

# Developing Training Materials for the On-Line Course "Project Method in Teaching Higher Mathematics"

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**Abstract.** The article reviews the process of developing training content of the on-line course on the project method for Mathematics teachers teaching at higher technical universities. The study presents the first stage in developing training materials and a model for the structure of the on-line course «Project Method in Teaching Higher Mathematics», which is in open access on the «Higher School Mathematics Teacher» educational platform. The original version of the course was designed on the basis of the findings of a survey among the Mathematics professors. It helped to find out the level of their awareness about using the project method in training engineering students. It also gave the authors of this paper good reason to recommend the on-line course for the professional development of Mathematics teachers. After uploading to on the platform the original version of the course, we managed to organize a discussion of the proposed content, structure and modes for submitting the course materials on the forum. The article discusses the process of modifying the course components, improving training material during the forum discussion. The analysis of the feedbacks from the course users on the forum, confirmed that the variety of submitted forms of course materials and the proposed topics satisfied the preferences of the course users with regard to the perception and awareness of the educational information.

**Keywords:** Project-based Learning, Training Content, On-line Course, Higher Mathematics Engineering Education.

## 1 Introduction

In the context of rapid technological development, there are many changes in the engineering education objectives, in which the emphasis is now placed on students' constant self-improvement, their ability to formulate a problem, find ways to solve it. While studying the training of technical speciality professionals, Lima et al. [1], van Hattum-Janssen [2], Fernandes et al. [3], Mills and Treagust [4] substantiated the fact that traditional teaching methods in higher engineering institutions (HEI) cannot meet the requirements of modern education. While expressing dissatisfaction with existing mathematical training programs for engineering professionals, more and more educationalists are becoming supportive of using active teaching methods. Thus, Weenk and van der Blij [5], Manrique et al. [6], Stojcevsky et al. [7] stress that the use of active teaching methods stimulates students' thinking and understanding the need to acquire knowledge for solving different issues of their future professional activities. Facing the necessity for students to become aware of the need for gaining knowledge, Felder and Brent [8] studied the ways to motivate students to become active participants of the educational process. Freeman et al. [9], while conducting the experimental study of the effectiveness of active teaching methods based on the principles of Sciences, Technologies, Engineering and Mathematics (STEM), proposed to use project methods in teaching.

There is a considerable amount of research on the topic of project-based learning. While studying the role of a teacher in the project-based training of future engineers, Van Hattum-Jansen [2] and Fernandes et al. [3] described project approaches in engineering education. Lima et al. [1] studied the issue of effective management of interdisciplinary projects in engineering education. Powell and Weenk [10] defined project-led engineering education, reviewing in detail the tasks and principles of this training technology. Zamyatina et al. [11] analyzed the advantages of project methods, shared the experience of implementing project-based learning in the educational process of an engineering university.

Despite the considerable amount of research on project-based training technologies, we still come across a number of controversial issues. The expediency of project-based teaching of junior students who study technical specialties still remains an open issue. Realizing that project-based learning of Mathematics contributes to establishing cross-curricular relations and solving problems of professional nature, Higher Mathematics teachers in Ukraine express their readiness to introduce this method into the educational process even for 1- and 2-year students. Expressing their desire to master the methodology of using project technologies, the majority of the interviewed teachers opted for training in the format of an on-line course. The analysis of the findings [12, 13, 14, 15] shows the effectiveness of using on-line courses for the professional development of teachers. This type of on-line courses is becoming more and more popular and has a number of advantages, such as following: the opportunity to work the training material through when it is convenient for teachers, in a comfortable environment, at their own pace and independently of others. In addition, the format of

the on-line course allows to diversify the modes of presenting the learning material, taking into account the user's individual needs. The forum users also have an opportunity to establish productive communication with their colleagues in order to resolve professional issues.

To find out approaches to developing on-line courses we turned to the papers by Perikos et al. [16], Wrigley et al. [17], M.Puzziferro and K.Shelton [18]. Comparing massive open on-line courses, which describe the development of training materials, and analyzing them, the scientists pointed to the importance of ongoing communication with future users of the courses when developing content. Scholars have described the use of different types of questionnaires to help the course developers verify that the training content lives up to students' expectations. Researchers designed these questionnaires to clarify the issue «What is the market of an on-line course and what they want». In addition, for those who are setting up to develop an on-line course, researchers advised following the experts' recommendations.

Having studied the general recommendations of Leicester Learning Institute [19] regarding the forms of presenting, structuring, and selecting content for on-line courses, we started developing training content for the «Project Method in Teaching Higher Mathematics» on-line course [20]. The original version of the course was uploaded to the «Higher School Mathematics Teacher» learning platform [21]. While designing this course, we took into account the concept of creating this platform, described in detail by Vlasenko et al. [22].

Therefore, the purpose of this study is to present the findings of the process of developing training content for the on-line course «Project Method in Teaching Higher Mathematics» [20], namely, the selection of content, effective forms of teaching material, with reference to a preliminary survey of Ukrainian teachers and further discussions on the forum.

## **2 Method**

While analyzing the possibilities of implementing project-based technologies in teaching Higher Mathematics in Ukrainian technical higher educational institutions, we surveyed the lecturers who teach Mathematical disciplines in higher school. To estimate Mathematics teachers' awareness of the project methodology of teaching, we worked out a questionnaire using an open on-line service and placed it on the «Higher School Mathematics Teacher» platform [21].

About 100 teachers of different ages, with different teaching experience (from 5 to 30 years) from Eastern, Central and Southern Ukraine participated in the questionnaire and the discussion of the problem. The majority of the respondents were from the following educational institutions: Donbas State Engineering Academy, Donbas National Academy of Civil Engineering and Architecture, the Institute of Chemical Technologies of the East Ukrainian Volodymyr Dahl National University, Cherkassy State Technological University and Pryazovskyi State Technical University. We also interviewed about 30 graduate students of Kryvy Rih Pedagogical University and Berdyansk State Pedagogical University, who plan to work as Higher Mathematics

teachers in technical HEI. The questionnaire consisted of 10 questions. The questions were designed with the purpose to find out:

- the degree of Higher Mathematics teachers' awareness of the project method of teaching;
- the degree of students' readiness for project activities;
- the teachers' willingness to work with on-line courses;
- the reasons that do not allow for effective use of the project method in teaching Higher Mathematics;
- the place and role of projects in teaching Higher Mathematics;
- most popular types of projects;
- optimal academic load, which should be given to project activities.

The analysis of the respondents' opinions helped us formulate the purpose of the course. It is to transform the existing theoretical experience on project technologies into easy-to-use educational content, to provide methodological recommendations on how to use the project method with consideration for the specifics of the subject of Higher Mathematics. To define the concept and the structure of the «Project Methods in Higher Mathematics» on-line course we used the Inductive Content Analysis Method. When choosing resources for analysis in Table 1, we focused on those that offer project-based Mathematics learning. There are such on-line resources as Australian National University [23], Professional Development Service for Teachers (PDST) [24], Teach Thought we grow teachers [25], Study.com [26], The Curriculum Project [27], Computing Technology for Math Excellence [28], MIT OpenCourseWare [29].

**Table 1.** Analysis of the Structure of the On-line Resources Offering Project-Based Mathematics Learning

<b>On-line re-sources</b>	<b>Theoreti-cal com-ponents</b>	<b>Practical com-ponents</b>	<b>Project Bank</b>	<b>Tasks for users</b>	<b>Ques-tions to course tutors</b>	<b>Re-strictions on access to the course material</b>
Australi-an Na-tional University	Research papers on the project method, theoretical information for each topic	Practical solutions on how to use projects in teaching Maths	Projects topics for getting Degree Builder	Research practical tasks	Through the forum	Access to courses is limited in time
PDST	Research papers on the project method	Videos on real-life classroom situations and live discussions between the lecturer	Projects topics for teaching Maths at primary schools	Accom-plishing tasks during Work-shops	Through the forum	Participa-tion in Workshops is limited in time

		and the students working on the project				
Teach Thought	Research papers on the project method	Practical solutions on how to use projects in teaching Maths	Project topics for teaching Maths at primary and high schools	Accomplishing tasks during Workshops	Through the forum	Flexible
Study.com	Research papers on the project method, theoretical information for each topic	Videos on real-life classroom situations and live discussions between the lecturer and the students working on the project	Projects topics for teaching Maths at primary and high schools	Quizzes and practice tests	Through the forum	Flexible
The Curriculum Project	Research papers on the project method, theoretical information for each topic	Practical solutions on how to use projects in teaching Maths	Projects topics for teaching Maths at high schools	Training workshops	Through the forum	Participation in Workshops is limited in time
Computing Technology for Math Excellence	Research papers on the project method, theoretical information for each topic	Presentations on the use of projects	Topics for multimedia projects and projects on the Web-development	Test preparation	Through the forum	Flexible
MIT OpenCourseWare	Research papers on the project method, theoretical information for each topic	Presentations on the use of projects, videos on real-life classroom situations and live discussions between the lecturer	Sample Maths project topics	Execution of projects in a team	Through the forum	Flexible

		and the students working on the project				
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Taking into an account the structure of the reviewed resources, and analyzing volunteers' responses, we shall now consider the concept of the course in detail.

The course material is divided into the following blocks.

**Block 1.** *Theoretical component of the course.* This module includes research papers on the project method and the required theoretical information for each lesson of the course.

**Block 2.** *Practical component of the course.* This module includes:

- practical solutions on how to use projects in teaching Higher Mathematics (projects that have already been tested in educational practice);
- video-lessons lasting up to 10 min. In these video tutorials, the course instructors briefly explain the theoretical issues of the course. Also, the course tutors are planning to create videos on real-life classroom situations and live discussions between the lecturer and the students working on the project.

Given that the course is intended for Mathematics teachers and students who master the profession, a significant amount of material is presented in the form of diagrams and tables that clearly demonstrate the logical connections between the basic concepts.

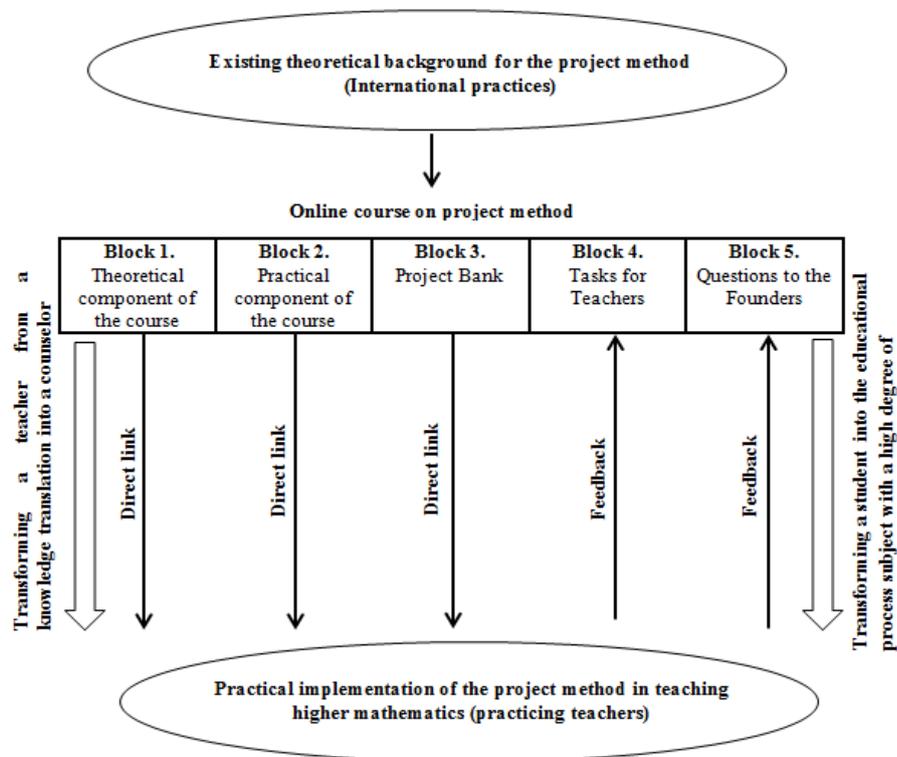
**Block 3.** *Project Bank.* This module contains project topics that should be used in teaching Higher Mathematics. Project topics are systematized by specialities and types of projects. The course moderators have the opportunity to constantly update this module with new topics.

**Block 4.** *Tasks for Teachers.* This module includes practical tasks to each topic of the course. The tasks placed here have a different format because working with the course involves self-assessment and peer assessment. Here are some examples:

- to work out an indicative plan for the implementation of the project on the specified topic (a sample plan is provided);
- to distribute the given project topics among students with different academic achievement levels, to provide justification for this;
- to evaluate the situation the students are in while working on the project, to outline ways of pedagogical influence to overcome it.

**Block 5.** *Questions to the Founders,* which you can ask to the course tutors at the forum and express wishes on the course improvement.

The objectives and basic structural elements of the course are presented in Figure 1.



**Fig. 1.** The structure of the «Project Method in Teaching Higher Mathematics» on-line course

### 3 Results

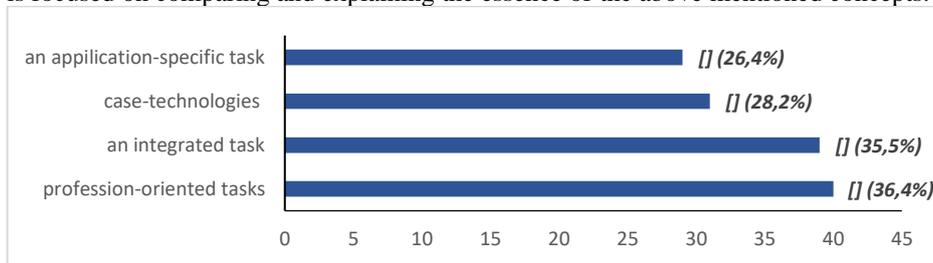
The analysis of the results of surveying of Mathematical disciplines teachers at Ukrainian higher education institutions gave grounds to state that:

- only 45% of the respondents are familiar with the basics of the project method;
- 85% of the respondents are not sufficiently aware of the essential characteristics of the project method, and as a result, it is often confused with other methods (often with the problem method);
- 78% of those surveyed do not understand the essence of implementing the project method in teaching Mathematics;
- only 27% of the respondents believe they are ready to effectively control students' project activities;
- 74% of those surveyed do not understand, how to choose objective criteria to assess project activities and how to recognize the results of the project implementation within the overall rating of the discipline.

These results confirmed our opinion about the relevance of developing the on-line course, which will cover the issue of using project technologies in teaching Higher Mathematics.

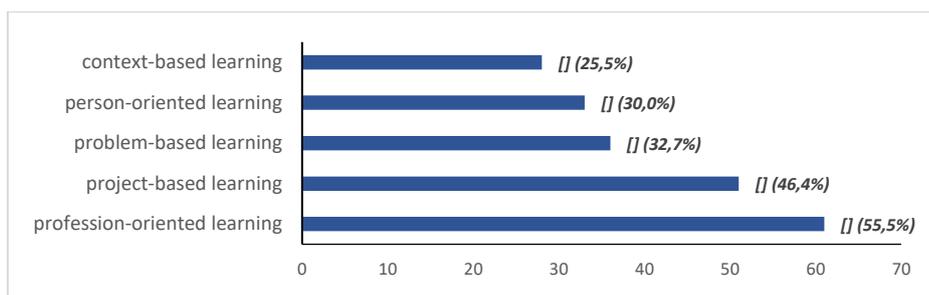
Among the important reasons why the project method is not used as often as it is desired: 80% of the teachers bring out the lack of time to develop, prepare and manage a project; 70% of the teachers mention the shortage of information on possibilities of implementing the project method in teaching Higher Mathematics; 60 % point the lack of willingness to use the project method in teaching. As a result, we have developed several on-line course lessons aimed at enhancing the teachers' motivation to implement project technologies in learning Higher Mathematics and a bank of project tasks with ready-made project examples.

36,4% of the teachers equated educational projects with profession-oriented tasks, 26,4% of the teachers equated educational projects with application-specific tasks, 35,5 % of those surveyed identify educational projects with intergraded tasks (see Fig 2). That is why, a significant part of the theoretical and practical content of the course is focused on comparing and explaining the essence of the above mentioned concepts.



**Fig. 2.** Distribution of the teachers' opinions on comparing educational projects with other types of tasks

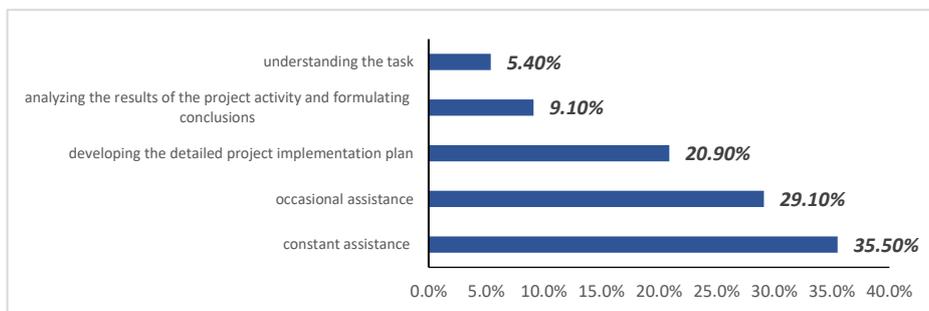
55,5% of the respondents think that profession-oriented learning the best corresponds to the principles of the competency-based approach to learning. 46,4% of the teachers give the second place to the project method. 32,7% of the teachers believe, that in the third place there should be problem-based learning. For 25,5% of the teachers, context-based learning comes fourth (see Fig. 3).



**Fig. 3.** Distribution of the teachers' opinions on choosing the priority type of learning

35,5% of the teachers consider, that students will demand constant assistance while working on the project. The other 20,9 % assume that the most difficult part of working on a project for their students will be the development of a detailed project im-

plementation plan. 5,4 % of the teachers think that the most difficult issue for their students will be the understanding of the essence of the project tasks. 9,1% of the teachers believe that their students will require the most help at the stage of analyzing the results of the project activity and formulating conclusions (see Fig. 4).



**Fig. 4.** Distribution of the teachers' opinions on the need to support students while working on projects

The data in this diagram served as a basis for developing tasks for teachers, the implementation of which will improve the quality of managing project activity of students at appropriate stages.

The analysis of the respondents' answers also helped us decide on the topics for the on-line course. The teachers were proposed to discuss these topics at the forum. 45% of the teachers pointed out that they were familiar with the basic ideas of the project method. Those teachers were invited to participate in the discussion of the original version of the on-line course. Thus, 44 teachers took part in the discussion of the course topics. The results of this discussion are presented in Table 2. The table shows the number of those teachers who gave the positive answer to the corresponding question.

We made all changes to the program and course materials to meet the needs of its users. The teachers' opinions made it possible to consider the issue of students' assessment according to the project activity as a separate topic. Moreover, we added the topic «Mini-Projects as an Effective Way to Prepare Students for the Implementation of a Project on Higher Mathematics». We took into account the teachers' wish to consider the application of the Inquiry method in teaching. Also through the forum, we obtained confirmation of the teachers' wish to work with the course.

Thus, the course is presented in Ukrainian and consists of 12 classes. We took into account the fact that the teachers may have no possibility to do more than two lessons per week. So, the course is designed to last for one and a half months. The users can start training at any time convenient for them and work at their own pace. Having estimated the maximum time required for each lesson to be 2.5 hours, we determined that the total course duration is 30 hours.

**Table 2.** Results of the Discussion of the Course Topics

No	Preliminary course topics	Accepted unchanged	Should be modified	Requires more than one lesson
1.	History of the project method	42	2	0
2.	Definition of the project. Significant and insignificant features of the concept	44	0	0
3.	Project method and problem method. Similarities and differences.	21	23	3
4.	Case-technologies and STEM-technologies	36	8	0
5.	Context method and project method	34	10	0
6.	Types of projects	28	16	2
7.	Good practices of using the project method in teaching Higher Mathematics	42	2	4
8.	Syllabus on Higher Mathematics with account for the use of the project method (place of projects, time input, topics, etc.)	35	9	5
9.	Practical classes on Higher Mathematics with the use of project technologies	23	21	8
10.	Project Reporting (execution Options)	10	34	32

The relevance of the on-line course content was discussed and approved during the International Conference on Sustainable Futures: Environmental, Technological, Social and Economic Matters (ICSF 2020) (Vlasenko et al. [30]).

## 4 Discussion

Kostrova's research [31] in the field of engineering education underlined significant isolation of Higher Mathematics from general engineering and speciality subjects. We share the opinion of Pais et al. [32] that students are often not aware of the specific purpose of studying Higher Mathematics, although, even in their junior years, they are oriented towards their future profession. This is the reason why the scientists point at the significant decrease in students' interest in this discipline. Following the scientists, we also criticize the fact that most teachers of Mathematical subjects prefer traditional teaching methods while students are just passive listeners during almost all of their classroom time.

We share the ideas of Kolmos et al. [33] on the feasibility of using project technologies in engineering education. It is obvious that project-based learning is an important tool for students' self-development and self-management and facilitates their rapid personal growth. However, unlike most researchers, we consider it not only quite possible but also advisable to use the project method for teaching junior students at technical universities. Analyzing the Mathematics teachers' willingness to use the

project method in teaching, we decided to keep disseminating among Ukrainian teachers the idea of using the project method.

The experience of Harris and Martin [34], Pelkola et al. [35] helped us elaborate an opinion that using such an on-line course is an effective means of remote professional development of Mathematics teachers in case they use the project method. We took into account the guidelines on developing an on-line course given by Hi [36], Burgess et al. [37], Donnelly and Agius [38], Volkova et al. [39], Lockwood [40] who recommend to use different forms of presenting material: images, diagrams, animations, and so on. The scholars also insist on the relevance of conducting a preliminary survey of the course users in order to prepare and improve training materials.

We also took into consideration the opinion of Im and Chee [41], who insisted on the importance of using forums for quality research. Using the teachers' comments on the course materials posted at the platform forum, we were able to adjust the learning content and confirm its readiness to be introduced into the process of further training of Mathematical disciplines teachers at Ukrainian HEIs.

## 5 Conclusions

The review of the pedagogical literature gives reasons to state that the project method of teaching is experiencing a surge of popularity again. The use of project technologies in teaching Higher Mathematics is appropriate and didactically grounded by the experts in the field of engineering education. The analysis of the results of the survey, done among higher school Mathematics teachers confirmed the lack of their awareness about using the project method in teaching. At the same time, it showed their willingness to improve this situation with the help of the designed on-line course «Project Method in Teaching Higher Mathematics' on-line course» [20]. The preliminary approbation of the course gives grounds to claim that it can be successfully used as a means for professional development of higher school Mathematics teachers.

Placement of the course on the «Higher School Mathematics Teachers» platform allowed for free access to the course materials. The development of the course structure and topics were based on the analysis of the results of surveying Mathematics teachers and the existing educational resources providing on-line education. The teachers' willingness to personally participate in the modification of the topics and materials of the course contributed to their engagement in the discussion of the course development at the platform forum. That, in turn, made it possible to expand the amount of the submitted educational material, forms of presenting educational content in order to the course users' preferences regarding the perception and understanding of educational information. The analysis of the answers of the first users of the course gave grounds to claim that the content and topics offered satisfied their preferences.

Among the directions for further research, we outline the introduction of the developed on-line course for the purpose of improving the readiness of Mathematical disciplines teachers at higher schools to use the project method in the practice of training engineering specialty students.

We are grateful to the academic staff and students who participated in the survey for helping in conducting the research.

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