Collaborative Learning Outcomes for Creation of Industry-Oriented Curricular: a Case Study of ERASMUS+ Project Physics

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***Abstract*— This work presents the development of industry-oriented, student-centered master-level curricular in the field of physical sciences in Belarus. The main target of ERASMUS+ project "Improvement of master-level education in the field of physical sciences in Belarusian universities" (Physics) is to facilitate the Bologna process in the Belarusian higher educational system at a transition phase from the former Soviet system to the Bologna one. The project also aims to study the labor market needs for supplying by highly-educated master level specialists in the in the field of applied physics specialties like functional nanomaterials, photonics for high-tech industry needs. The approaches developed and applied in this project facilitate a creation of an integrated, logically connected system of educational methods and tools. In our research we focus on application of appropriate assessment methods for Learning Outcomes. Since the project targets on the creation of industry-oriented curricular, this research pursues to involve industry partners in a collaborative work on development and evaluation of contemporary education courses and programs in applied physics. In the paper, we demonstrate examples of direct and indirect assessment methods. This paper provides a unique experience of collaboration between EU universities, leading Belarusian HEIs, Belarusian enterprises, and professional associations on behalf of creation of the industry-oriented curricular in the applied physics topics.**

Keywords — education, learning outcomes, industry-focused curriculum, ERASMUS+.

I. Introduction

This work presents the development of industry-oriented, student-centered master-level curricular in the field of physical sciences in Belarus. The main target of ERASMUS+ project "Improvement of master-level education in the field of physical sciences in Belarusian universities" (Physics) [1] is to facilitate the Bologna process in the Belarusian higher educational system facing a transition from a "5+1" system (former Soviet system) to the Bologna "4+2" system. The project also aims on studying the labor market needs for supplying by highly-educated master level specialists in the in the field of applied physics specialties like nanomaterials, photonics, directed on high-tech industry needs.

The approaches developed and applied in this project facilitate a creation of an integrated, logically connected system of educational methods and tools. The training of master students in physical sciences is characterized by practice-oriented courses, programs and educational tools (e.g. using digital learning environments and e-books). An exchange of good practices between three European universities (Riga Technical University - RTU, KU Leuven, University of Cyprus - UCY) and Belarusian universities improved educational (e.g. defining, educating and evaluating appropriate learning outcomes) and linguistic competences of the Belarusian teaching staff.

Feedback from stakeholders (students, teachers, researchers, employers, labor market, a national accreditation institution) has been obtained during the entire project life cycle. It was used for adjustment and enhancing of learning outcomes defined in the project.

In this paper, inter alia, we describe methods of obtaining feedback from the stakeholders, i.e. selected groups of students and teaching staff at the development stage of the courses. Additionally, we describe the courses testing methods and evaluations during the autumn and spring study semesters in academic year 2017-2018, after the courses were accredited by the universities and the Ministry of Education of Belarus. The paper also discusses the methods and results of the "post-ante" survey implemented by potential employers and professional associations. We compare and analyze the inputs of stakeholders into the development of new curricular with the post-ante survey results. It should be noted that the expectations of the stakeholders at the beginning of the project and the evaluation marks at the end of the project, showed a good correlation.

In our research we focus on application of appropriate assessment methods for Learning Outcomes (LO) [2]. Assessment methods are the tools and techniques used to determine the extent, to which the stated learning outcomes are achieved [3]. A variety of methods, qualitative and quantitative, direct and indirect, should be used. Since the project targets on the creation of industry-oriented curricular, this research pursues the involvement of industry partners in a collaborative work on development and evaluation of contemporary education courses and programs in applied physics. In the paper we demonstrate examples of direct and indirect assessment methods. The research provides a unique experience of collaboration between three EU universities, four leading Belarusian HEIs, Belarusian enterprises, and professional associations on behalf of creation of the industry-oriented curricular in applied physics.

II. Methods to Develop and Enhance Learning Outcomes

Learning outcomes intended for the courses achievement compiling a program should correspond to those of the full program, being harmonized among all of them and at the same time being not overlapped a lot. They should be achievable and be close in the most extent to the intended learning outcomes both of the course and program as well. As far as the purpose of any study program is a specialist for industry, then the development of a course and a program as a whole and some details like purposes and LOs seems logically to start with the needs analysis of the representatives of industry. Regularly as well as in this case that is either survey or questionnaire for the representatives from industry, who mostly work with the students at internship or young professionals at once after the studies. These are those professionals who assist young professionals to adapt themselves at their beginning of the career and better know, what should be expected from the professionals in the field and what knowledge and skills are mostly required at the working place.

Besides the need analysis of industries and in the same extent, the requirements of the European Qualification Framework to the professional levels and qualification should be taken into account, while developing the LOs and their measurement instruments for the students [4]. The levels of the EQF are defined in terms of learning outcomes, i.e. knowledge, skills and autonomy-responsibility, therefore the following the EQF will fully meet the requirements to LOs development. Countries are expected to develop national qualifications frameworks on the basis of the EQF to implement it. As the study level of the developed programs and courses is a Master and one of the purposes is to align the programs with the European higher education system and Bologna process then levels 6 and 7 form EQF were taken as a basis for the programs development. These are advanced or highly specialized professionals with an ability of independent problem solving and technological process management and control skill [5]. Therefore, the selection of the LOs should correspond to the higher level of the developed cognitive processes: starting at least from the application of new knowledge in new circumstances up to synthesis and creation of a new product [6].

Thus, starting the development of the new or modifying study programs and its courses with the analysis of the answers for questionnaires of the industrials and sorting the basic information for a number of key LOs could be distinguished for the whole program at first. Then the LOs of each particular course within this program should be developed, which in their turn result in the real achieved LOs of the program.

In the Physics, questionnaires have been developed for the transition of the higher education of the purpose program to the system of 4+2 to face the Bologna principles.

The purposes of the questionnaires are:

- ideas accumulation to form the 2-year practice-oriented master courses in the modified or new programs;
- comprehension of the requirements of research institutions / enterprises to the qualification of alumni of the practice-oriented master courses;
- comprehension of the requirements of research institutions / enterprises to the education process of the master students in the system “4+2” with 2-year education duration.

The full process of the LOs elaboration for a particular program needs and demands starts with the survey that gives an opportunity to distinguish particular necessities in knowledge and skills obtained by the industrial specialists. Taking into account the necessary level of the learners and further specialists cognitive domain the LOs of the whole program and concrete courses are emphasized (Fig.1). Block A in Fig.1 demonstrates both the process of the LOs development for a program and results of the studies - achieved LOs - that can differ from the initially planned, that requires a sort of decision making whether they need updating or this difference is a result of a student’s individual approach to the studies.

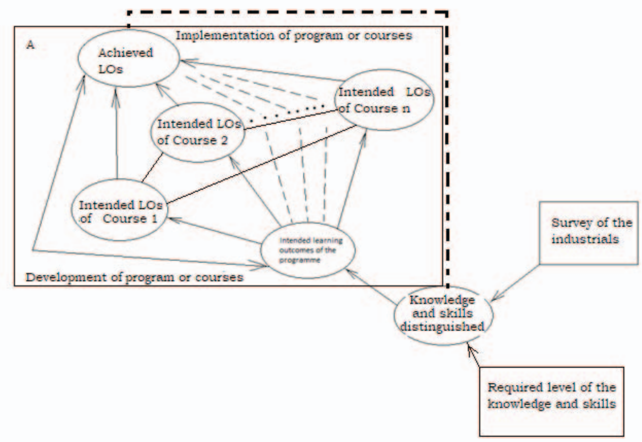


Fig. 1. The process of the LOs development within the scope of program and courses development

In order to get a correct feedback from the achieved LOs and to make a correct decision for further activity, the LOs should be measurable [3]. An appropriate estimation of the achieved LOs is possible in the case if the assessment methods within the course correspond to the evaluated LOs. In other words, the process of the LOs development includes the elaboration of the particular types of the knowledge and skills control (tests, exams, projects, etc.) correspondent to both the way and level of the studies and the LOs that should be estimated.

Learning outcomes are statements that specify, what students will know or be able to understand and to do as a result of a learning activity. Outcomes are usually expressed as knowledge, skills or attitudes. The learning activity could be, for example, a lecture, a module or an entire program. Learning outcomes must not simply be a "wish list" of what a student is capable of doing on completion of the learning activity. Learning outcomes must be simply and clearly described. Learning outcomes must be capable of being validly assessed [7,8].

Program learning outcomes describe the essential knowledge, skills and attitudes that it is intended that graduates of the program will be able to demonstrate [9].

There are two types of Learning Outcomes:

- Type that refers to those learning outcomes that can be assessed during the program, i.e. within the various modules.
- Aspirational or "desirable" learning outcomes indicate what a good quality student would be expected to achieve by the end of the program. This type of learning outcome may not be assessed at all but gives an indication to employers and other agencies the type of standard of practical performance that graduates of the program will display at the end of the program [10].

The linking point between the studies and their further successful application at the working place can be considered as the actions that a further specialist should be able to do at the output of each study activity and at the end of the all the studies generally.

The process of adjustments and enhancement of learning outcomes will be continued beyond the Physics project at least one year (for two-years master degree students), therefore the contribution of industrial partners as potential employers is inevitable. In our research we focus on application of appropriate assessment methods for learning outcomes. Assessment methods are the tools and techniques used to determine the extent, to which the stated learning outcomes are achieved.

III. Implementation and Results

In this project, we developed innovative curricular promoting industry-oriented, student-centered master-level curricular in the field of physical sciences in Belarus. This approach contains evaluation by the main stakeholders (students, teachers, researchers, employers, national accreditation institution and the Ministry of Education of Belarus) during the entire project life cycle. The education curricula has been developed and adjusted according to the stakeholders feedback in several stages (see Fig. 2):

- Gap analysis, which includes existing curricular analyses, elaboration of the best practices of EU partners and input from the industry representatives.
- Development of new curricular: learning, teaching, didactic materials, and development of learning tools.
- Accreditation of the courses and education programs.
- Ongoing obtaining of the feedback from teachers and students during the courses development process.
- Testing of new and modernized courses and obtaining feedback from stakeholders.
- Post-ante evaluation and feedback from potential employers.
- Feedback from external experts on quality assurance, conclusions, and adjustments of the curricula.

In the next chapters the authors describe the listed activities in more details.

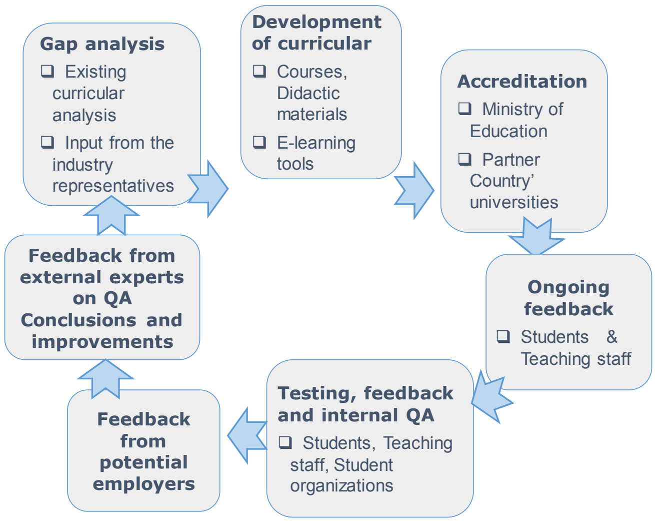


Fig. 2. Feedback from stakeholders on learning outcomes

A. *Gap analysis and ex-ante survey of the employers*

First, we evaluated existing courses and training programs in Belarusian partners' universities against the best practice of EU universities. Then, in the beginning of the project in February of 2016 we arranged a survey of professional associations, research institutes, and universities as employers of master graduates aiming to investigate the specific needs of the labor market in Belarus. The survey was developed using guidelines and recommendations of EU partners, which were slightly modified taking into account the educational and cultural traditions of Belarus [12].

The survey was conducted involving eight teams from four leading Belarusian universities (Belarusian State University - BSU, Belarusian State Technological University - BSTU, Francisk Skorina Gomel State University - GSU, Yanka Kupala State University of Grodno - GrSU), the Belarusian Physical Society - BPS (a non-governmental professional organization), the Research Institute for Nuclear Problems of BSU - RINP, and the Republican Association of Nano-Industry - RANI.

The survey targeted three fundamental issues on behalf of the future curricular. The first one was related to the industry – academia secondments, the second one was devoted to the adjustment of the educational tasks to the labor market needs in this sector, and the third issue was dedicated to the identification of missing entrepreneur skills and abilities.

The findings of the survey provided a fresh look and gave an aspiration to create the new curricula. Among recommendations obtained in the survey some of them required to renovate dramatically the teaching process of the master students. One of the recommendations was to reduce the time for studies of the "non-core" and social-humanitarian disciplines, since the training time at the undergraduate level will be reduced from 5 to 4 years. It would help to strengthen the fundamental training of master students in physical and mathematical disciplines, and to improve their general technical skill. The respondents recognized, the basic knowledge in "non-core" subjects may be obtained mainly at a level of secondary schools.

The proportion of theoretical and practical training for master level students was recommended from 1/3 to 2/3 – the number of hours for laboratory/practical training must exceed the number of lectures at least by 30 %. Additionally, about 75 % of the respondents have noted such skills as theoretical calculations, construction of mathematical models for physical processes and phenomena, programming, automation of the experiment.

It was advised to strengthen the training of master students in the field of programming skills and some specialized disciplines. Besides, it was recommended to introduce new disciplines related to physics of low-dimensional systems, nanotechnology, and biotechnology. It was recommended to attain general skills of working with control/measuring equipment and of mastering the computer science-related techniques. Master students should have knowledge in the field of general and theoretical physics, higher mathematics and mathematical physics, specialization disciplines (about 40 %).

I was also noted the need to establish stable interdisciplinary connections between the blocks of mathematical, physical, and special disciplines. Otherwise, the fundamental training may be degraded to a set of disparate information, therefore, the graduates could fail to acquire the adequate skills in solving of research problems or even can lose the ability to use their knowledge in practice.

After the team had concluded the survey, it became apparently that systematic changes in the approach to the teaching process of master students would be required. It was necessary to go from the "mere lectures" to a more balanced teaching approach involving both practical and theoretical training of master students. Therefore, learning outcomes have been adjusted according to recommendation of the survey.

B. Approach to develop new industry-oriented curricular

The project team developed a number of new and updated courses and labs: BSU: 21, GSU – 9, BSTU – 4, GrSU - 3 courses and laboratory practicums with the number of credit points 102. All courses were accredited by the universities. Furthermore, two Model (standard) programs were accredited by the Ministry of Education of Belarus: "Functional nanomaterials" and "Photonics". Due to excellent collaboration the consortium exceeded the targets, set before the project (see https://dl.bsu.by [11]).

The project partners also developed and uploaded in e-library five electronic books: Functional nanomaterials, Photonics, Applied physics, Applied informatics and Research towards master thesis. The chapters of the e-books are available in English and Russian. By now, three of them received ISBN numbers and are available via the Latvian National Library website. Collaborative elaboration of the e-books provided a multiplicative effect, since it promoted the exchange of knowledge between EU and Belarusian universities, between Belarusian universities themselves, as well as enhanced the development of new study programs, lecture courses and laboratory practices. For example, thanks to experience obtained in the practice-oriented training Grodno SU put in plans arrangement of the system of practice-oriented work in the 2018-2019 academic year.

Professional organizations, Physical association and Republican Association of Nano-Industry (RANI) were providing contribution through the all project life cycle. For example, RANI, which presents 19 members that include the institutes of National Academy of Sciences of Belarus, educational institutions, industrial and business organizations, advised about the content of curricula at the beginning of the project; its experts evaluated the courses materials at the end of the projects. RANI utilized the opportunity to attract students from the first courses to participate in the implementation of several fundamental and applied projects, conducted by the RANI members. All this helps to solve the issues of vocational guidance and promotes the involvement of high school students in scientific activities starting from junior years. This made the employment process of graduates more efficient.

A learning – teaching model in the ICT based learning environment was developed in the project. The model is based on a learning process embedded in a learning environment, taking into account the learning objectives, the student characteristics and the necessary evaluation and assessing of the students. The application of this learning model has been initiated by KU Leuven and developed together with Belarusian partners [14]. The training of the partners on how a digital learning environment facilitates to structure and follow-up the learning process was arranged by KU Leuven and RTU.

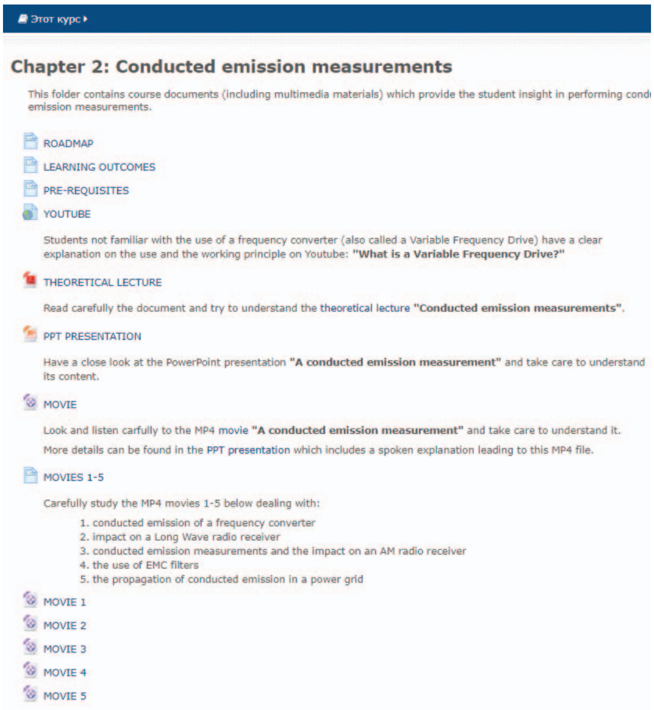


Fig. 3. Course material with LOs at e-learning platform

The learning model has been acquired by teachers, students and members of professional association during the workshops. Structuring the course contents into small compartments in order to allow the implementation in the digital learning environment was taken in account during the development of the course materials and exercises. The learning model includes all necessary components for the teaching process: roadmaps, learning outcomes, prerequisites, theoretical lectures, etc. (see Fig. 3). The open source software "Moodle" hosted by BSU was selected as the learning platform for introductions, demonstrations and practicing the use of an ICT-based learning environment. The platform forms a critical component for ensuring sustainability beyond the project, as learning and teaching material and will be used and developed after the end of the project.

C. The methods of students and teachers trainining and ongoing feedback on expected learning outcomes

In order to develop competences of staff in their field of expertise, to promote understanding of educational policies, practices and e-learning systems we arranged 11 workshops for teachers and students. The main topics of the workshops have been devoted to the development of content of the five electronic e-Books, to the topics of modernized curricula, to the Standard Programs accreditation in the Ministry of Education, to the acquisition of innovative teaching methods and electronic environments, to the curricula development, tuning, testing, and the analysis of testing results.

Additionally, teachers of Belarusian universities improved their professional English language skill at the course in KU Leuven in June 2017. Teachers training on novel teaching methods including ICT tools was arranged by RTU and KU Leuven staff in February 2018. Three students training courses were organized: at KU Leuven, University of Cyprus and RTU. Academic staff of Belarusian universities participated in the training as well as teachers and as trainee.

Students for the training courses were selected based on the degree of closeness of curricula for specialists and master-level students in the field of functional nanomaterials, photonics and applied physics. Selection of candidates for the training courses was arranged according criterions such as English language skill, academic progress and motivation of the candidates. The selection of the students was arranged through announcements and interviews on a competition basis. Participants, who would be involved in these activities, were informed, identified and selected in open way, for example, an announcement for GrSU students for training in Nicosia was published at YouTube. All these activities raised interest and motivation of the staff and encouraged competition among students for participation in the project activities.

EU and Belarusian partners created a system for getting a feedback from the students and academic staff, which were involved in the training courses as "ongoing feedback". This helped to evaluate some elements of new courses before the start of two years testing in Belarusian universities. Further, we offer an example of getting feedback on the course material and methodic.

In a frame of Physics, a group of Belarusian students and professors participated at the second training course arranged by RTU in September - October 2017. The targets of this training included:

- To get very prompted feedback, to analyze success and faults and start corrective actions, if needed, and to find evidences about whether learning outcomes could be achieved.
- To evaluate some elements of new courses before the start of two years testing in Belarusian universities.
- To introduce a new approach that promotes innovation competences acquisition by students.
- To get any comments, suggestions about the training method and what students and teachers liked and what could be suggested for improvements.
- To evaluate how the level of knowledge of English language impacts on the success of the training.

The training course was conducted by RTU, BSU and Belarusian Physical Society teaching staff. Belarusian partners were presented by 16 students, moreover, 5 Belarusian professors and lectors participated simultaneously as teachers, learners and evaluators. The majority of the students had started their fourth year' education course.

The survey was presented in the form of an anonymous questionnaire and answered by the participants at the last day of the training. The survey included a set of questions, where participants were asked to rate, according to their perception, the relevance of each of the following evaluation criteria, using a Likert scale from 1 (not relevant) to 5 (very relevant). The distance between each scale point is assumed equal, and 3 represents the neutral value in this scale.

Fig. 4. Students and teachers evaluation marks

We asked the respondents to answer to 11 questions. Ten of them were devoted to the content and quality of organization of the course. Furthermore, we included one question about English language skill, which, as we considered, could help to evaluate the ability of students to acquire learning material (see Fig. 4). The number of answers (21) was the same for all topics, reflecting that all participants were ready to provide answers about each topic. We observed differences in the means and the distribution of the answers provided by our participants, and we also analyzed the responses of participants slicing the answers by university' dimension. Additionally, one more dimension was analyzed together with the universities – Teachers (see Fig. 4).

Analysis of the answers revealed commonalities in the answers among the universities. For example, "The lecturer/professor's attitude to the students was positive and helpful" was evaluated by BSU students as M = 4.667, BSTU students: M = 5.000, GoSU students: M = 5.000, GrSU students: M = 5.000, and by the teachers: M = 5.000. However, we found significant differences in the answers among the universities. For example, "The time for the completing of the practical tasks was enough" was evaluated by BSU students as M = 2.000, BSTU students: M = 3.333, GoSU students: M = 3.800, GrSU students: M = 4.200, and by the teachers: M = 4.200.

Discussions of the findings of the survey:

- We noticed that evaluation marks given by GrSU students are closer to these ones provided by the teachers. It can be explained, because GrSU administration arranged selection of candidates for training courses according criterions such as English language skill, academic progress and motivation of candidates.
- We admitted that it is worth to include any direct question about self-evaluation of personal contribution to deliverables of the team a student participated.
- We found a direct link between English language knowledge and evaluation marks of the topics of the questions
- Taking into account divergent opinions expressed by different groups of respondents we need to look for appropriate balance between theoretical and practical parts of curricular developed in the project.
- Evaluation of the feedback demonstrated a high interest of trainees to obtain new knowledge and practice.

More deep analyses of students and teachers responses one can see [13].

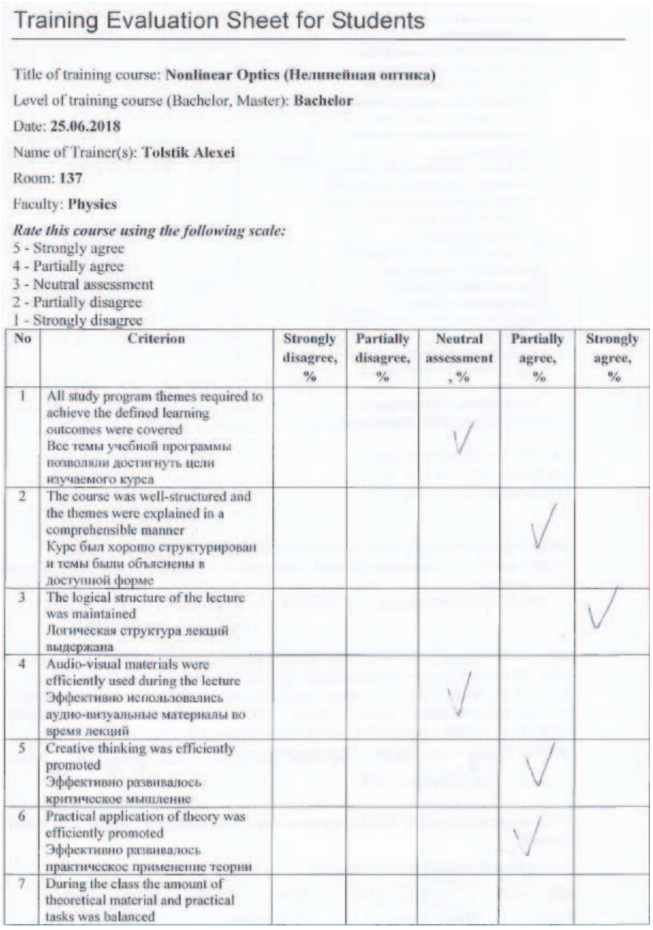
D. *Evaluation the outcomes of integrated courses and training programs*

All new courses were tested, and the outcomes were evaluated firstly in the autumn and then in the spring semester of the academic year 2017-2018. The target was to collect feedback from stakeholders: students, student organizations and teachers. For evaluation of learning outcomes, we applied (attitude based) indirect method: a survey.

For testing procedure, we used the students' questionnaire, which includes 12 statements. The students had to express their opinion that was graded in five degrees: from "Strongly disagree" by "Strongly agree". Additionally, the student had to answer to three open questions: "What did you like in the course?", "Outline three points you would like to take with you/have learnt in this class", and "Do you have any suggestions for further improvement of the course? (If so, please give details and if you would like to be contacted about this idea please include your email address)". The open questions would help to understand better, why a student agrees or disagrees with a particular statement about a training course.

We also asked a student to provide some additional personal information: gender (Male/Female/Prefer not to specify), age and origination (domestic or EU student).

At Fig. 5 you can see an example of a filled in student' questionnaire. Due to lack of space we showed only the first page of the questionnaire' sheet.



Training Evaluation Sheet for Students

Title of training course: **Nonlinear Optics (Нелинейная оптика)**

Level of training course (Bachelor, Master): **Bachelor**

Date: **25.06.2018**

Name of Trainer(s): **Tolstik Alexei**

Room: **137**

Faculty: **Physics**

Rate this course using the following scale:
5 - Strongly agree
4 - Partially agree
3 - Neutral assessment
2 - Partially disagree
1 - Strongly disagree

No	Criterion	Strongly disagree, %	Partially disagree, %	Neutral assessment, %	Partially agree, %	Strongly agree, %
1	All study program themes required to achieve the defined learning outcomes were covered Все темы учебной программы позволяли достигнуть цели изучаемого курса			√		
2	The course was well-structured and the themes were explained in a comprehensible manner Курс был хорошо структурирован и темы были объяснены в доступной форме				√	
3	The logical structure of the lecture was maintained Логическая структура лекций выдержана					√
4	Audio-visual materials were efficiently used during the lecture Эффективно использовались аудио-визуальные материалы во время лекций			√		
5	Creative thinking was efficiently promoted Эффективно развивалось критическое мышление				√	
6	Practical application of theory was efficiently promoted Эффективно развивалось практическое применение теории				√	
7	During the class the amount of theoretical material and practical tasks was balanced					

Fig. 5. An example of a filled in student' questionnaire of Belarusian State University

As an example, we consider the results of courses testing at BSU at the Spring semesters of 2017-2018 education year. It was carried out at three departments of the Faculty of Physics, which students are specialized in the directions "Nanomaterials and nanotechnologies" and "Photonics" with a specialty "Physicist Engineer". The consolidated feedback related to three new developed courses was evaluated.

The date of testing: April – June of 2018. Statistics on the answers is given on the course in percentage. Questionnaire forms have been proceeded: 31. Questionnaire forms were found valid: 31 (see Table 1).

Looking at the results we noticed that a large positive feedback ("Partially agree" and "Strongly agree") was received about the lecture course Nonlinear Optics – 88.8%. However, the other two courses received less than 80% i.e., 79.6 and 73.6 respectively. The results point out that the LOs of two latter courses have been achieved partially, therefore corrective actions are needed before the beginning second education year of master-level students.

TABLE I. THE STATISTICS OF STUDENTS RESPONSES

Course title	Degree bachelor, master	Testing results				
		Strongly disagree %	*Partially disagree %*	*Neutral assessment %*	*Partially agree %*	*Strongly agree %*
Nonlinear Optics (lecture course)	4-year course	1.6	0.4	9.1	22.7	66.1
Semiconducting devices (lab. practice)	4-year course	0	6.5	11.7	39	41.6
Integrated Environment for Engineering Computing (lab. practice)	4-year course	4.2	8.3	13.4	29.1	44.5

A questionnaire created for teachers asks to evaluate, how the students acquired the course material and requires to provide analysis of the competences, which students obtained during the semester, e.g. "development of critical thinking", "causal-investigatory analysis", "development of practical experience and skills", etc. The teachers are also asked to give suggestions about activities aiming to achieve LOs. Among the teacher's answers one of the most significant recommendation was "*To consolidate lecture materials, it is necessary to supplement the preparation of students with practical exercises and (or) laboratory practical works*". This recommendation is in align with the recommendation of the employers survey, arranged at the beginning of the project (refer to the chapter "A. Gap analysis and ex-ante survey of the employers").

E. Post-ante evaluation: a feedback from the industry

Since the potential employers were involved in the development of new curricula throughout the whole life cycle of the project, we arranged a post-ante survey close to the final stage of the project. For the project team, it was crucially to get evaluation of the main project deliverables from the experts, who represent the industry and employers.

The components of a measurable program outcomes can be considered quite similar as for learning outcomes, excepted that the actors of the programs are not the student, but potential employers. Therefore, we applied indirect assessment methods as a combination of satisfaction surveys (peer institutions benchmarking).

In February 2018, the BSU conducted a survey of experts represented employers (post-ante) on the evaluation of LOs. The main tasks of this survey were:

- Review of curricula in the specialties "Functional nanomaterials" and "Photonics" for a 2-year practical-oriented magistracy with in-depth training.
- Review of the curricula of courses and laboratory works for the specialties "Functional nanomaterials", "Photonics", "Physics" and "Nanomaterials and nanotechnologies" for the training of specialists in the field of physical sciences within the framework of the 4-year (bachelor) and 2-year master's degree of the teaching cycles.
- Accumulation of ideas for the completion of the formation in Belarus of a system of higher education of the European type "4 plus 2", which should comply with the principles of the Bologna process and strengthen the training of specialists for the high-tech industry and modern science.
- Comprehending the requirements that employers (research institutions/enterprises/ universities) impose on the training and qualification programs of graduates of a practice-oriented magistracy.
- Identification of the requirements that employers (research institutions /enterprises/ universities) apply to the process of training of bachelors with the 4-year cycle of training and undergraduates with the 2-year training cycle.

All questionnaires were sent to responders by e-mail. The answers, received in the form of questionnaires' scans, were sent by mail of by post. For the review, two types of questionnaires were proposed: a curricula questionnaire and a questionnaire for the evaluation of the courses and laboratory study programs. Each questionnaire included two types of questions. One type of questions requested information about expert (age, position, professional experience in education, science and industry, gender, etc.). The second list of questions included information concerning the expert's opinion on the quality of curricula and study programs and solicited suggestions for improving the curricula and study programs.

For each expert, depending on the experience in the field of education, it was offered from 2 to 5 approved curricula, courses/laboratory study programs.

The experts evaluated curricula, which were approved by the Ministry of Education of the Republic of Belarus:

- Master's degree program 81 03 Functional nanomaterials_2 years
- Master's degree program Physics of Nanomaterials and Nanotechnologies_1 year
- Master's degree program 81 02 Photonics_2 of the year 2017
- Master's degree program 1-31_81_02 Photonics_1 year 2012.

Additionally, the experts evaluated training courses and laboratory works (totally 9 pieces) that were developed in the "Physics" and approved by the Rector of BSU:

- Physical chemistry of the surface
- Optics of nanostructures

- Spintronics
- Nanomaterials in power engineering
- Trends in the development of electronics and electronics
- Nanotechnology in electronics
- Optoelectronics and microelectronics
- Coherent optics and holography
- Conducting composite nanomaterials

A total of 9 experts were interviewed, according to the specialization profile of the curricula and programs: 4 from RANI (mainly the laboratories of the Institute of the National Academy of Sciences of Belarus), the heads of the departments and laboratories of Belarusian universities, three experts from the Belarusian Physical Society (BPO) (the management of the BPO Presidium), two from Research Institute on Nuclear Problems (Deputy Director and Leading Scientific Researcher) and one of The Belarusian-Japanese private enterprise LOTIS-TII PE ltd. (leading engineer for production of high-tech products). Since all named organizations represent the employers of Belarusian graduates, we can consider the survey as quite representative. Furthermore, these organizations represent the majority of research institutes of the National Academy of Science of Belarus.

The analysis of the results of answers to the questions is presented in the form of two tables: "Summary Table 1 of the answers to the questions in questionnaires for validated curricula", "Summary Table 2 of the answers to the questions in questionnaires for courses/laboratory study programs" and "Summary Table of professional experience of participants in the survey on courses/laboratory study programs". We do not publish them due to the lack of space (it can be seen on the web of BSU [11]). The filled in questionnaires contain comments and suggestions about the programs and the courses, which are very useful to tune the education programs before the second year testing, which is planned to be done beyond the project.

The preliminary conclusions acknowledged benefits of collaboration with the potential employers for successful achievement of LOs during the all life cycle of elaboration of the education courses and programs:

- All the survey' participants approved the need for the transition of higher education in Belarus to the Bologna 4 + 2 system, which is justified by the statistics of answers to the questions and explanatory notes to some of the questions.
- All the survey participants approved the need for the introduction of training programs in the specialties "Functional nanomaterials", "Photonics", "Nanomaterials and nanotechnologies".
- Approximately 90% of the interviewed experts confirmed the importance of the introduced courses and laboratory works, although the programs themselves have certain comments that will be used to correct (tune) them.

CONCLUSIONS

This research demonstrates that the development of new study programs and courses should be based on current or future societal needs, i.e. on the labor market requirements for public or private research and development. Therefore, in order to succeed LOs potential employers should be involved early in the process of a new study programs and courses development, for example through employer panels, surveys, even as authors of the course books, and etc.

Taking into account divergent opinions expressed by respondents of the ex-ante survey in the beginning and the post-ante survey close to the final stage of the project, we need to look for an appropriate balance between theoretical and practical parts of a curricular developed in the project. This can be a subject of research beyond the Physic project.

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