Case-Based and Project-Based Methods for Effective E-learning in ICT Safety and Security

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Abstract. The objective of this paper is to develop a practical E-learning framework with implementation of case method and project-based learning. In paper we obtain the following results. Content of the massive open online course (MOOC) "Safety and Security of Control Systems" is analyzed. This MOOC was introduced in 2017 for master students program "Cybersecurity" at National Aerospace University "KhAI" (Kharkiv, Ukraine). A core part of this MOOC is a project devoted to safety and security assessment of real systems and software. Taxonomy for indicators of E-learning effectiveness is proposed. Case study was done in Ukraine between students of Cybersecurity program after finish of study of the MOOC "Safety and Security of Control Systems". A sample includes 40 master students involved in the course learning during 2017-2019. Case study results confirmed a set of hypotheses related with E-learning effectiveness when case method and project-based learning are implemented.

Keywords: case method, E-learning, homework, learning efficiency, MOOC, project-based learning.

1 Introduction

Online learning also named as electronic learning (E-learning) means 100% virtual education via internet media with support of information technologies (IT). E-learning entails a huge transformation of education which becomes more and more distance as well as personalized. A modern approach to E-learning implementation is consists in development of massive open online courses (MOOCs). Despite numerous well known advantages and disadvantages of E-learning we put emphasis on the challenges and opportunities related with application of this relatively new education technology, such as: individual approaches to students with opportunities to build individual learning trajectories based in student-oriented approach [1]; application of Learning Management System (LMS) as centralized environment for administration, documentation, tracking, reporting, and delivery of learning courses [2]; needs in essential scope of relevant studies and data, that would provide a strong background for empirical based analysis [3]; choice of relevant indicators to make qualitative and quantitative assessment of E-learning [4]; high degree of importance of students' homework which can be organized in both individual and collaborative manner [5]; needs in

choice of effective teaching methods depending on features of courses and sciences; in the paper we discuss the case method [6] as well as the project-based learning [7] applied for the course devoted to safety and security of control systems [8].

It is needed to notice concerning some gaps in researches devoted to the above points. The actual research is directed to fulfill some of these gaps. Based on the above, we develop a concept for our research area (Fig. 1). This concept recognizes dramatic importance of students' homework for successful implementation of the whole E-learning process. After that, we take into account learning course defendant features and discuss in this paper the course "Safety and Security of Control Systems" [9] which is provided since 2017 by the Department of Computer Systems, Networks and Cybersecurity of National Aerospace University "KhAI" (Kharkiv, Ukraine). Also, we discuss the additional values which are provided by application of the case method as well as project-based learning for E-learning.

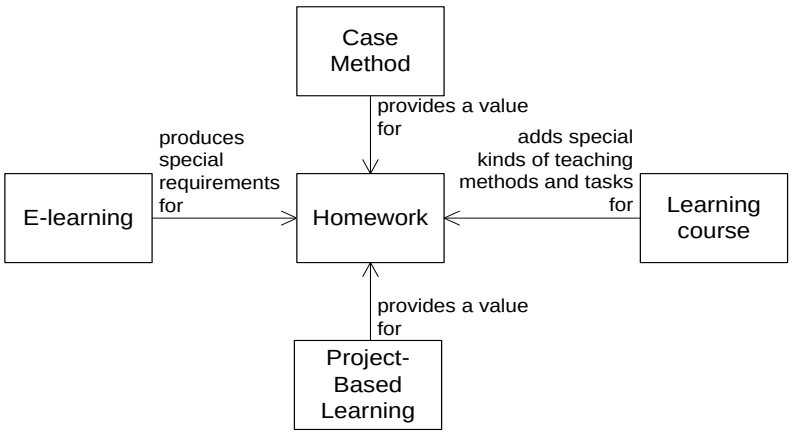

Fig. 1. A Concept of the paper: an influence of a learning course, the case method and the project-oriented approach to homework during E-learning

2 Literature Review

In our literature review we mainly orient to STEM (Science, Technology, Engineering and Mathematics). Also, based on our paper concept (Fig. 1), we include in our review scope researches related with E-learning homework, case method and project-oriented approach.

The purpose of homework is to teach a student to meaningfully and independently work first with educational material, then with scientific information, to lay the foundations of self-organization and self-education in order to instill the ability to continuously improve their skills [10]. Homework can include individual and group activities carried out under the indirect guidance of a teacher during classroom and extracurricular activities, stimulating cognitive activity, developing intellectual abilities and needs of the individual in self-education. Modern approach to homework is important because the focus is changed from passive teaching to active self-education. LMSs support students' homework with a set of tools such as quiz and tests, a forum,

a glossary and a wiki section, links to additional resources and webinars. Many studies known did not demonstrate the expected correlation between time spent on homework and students' academic achievement [11]. It means homework effectiveness is highly dependent from a manner of its organization. However, the homework organizational principles are insufficiently represented in existing researches. Also we found big contradictions in arguing, is group homework more effective than individual homework or vice versa [12].

Case method or case study means the analysis of realistic economic, managerial and other situations (cases) in order to teach participants certain skills during the discussion of the case, including through the training of other participants [13]. Firstly Case Method was implemented at Harvard Business School in the 1920s [14]. At that time, teachers were faced with the problem of the lack of actual business manuals. The way was found as a description of specific situations from the practice of real companies. The cases as simplified descriptions of problematic business situations were offered to students, and students had to find and substantiate solutions. From the field of business education case method was extended to social sciences and STEM [15]. Since 1990-s case method was started to apply in the post-soviet countries. It is worth to mention a fundamental work "The Case Study Method: Anatomy and Application" [16] published in Kyiv in 2002.

The most part researchers agreed there a number of advantages of case method application for education such as orientation to students' individuality, development of entrepreneurial and managerial skills as well as problem-solving abilities and critical thinking, increasing motivation for learning, active involvement in the educational process, getting experience of team work and communication, decision making in conditions of stress and uncertainty [17].

The most of the studies in area of case method are traditionally devoted to business education [18], and we put emphasis on needs of experience transfer from business education to technical education. So there are not many papers demonstrated case method application for the STEM domain, but between the known papers we pay attention to the few following researches.

Case method is used for teaching in automobile design course at some Chinese colleges [19]. Only some qualitative assessments are provided in the paper. The conclusion is case method positively affects students' understanding of material, creates a positive and creative atmosphere during teaching sessions, as well as permits to create to lectures high quality interdisciplinary curriculum. Russian studies related to the use of case method in chemistry have shown an increase in student achievement and professional self-awareness [20], which coincides with the results obtained for entrepreneurial education [21].

There are some empirical studies, which do not confirm effectiveness of case method application in education. For example, the paper [22] explores hypotheses about the impact of case studies and other teaching methods (lectures and business simulations, which means working with an interactive model of the economic system) on the development of skills such as problem solving, interpersonal communication, and professional identity. This study shows that business simulation is more effective, than case method from the point of view of development students' skills.

One more important issue is a set of indicators which are used for case method effectiveness assessment as well as for education effectiveness assessment as whole.

Such indicators include indicators determined by teachers and indicators determined by students [23]. It should be noted that, in our opinion, the assessment of the learning process by students only is quite subjective, since students do not fully possess information about the actual usefulness of the acquired skills and knowledge.

The case method is also used to conduct scientific research in the conditions of the impossibility of collecting data sufficient to perform statistical analysis [24], when, firstly, it is necessary to analyze the object or phenomenon directly in the context of its development, secondly, it is impossible to control the environment in which the object is located or a phenomenon occurs, and thirdly, the number of instances insufficient for static analysis is observed. A comparative analysis of the main approaches to the implementation of the epistemological and methodological aspects of the case method was performed in [25], while the case method allows combining quantitative and qualitative research methods [26]. For example, the cases in the study provide a descriptive representation of three innovative career and technical education programs in energy management and alternative energy programs at the U.S. community college level [27].

Project-based learning (PBL) is aimed at training students to use the acquired knowledge and skills, and most importantly to be able to solve real professional tasks. Project training usually runs in parallel with the main schedule and helps students transfer knowledge and skills from classes to the real work environment in which they plunge during the project activity [28]. Advantages of PBL are very similar with advantages of case method. There is active and creative learning of students, facing of real life and real professional work, a positive impact on student motivation, training in teamwork skills and in project management [29]. At the same time it is a huge challenge for students and teachers, which can be pretty unusual and hire extra efforts.

Researchers state some important features of PBL, like the following [30]. PBL projects are central, not peripheral to the curriculum, so students learn the fundamentals of disciplined via the project. Projects involve students in investigations that provoke the transformation and construction of knowledge. Projects are student-driven and do not end up at a predetermined results since students are provided with more autonomy than usually. Project should be realistic in difference with usual school exercises. For example, the [31] describes a case study devoted to implementation software development on the agile base between software engineering students. Results of the case demonstrate essential improvement of understanding agile development process. A conclusion is the most part of students became ready for employment at software development companies.

3 Objective and tasks

Based on the performed literature review, we recognize some gaps in area of research related with case-based and project-based E-learning. These gaps are in the area of some lack of empirical data as well as a lack of theoretical basis for development of MOOC supported with PBL and the case method. The objective of this paper is to develop a practical E-learning framework with implementation of case method and PBL. To achieve the paper objective we perform the following research steps:

- Firstly, we analyze theoretical and practical content of the MOOC “Safety and Security of Control Systems”;
- Secondly, we propose taxonomy for indicators of E-learning effectiveness;
- After that, we do setting a field questioner based study of experience of students involved in E-learning of the MOOC “Safety and Security of Control Systems”;
- Finally we develop a practical E-learning framework with implementation of case method and PBL.

4 Analysis of the MOOC “Safety and Security of Control Systems”

The MOOC “Safety and Security of Control Systems” was introduced in 2017 for master students program “Cybersecurity” by the Department of Computer Systems, Networks and Cybersecurity at National Aerospace University “KhAI” (Kharkiv, Ukraine). The goal was initially to make the course as a problem solving, so it is aimed at solving a practical problem: preparing for safety assessment against the requirements of the standard IEC 61508 “Functional safety of electrical/ electronic/ programmable electronic safety-related systems” or other similar safety standards. Another purpose of this course was to make it fit for industrial training.

Thus, the course participants received the whole set of advantages of MOOC users, like learning with small information blocks, study at a convenient time, if a student did not understand something or missed, then he “scroll through” it again, etc. In the subject area, the benchmark was made primarily for Industrial Control Systems (ICS), but other control system architectures are also considered like embedded systems, and Internet of Things (IoT). A look at security was directed from the point of view of safety assurance. However, where appropriate, a relation between safety and security is demonstrated, for example, a common life cycle of safety and security. It was considered which techniques of safety assurance can increase the level of security.

The course includes six lectures or, in MOOC terminology, six weeks of study. Primary, the lectures were posted on the YouTube channel in the form of the following playlists (see Fig. 2): Lecture 1. Introduction; Lecture 2. Requirements of safety standards; Lecture 3. Functional safety management; Lecture 4. Safety and security life cycle; Lecture 5. Quantitative assessment of safety; Lecture 6. Techniques and measures of safety assurance.

Every lecture is supported with a set of 5-10 minutes videos in quantity from four to seven per one lecture as well as with lecture slides and homework items. Students’ homework includes the following items: video lectures and slides of lecture for independent learning of theory; answer to test questions (quiz); reading of recommended literature, including literature included in the curriculum specially for mandatory individual learning; study of additional materials exceeding the scope of the course program; the course project, which is the most important part of the course practicum.

The course learning contains the following techniques: asynchronous interactive learning with video lectures during a primary study of theoretical material; self-paced independent learning with slides of lectures and recommended literature during a deep study of theoretical material; collaborative learning during implementation of the course project (Fig. 3); synchronous learning during consultancy leaded by a teacher.

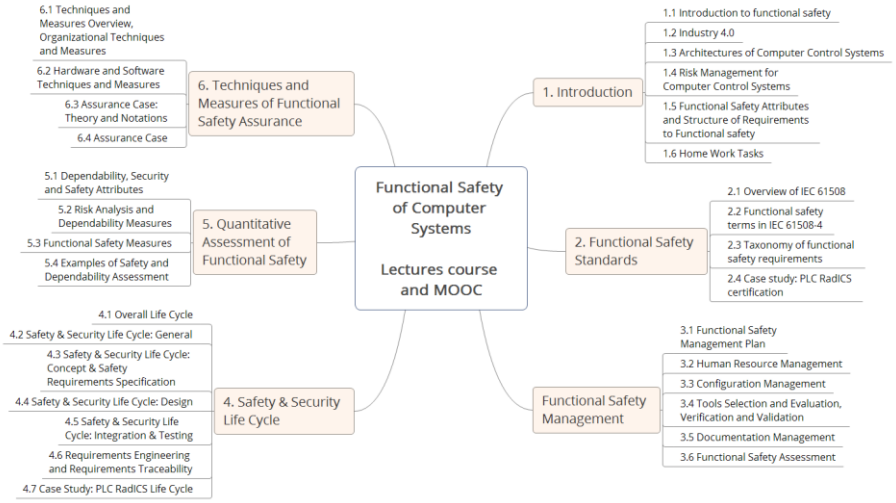

Fig. 2. Structure of the MOOC "Safety and Security of Control Systems"

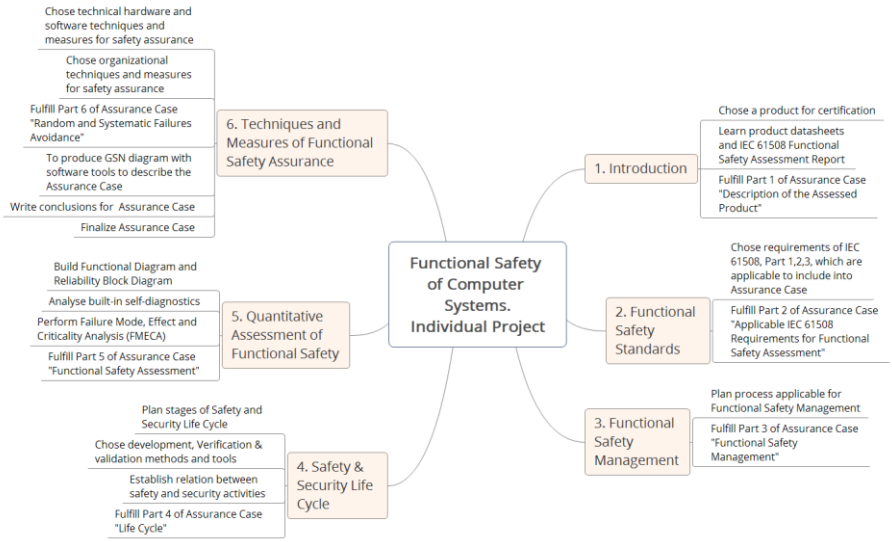

Fig. 3. Structure of the Assurance Case template for performance of the course project

The course project performance is the main objective and result of the course learning. First of all, the project is necessary to solve an applied problem based on the acquired knowledge. The main task of the project is to develop a document covering the analysis and assessment of safety and security related with the lecture material. This document is called the Assurance Case in accordance with the actual practice of safety and security assessment [8]. The development of the Assurance Case is now used in the practice of assessment and certification against safety and security re-

quirements. The components of ICS like controllers, actuators and sensors are offered as subjects of assessment. Students are given the Assurance Case template, and they fill it out in stages, based on the material in each lecture. During the project implementation we assign project teams with two, three or four students depending from their preferences. The structure of the Assurance Case template associated with the lecture content for the course project performance is represented on Fig. 3.

5 Taxonomy of E-Learning Effectiveness Indicators

The proposed three-level taxonomy of E-learning effectiveness indicators is presented in Table 1. This taxonomy is a good starting point to analyze the known empirical researches, but also the taxonomy can be enriched by results of new experiments.

Table 1. Taxonomy of E-learning effectiveness indicators

Stakeholder who defines indicators	Group of indicators	Example of indicators
Teachers	Students' knowledge assessment	Performance assessment metrics
		Results of passing of tests and exams
		General results of studies at the university
	Students' soft skills assessment	Soft skills assessment metrics
		Abilities to follow E-learning
	Self-assessment	Abilities to drive E-learning
		Satisfaction with E-learning
	Process and LMS assessment	Process and LMS assessment metrics
Students	Self-assessment	Abilities to follow E-learning
		Satisfaction with E-learning
	Process and LMS assessment	Process and LMS assessment metrics
	Teachers' assessment	Abilities to drive E-learning
	The influence on the development of competencies	Influence on the theory understanding
		Influence on the development of hard / soft skills
	Opportunities of applying the competencies in practice	The influence on the development of hard / soft skills
Graduates	Degree of satisfaction with the former educational process	Quality of the working environment
		Salary
	Opportunities of applying the competencies in practice	The influence on the actual hard / soft skills
Employers	Satisfaction with the employees' results	Key Performance Indicators (KPIs)
		Salary

Researches, which are analyzed above, deal mainly with the education performance indicators defined by teachers and students in the learning process. It should be noted that assessment of the learning process by students is quite subjective, since students do not fully possess objective information about the actual usefulness of the acquired skills and knowledge. The same applies to some extent to teachers. Complaints about the lag of teachers' experience from life's realities are justified in many cases. Therefore, if teachers are working in the framework of the curriculum only, they can also not always fully appreciate the objective usefulness of the knowledge and skills taught. Therefore, in our opinion, it is necessary to take into account two more important categories of indicators. The first category is effectiveness indicators determined by graduates during some time after the end of the graduation, and the second category is effectiveness indicators determined by the employer. A challenge is to take valid and relevant data to estimate these kinds of indicators, but modern online technology can help to resolve this issue.

6 Case Study of E-learning Effectiveness

Our research setting is Ukrainian National Aerospace University "KhAI". Computer Systems, Networks and Cybersecurity Department introduced a new education program "Cybersecurity" in 2017. During 2017-2019, four groups of master students have been graduated in accordance with the Cybersecurity program. One of the courses of this program, named "Safety and Security of Control Systems" was provided on completely E-learning basis as a MOOC with use YouTube for video files disposition as well as Google Drive for distribution of all other course materials.

A non-random sample covers all general population of 40 students, which is presented in Table 2 with gender details. It should be noticed that in 2017 we taught two groups of students because the Cybersecurity program update and shifting of the considered MOOC to other semester. The groups of students were 8 to 12 people, so it was easy to distribute and to collect the study questionnaire since individual communications have been established between teacher and students.

Table 2. A sample of students for study

	2017(1)	2017(2)	2018	2019	Total
Male	9	10	8	7	34 (85%)
Female	3	2	0	1	6 (15%)
Together	12	12	8	8	40

Study design is based on a set of the following hypotheses related with E-learning effectiveness (see Fig. 4): Hypothesis 1 (H1): Students are satisfied with E-learning process; Hypothesis 2 (H2): Students prefer E-learning format faster than traditional format; Hypothesis 3 (H3): Theoretical E-learning materials can be presented in a form which is understandable for students; Hypothesis 4 (H4): Practical E-learning exercises can be presented in a form which is understandable for students; Hypothesis 5 (H5): E-learning motivates students to get new knowledge.

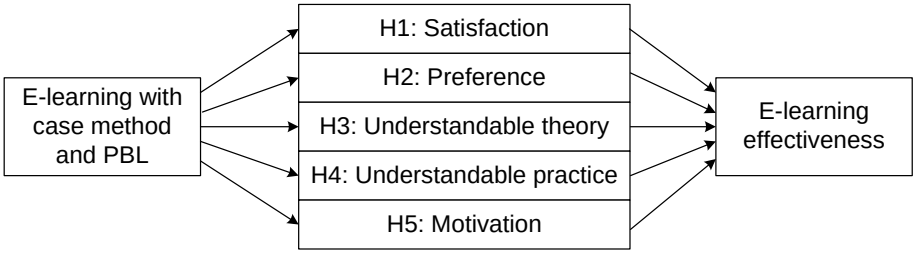

Fig. 4. A structure of the hypotheses network

All students were asked to fulfill the questionnaire after the end of the course study. The questionnaire contains five parts related with five stated hypotheses. Five-degree scale is used to estimate students' agreement with the questionnaire statements. Also we asked students to indicate the positive issues of the course as well as the issues which can be improved. For this part we calculate quantity of students who are agree with one or the other statement. One student can choose more than one statement. Results of the study are presented in Table 3. We also include average exam grades in ECTS points to Table 3.

Results of review confirmed the truth of the hypotheses H1-H5. An average satisfaction degree is 4.2, so H1 "Students are satisfied with E-learning process" is confirmed. An average confidence level for E-learning preference is 4.1, so H2 "Students prefer E-learning format faster than traditional format" is confirmed. An average understanding level of the lecture materials is 4.0, so H3 "Theoretical E-learning materials can be presented in a form which is understandable for students" is confirmed. An average understanding level of the project materials is 3.9, so H4 "Practical E-learning exercises can be presented in a form which is understandable for students" is confirmed. We notice, the degree for project materials understanding is the lowest because the project is really the most difficult and challenging part of the course. An average motivation degree is 4.3, so H5 "E-learning motivates students to get new knowledge" is confirmed. All ratings from students are in the range from 3.8 to 4.5 what mean a low level of the dispersion.

An average exam degree is 77.7. Three groups of students got high level degree more than 80 on the average, and only the second group at 2017 got 64.3, what affect dramatically the degree for all four groups.

The most important issues for students are opportunities to be free in a choice of a place and a time of study (80% of respondents). After that students emphasize the importance of a new view for security issues (62.5%), availability of all the course materials at one place (57.5%), and an opportunity to drive a real world project (47.5%). The main concern of students is a lack of teacher support (90% of respondents). Concerning this point it is worth to notice, that it is the main challenge which face students during E-learning, and also this is the main difference between E-learning and traditional "face-to-face" learning. We understand a lack of the self-driven behavior is a big challenge during the project performance. It is also highlighted with other students' issues such as the requests for more detailed steps for the project implementations (82.5%) and for more transparent expectations and acceptance criteria for the project (67.5).

Table 3. Results of case study

	2017(1)	2017(2)	2018	2019	Average
Satisfaction level for the course learning	4.5	4.0	4.1	4.2	4.2
E-learning format is better for me than traditional (confidence level)	4.3	3.9	4.2	4.0	4.1
Understandability of the lecture materials	4.1	3.9	4.0	4.2	4.0
Understandability of the project materials	3.9	3.8	4.0	4.1	3.9
Motivation for self-learning	4.4	4.1	4.5	4.4	4.3
Exam degree (ECTS)	84.2	64.3	83.1	82.5	77.7
Positive issues of the course					**Total**
Opportunity to study at any place at any time	10	9	6	7	32 (80%)
A new view for security issues	8	5	5	7	25 (62.5%)
Availability of all the course materials at one place	7	6	4	6	23 (57.5%)
Opportunity to drive a real world project	5	3	6	5	19 (47.5%)
Improvement points of the course					**Total**
More teacher support	11	10	8	7	36 (90%)
More detailed steps for the project implementations	12	10	6	5	33 (82.5%)
More explanations for the lecture materials	8	7	7	6	28 (70%)
More transparent expectations and acceptance criteria for the project	10	8	5	4	27 (67.5%)
Do provide the project subjects from software engineering area	5	4	1	3	13 (32.2%)

We continue to work for more transparent and understandable project descriptions. The degree of project material understandability increased from 3.8-3.9 in 2017 to 4.1 in 2019. The same, the number of students who need more explanations for the project steps decreased from 12 (100%) in 2017 to 5 (62.5%) in 2019, and the number of students who expect more transparency and acceptance criteria decreased from 10 (83.3%) in 2017 to 5 (33.3%) in 2019. It is also important for students to have the project subject in the field related with the students' experience in software engineering (32.5%), including ICS and IoT.

7 E-learning Framework with Case Method and Project-Based Learning

An integral part of this research joints all outputs in a view of E-learning framework supported with case method and PBL. This framework is presented on Fig. 5 Below we briefly discuss the main parts of the framework.

PBL principles are related with approach to choose and drive the project as the core practical activity of the course. We adopt the approach proposed in [30] with the following principles:

- Projects are the central item of the course and the central teaching strategy, because students learn the course via the project;
- Projects involve students in a special kind of investigation directed to knowledge construction and transformation;
- Students play the main role in projects performance, and projects are realistic.

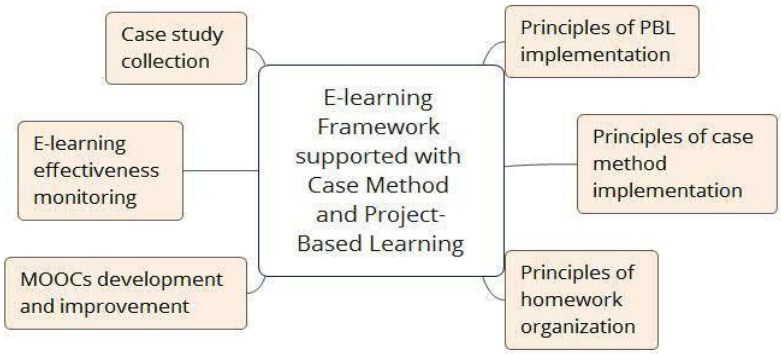

Fig. 5. A structure of the E-learning framework supported with case method and PBL

Principles of case method implementation are close related with PBL approach. The main idea is to propose for students a real software-hardware product and real documents covering safety and security assessment and assurance. Successful case method implementation suggests consideration of all best practices related with PBL and homework organization.

Homework organization includes supplying of students with all materials and instructions. Principles of homework are the following: collection of online materials in the LMS area; combination, depending on the material being studied, of various forms of homework (such as classroom individual or group study, extracurricular individual or group study); student-centered approach with the formation of an individual trajectory of the education and homework depending on the individual preferences of students and the recommendations of teachers; focus aimed at the development of creative and research competencies; monitoring by teacher in order to analyze adoption of learning material by students; analysis of the opportunities to improve the homework process; taking into account curriculums of other interrelated academic courses.

MOOCs development and improvement bases on using of the modern design tools and LMS. Other MOOCs related issues lay in students feedback monitoring and continuous improvement. For E-learning effectiveness monitoring teachers should choose a set of appropriate effectiveness indicators. An example of taxonomy is presented in Table 1. Results of effectiveness monitoring are outputs of a case study organized to supply stakeholders with relevant empirical data. Periodical field review can be a method to implement a case study. Also other relevant case study can be included in data collection to support cases meta-analysis.

8 Conclusions

Twenty years after beginning of intensive implementation of E-learning we continue to follow technologies rather than theory like "the cart has been placed before the horse" [32]. However, pedagogic innovations are such important like technological innovations especially, if a lack of students' motivation is founded.

In this paper we obtain the following results. Content of the MOOC "Safety and Security of Control Systems" is analyzed. This MOOC was introduced in 2017 for master students program "Cybersecurity" by the Department of Computer Systems, Networks and Cybersecurity at National Aerospace University "KhAI" (Kharkiv, Ukraine). A core part of this MOOC is a project devoted to safety and security assessment of real systems and software.

Taxonomy for indicators of E-learning effectiveness is proposed. This taxonomy contain three the following levels: stakeholder who defines indicators including teachers, students, graduates and employers, group of indicators and single indicators.

Case study was done in Ukraine between students of Cybersecurity program after finish of study of the MOOC "Safety and Security of Control Systems". A sample includes 40 master students involved in the course learning during 2017-2019. Case study confirmed a set of hypotheses related with E-learning effectiveness when case method and PBL are implemented. We found the truth of five hypotheses, H1-H5 (see Fig. 4).

Also we checked the main issues which increase or decrease quality of E-learning. The students' opinion is the most important advantage of E-learning is an opportunity to be free in a choice of a place and a time of study (80% of respondents). After that students emphasize the importance of a new view for security issues (62.5%), availability of all the course materials at one place (57.5%), and an opportunity to drive a real world project (47.5%). Students are concerned about a lack of teacher support (90%), needs for more detailed explanation concerning steps of the project implementations (82.5%) and more explanations for the lecture materials (70%), more transparent expectations and acceptance criteria for the project (67.5) and more the project subjects from software engineering area (32.2%)

Finally, we develop a practical E-learning framework with implementation of case method and PBL, which includes the following entities: principles of PBL implementation, principles of case method implementation, principles of homework organization, MOOCs development and improvement, E-learning effectiveness monitoring, and case study collection. A practical value of the paper is determined by development of a framework for effective E-learning implementation based on the principles

of PBL and case method. A theoretical novelty of the paper lies in a technique of E-learning effectiveness analysis supported with new experimental data.

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