responsible decision-making.

The processes of development in higher education outline new orientations of teaching and learning, which indisputably determines the modern methodological determinants:

- the new paradigm for education
- the theory of the quality of education and training
- self-regulated learning as a component of modern educational goals and their fundamental role in the design of the overall methodological activity.

The authors, in this case researchers, believe that STEM-PBL in an academic environment provides the contextualized, authentic experiences needed by students to facilitate learning and build meaningfully powerful scientific, technological, engineering and mathematical concepts supported by language skills, social research and art, thus being a prerequisite for their personal and future professional development.

The possibilities of PBL in practical exercises can be used by the teacher to develop SCL, encouraging students to explore opportunities, try ideas, work in a team, revise and reorganize their thinking and present their best solutions. The aim is to maintain motivation to work on the specific educational content in view of its importance for future educational and professional tasks.

For higher education graduates, STEM-PBL is a perspective that guarantees the success of individual careers in most professions. It is a basic concept for human resource development in most successful business companies worldwide. That is why there is a need for innovative curricula in which students can expand their experience and be able to transfer knowledge into non-standard academic activities, such as those that cause excitement and additional motivation to learn. [7]

II. Materials and Methods

II.1. STEM-PBL design

In the environment of many areas in higher education, there are lots of challenges in recruiting motivated students - competent learners. Science and engineering subjects are considered "difficult" and "unattractive" for young people, as there is some erosion of learning skills. This fact, in some cases, is strongly influenced by secondary education. Less and less prepared young people are entering higher education, some of whom turn out to be students in specialties that are inevitably related to the study of these difficult subjects. This has serious implications for learning and teaching approaches, as well as in student support and retention systems, especially in the early stages of learning.

In many specialties there are also students of different nationalities who come with their experience from different educational systems and this has an indirect impact on the general appearance of the skills that are applied among students.

This article presents a design of STEM-PBL, which is part of a study focused on exploring the possibilities through the methodological tools of project education, built on the principles of managing the process of forming self-regulated student learning in major academic disciplines.

II.2. Participants and topic

The STEM-PBL model was applied in the period 2017-2019 during the training of 189 first-year students of the Medical Faculty of Sofia University "St. Kl. Ohridski" from Bulgaria, Ukraine, Russia, Germany, Serbia, Macedonia, Turkey, Syria and 21 students biotechnology engineers of UCTM - Sofia in 2018/2019 academic year. The students are between 19 and 27 years old.

The design of the experimental model of the project-STEM demonstrates the possibilities for application of PBL in the academic environment in different professional fields, united by common objects of research and knowledge. The project work is included in the curriculum for practical exercises in the respective discipline.

The topic of the project is respectively for medical students **"Study of the causes, spread and treatment of some parasitic and transmissible diseases in humans"** and for bioengineering students **"Instrumental methods for separation and analysis of bioproducts."**

II.3. Structure of the experimental model

In the presented experimental design of STEM PBL opportunities are created for project work, divided into three stages with interim reports, as STAGE 1 and STAGE 2 are informationally and semantically connected. In practice, this largely allows the registration of individual contributions and corrections, with no negative effect upon the freedom of personal choice and the successful completion of the project for each of the participants (Fig. 1).

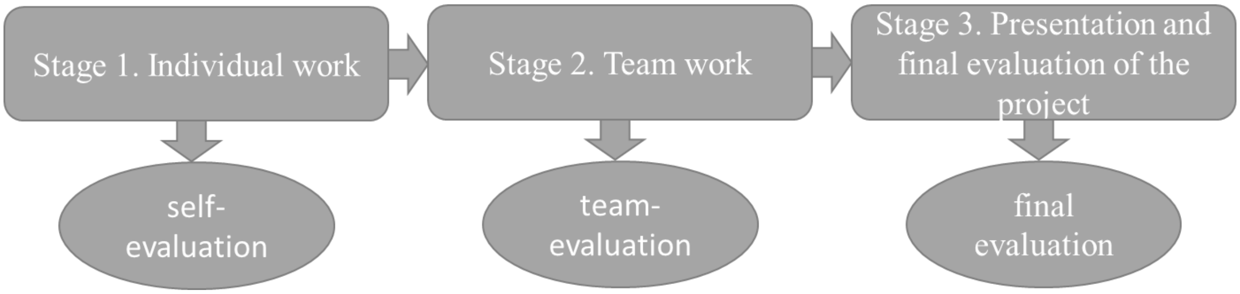

Figure 1. General structure of the project

The first stage of the project lasts three weeks for medical students and five weeks for biotechnology engineering students. It covers mainly individual work of students with the following main activities: (1) theoretical research, (2) visualization and (3) presentation (Fig.2.)

Activity 1 is related to the collection and analysis of information from various sources and for medical students it is about the causes, vectors and hosts of various parasitic diseases in humans, and for biotechnology engineering students - about the application of various instrumental methods for analysis of bioproducts. The visualization illustrates the text of Activity 1 through appropriate images.

A web-space was created for the needs of the project, where all materials are freely available for the participants in the project and through which Activity 3 (presentation) is carried out. The common web-space for the project provides an opportunity on the one hand for sharing, cooperation and self-control between students, and on the other hand allows the teacher, in this case a researcher, to discreetly provide information about the project process, its progress and for feedback [8] regarding the clarity and correctness of the given instructions regarding the project tasks.

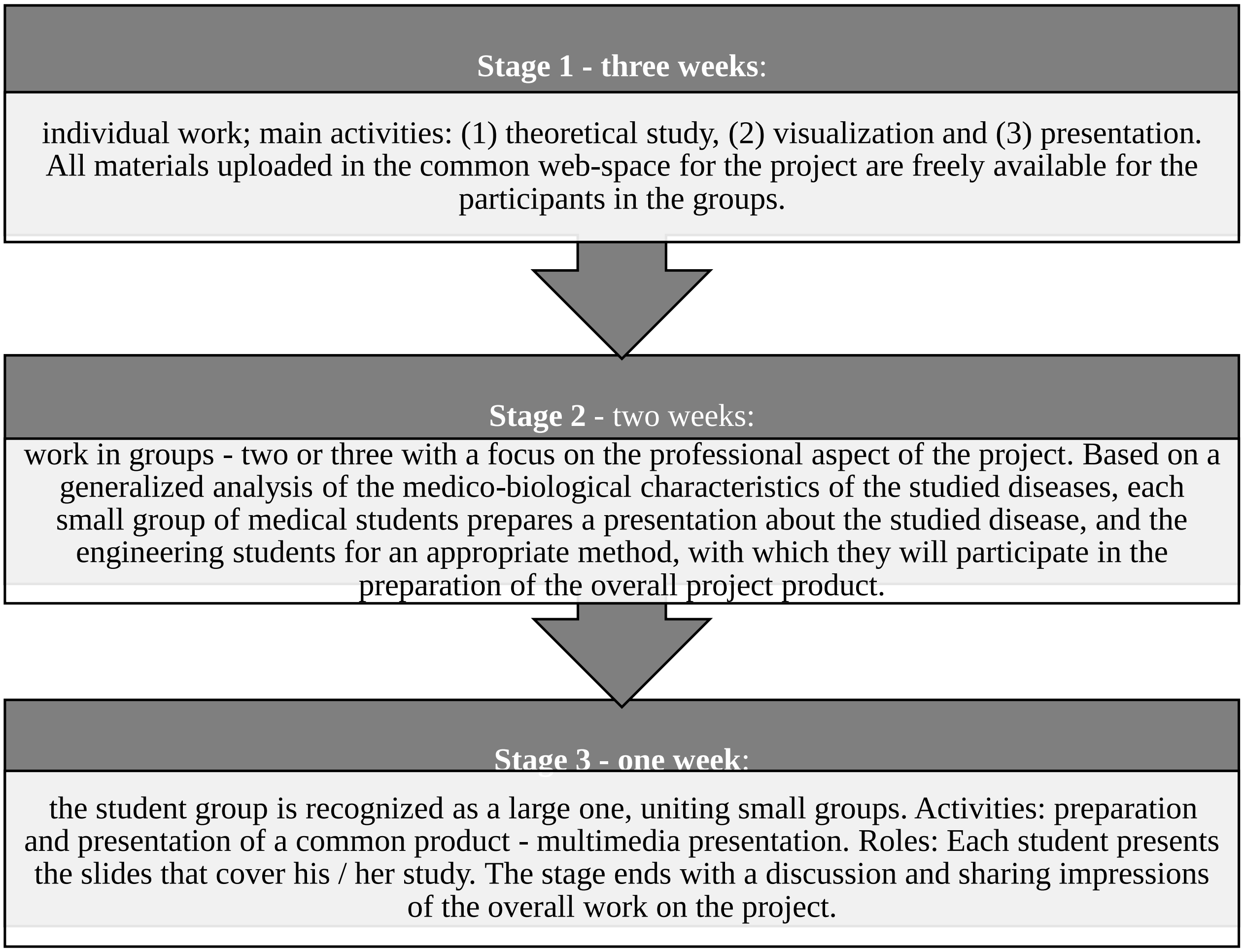

Figure 2. Model of STEM PBL applications

The second stage of the project has the same duration as STAGE 1 and the students perform the same type of activities. The differences are in the way and focus of the student work, as well as the different type of visualization. During this stage, students work in small groups of two or three, and the activities focus on the professional aspect of the project. Based on a summary analysis of the medico-biological characteristics of the studied diseases, each small group of medical students prepares a short presentation about the studied disease, and the engineering students for an appropriate method, with which they will participate in the preparation of the overall project product. (Fig.2.)

In STAGE 3 the student group is recognized as a large one, uniting the small groups. This last stage of the project work lasts one week. The student activities are: (1) preparation and (2) presentation of a common product - multimedia presentation, with included roles: each student presents the slides that cover his/her research. The stage ends with a discussion and sharing of impressions from the overall work on the project. (Fig.2.)

As a way to provide additional information about the project process in the group, if necessary, the teacher accepts the role of a "friend-critic", which is a good strategy to ensure effective group work.

II.4. Assessment methods

To evaluate the effectiveness of STEM-PBL, the following were used: 1) test method and 2) survey method.

Two types of tests were applied in the test method: a test for assessment of knowledge - before the beginning of the project, which assesses above all the students' knowledge of facts from the respective discipline and the importance of basic concepts; knowledge application test, showing the level of knowledge that students have and its application after the end of the project.

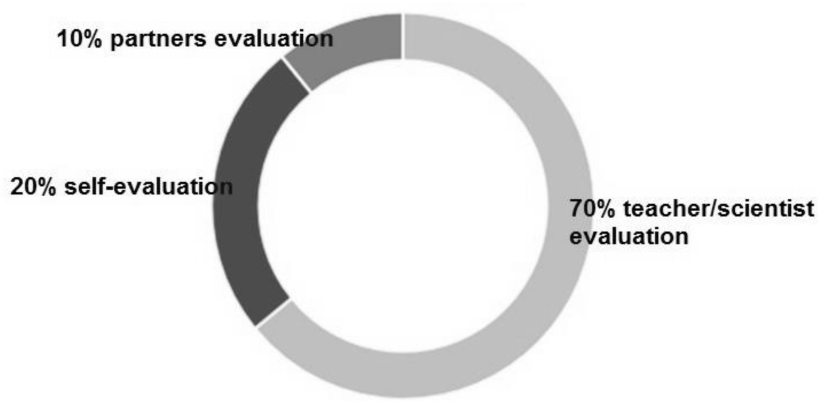

Figure 3. Project performance assessment system

Assessment of the way the groups function, i.e. of the processes and mechanisms through which STEM-PBL achieves its goals and efficiency, was carried out through the questionnaire assessment of skills. **Self-assessment** and **peer assessment** were applied at different points in the project work, each with two parts. *Part* A of the self-assessment provides information on the development of the studied skills, necessary for the acquisition of lifelong learning skills. *Part B* of the self-assessment collects information in seven areas through group interactions and is specifically focused on self-directed learning and self-awareness, key features of PBL. *Part B1* of the peer review is essentially a qualitative assessment of the project work, and *Part B2* - a quantitative assessment (in %) of the project work of each member of the student group.

The final assessment of the project work is complex and is formed by three components with different weight: 70% - external assessment (teacher / researcher assessment), 20% - self-assessment (10% of part A and part B of the self-assessment) and 10 % – peer assessment (Fig. 3). The acquaintance with the criteria and the ways in which the project work will be assessed is known from the very beginning of the STEM-project and the attention of all is directed to the formative assessment, where the teacher and students have shared expectations about the assessment strategies each of which has motivational, cognitive and informational purpose.

The project performance assessment system used in this way supports the basic ideas of PBL, helping to clarify what a good project implementation is - to identify the transferable skills that all participants have at some level and to use all means, which are likely to contribute to their development.

III. Conclusion

The presented design of STEM-PBL provides opportunities for learners for active learning: both to engage with the content of tasks, to further develop and improve their learning skills, as well as to form new skills - cognitive and communicative (cooperation, team management, etc.). These characteristics are grounds for application of the model in an academic environment, taking care to avoid problematic moments in the organization of training. Such problems may arise from lack of experience, tension and disagreement, or inability to account for individual contributions.

The processed results of the study show a generally positive characteristic of the applied STEM-PBL model with a fairly high % (over 80%) of affirmative assessments in terms of: (1) set goals and achievement of results, (2) organization of training and 3) individual progress and positive effects on the SRL.

The design of STEM-PBL, built on solving real (practical) scientific and professional problems, is applicable in the specialties of medicine and engineering. STEM-PBL can have its place in academic courses of study in basic disciplines, where students study basic sciences and directs teaching to the development of learning skills. The data from the research show that students are encouraged to search independently in scientific issues and stimulate the development of cognitive skills of a higher order. It helps to educate better-motivated students, who are supported to take responsibility for their own development.

Conflict of interests

The authors declare no conflict of interest.

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Legends to figures:

Figure 1. General structure of the project

Figure 2. Model of STEM PBL applications

Figure 3. Project performance assessment system