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Designing General Engineering Module for Bachelor's Production and Technology Programs

Ural Federal University named after the first President of Russia B.N. Yeltsin

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The article describes the experience of "General Engineering" module development for the educational program of Higher engineering school of UrFU. Being developed in the context of relevant international projects and initiatives, the module is designed as interdisciplinary, practice-oriented and student-centred. There are examples of the module learning outcomes correlated with the methods of their development and assessment. The main idea of the module design is the development of the process map which includes the module learning outcomes, achievement indicators, methods to define the module learning outcomes and the course content. Special attention is paid to assessment tools, in particular to the interdisciplinary project.

Key words: interdisciplinarity, the module learning outcomes, assessment of learning outcomes, educational project, internationalisation of education, standards CDIO initiative.

In this work we would like to share the experience in designing module-based bachelor's program "Production and Technology" of UMMC-UrFU describing one of the program modules.

Let us consider some learning outcomes of bachelor's program "Production and Technology", which are stated in the Higher engineering school standard [1], developed by faculty members and approved by the Scientific Council of UrFU. Upon completion of bachelor's program "Production and Technology" the graduates are to be able to:

- apply the system of fundamental knowledge (mathematics, natural-science, engineering, economics) to identify, define and address profession-related issues;
- apply efficient methods of information processing in professional activity, using modern IC-technologies;
- plan and provide experimental and industrial testing and analyze the data obtained ;
- analyze scientific and technical information, observe national and international experience in the sphere of professional activity;

etc.

The methods to define learning outcomes of the module largely overlap those to define learning outcomes of the educational program. While the expressions may be different, they should be within the same semantic scope, and the learning outcomes of the module are to be correlated with the learning outcomes of the program itself [2]. Interdisciplinary projects play an important role in learning outcomes assessment [3], which allows us to avoid fragmented information and connect the disciplines within the module.

The learning outcomes may be defined in details with regard to different disciplines but at the level of a separate discipline it seems to be more efficient not to define the learning outcomes but to determine the indicators to measure the results. In this case the connection between the module learning outcomes, the indicators of the achievements at the level of the separate discipline, the course content and assessment procedures is transparent. It is indubitable that the learning outcomes should be connected with the other modules. The number of learning outcomes is directly dependent on the size of the module and is about 5-7 outcomes on average.

Let us turn to the development of module learning outcomes by the example of the module "General Engineering" which is included in the basic bachelor's program "Production and Technology", developed and implemented by UrFU.

The aim of the module, that is "to develop the scientific worldview and the skills to apply general engineering knowledge for scientific and technical task solving", was defined according to the competences designated in bachelor's program "Production and Technology" (Metallurgy) – practice-oriented training of engineers and technicians of the lowest and middle levels of management structure under the order of UMMC.

To reach the aim vertical and horizontal relationships between course curriculums within the education program were improved and the list of integrated competencies, which are to be developed in the result of the multidisciplinary module learning, was designed. Upon completion of "General Engineering" module the student will be able to:

- find out the matter of problems which he/she faces within professional activity; determine the sphere of engineering knowledge; use appropriate physical tools and mathematical methods to solve problems.
- design mathematical modules for engineering tasks.
- plan and carry out theoretical and experimental research, counting, and data analysis.
- use modern software products and information services to solve engineering tasks.
- design engineering and workshop documentation in accordance with standards, technical requirements and other prescriptive documents.

This is how the learning outcomes of "General Engineering" module were designated in bachelor's program "Production and Technology" of UrFU.

Let us give an example of an achievement indicator at the discipline level – "to identify the sphere of general engineering knowledge". This indicator reflects the ability of the student to refer the task to the sphere of engineering knowledge. To assess the outcome of "using modern software products and information services to solve engineering tasks" such indicators as using file lockers, e-mail, on-line calculators, e-learning tools etc. are applied.

Designing the module of the education program one should pay special attention to developing the methods to achieve and assess the outcomes. It is indisputable that active learning methods should be regarded as predominant when choosing the methods to obtain desirable outcomes, the educational tools, the educational resources and techniques. There are no doubts that active learning methods are the methods of future. As for assessment tools, the range of them is still limited, which is the result of the traditional curriculum. There is a quotation by professor D. Hawker, a consultant of the World Bank and an expert in education reforming and education quality assessment, which is to the point here: «Assessment system caters for education but not visa verse».

About 85 per cent of a diverse range of assessment tools are those to identify weak points and lack of knowledge. It is these assessment tools that are included in our curriculum: exams, pass-failed tests and graded tests. But they all presuppose remembering, immediate knowledge. The test checks the knowledge, while it only partially deals with comprehension. Tests, homeworks, reports, essays and others reflect a single and particular achievement.

What is the way to find out how much the student knows and what he/she can do? More and more often teachers use contextual tasks and case studies which expand the possibilities of assessment criterion application. Doing contextual tasks and working with case studies the student learns how to use the abilities and apply the skills, acquired in the process of education, not only within the scope of educational environment but also beyond it.

In our opinion, the project can be regarded as a special tool which represents integrated assessment of a range of knowledge, abilities and skills. The project may be a part of the student's portfolio and represent the dynamics of educational process. Therefore, the project was chosen as the main tool to assess the achievement of module outcomes.

There is no particular method to assess all learning outcomes so it is necessary and perspective to use several tools of assessment.

Within the module "General Engineering" the following assessment tools were chosen: testing (process monitoring and intermediate control), to esteem knowledge, an element of rating system of UrFU. The students familiarize with the base of test tasks in advance. The students submit their reports on laboratory works. Discussion of case studies takes place. The competition of contextual tasks solutions is held. The final pass-fail test is the tribute to traditional curriculum. The interdisciplinary project plays a special role in the educational process and we will turn to it later.

So, we have figured out the aim of the module, outlined desirable module outcomes, compared the indicators of the outcomes and proposed the methods to obtain and assess them. The next step is to develop the content of the course which will determine the disciplines of the module. Let us regard a fragment of the process map of "General Engineering" (Table 1). The content of the course specifies the disciplines to be taught, as well as the blocks within the latter.

The disciplines of "General Engineering" module are: engineering graphics (perspective geometry, machine drawing, computer graphics); mechanics (mechanics theory, mechanics of materials, machine elements and principles of design); materials science; metrology, standardization and accreditation.

Let us take as an example the discipline of engineering graphics which, according to the process map, is to contain the following blocks.

Block 1. Perspective geometry

The perspective method of space representation. Orthogonal projections. The ways of drawing conversion. Surfaces and their interactions. Axonometric projections.

Block 2. Machine drawing

The notion of standardization. The standards of USDD (Unified System of Design Documentation). How to draw and mark a component's parts. Sketches. Shop drawings. Assembly drawing.

Graphs, tables and diagrams making. Rendering. Computer-assisted drawing systems. Higher education institutions adapting to Federal State Educational Standards, the aim of modern engineering education is to make the educational process less fragmentary. It is possible to meet this goal by implementing project-oriented learning in practice-oriented bachelor's programs.

We turn to the crucial point – the interdisciplinary project within the scope of which students improve their integrated competences, demonstrate the knowledge of terms, methods,

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Table 1. The Fragment of the Module Process Map.

Learning outcomes	Indicators	Assessment tools	Teaching methods	Module blocks
Upon completion "General Engineering" module the student will be able to design workshop documentation in accordance with the requirements.	The students make drawings of items in accordance with standards in force. The student is able to get through the drawing the form of the parts and there correlations within an assembling item. The student uses computer graphics to work with design documentation. The student is able to find, use and compile documents within the spheres of metrology, engineering law, standardization and accreditation.	Knowledge testing. The defense of the interdisciplinary project stages. The test in the form of the work presentation.	Practice classes oriented towards the interdisciplinary project. Laboratory work in well-equipped classrooms. Individual and group work on documents design. Students' works presentation and defense.	Orthogonal projections. The ways of drawing conversion. Surfaces and their interactions. The notion of standardization. The USDD standards. Component's parts drawing. Shop drawings and sketches of components. Types of components joining.. Assembly drawing. Detailing. Graphs, tables and diagrams making. Rendering. Computer 3D-technology for design documentation. Engineering law and standardization. Conformity assessment.

information technologies and spheres of learning outcomes application. The aim of the interdisciplinary project is to assess the achievement of module learning outcomes. It includes simple examples of project design stages, which help to demonstrate how fundamental knowledge to be applied and provide the integrated assessment of the student's activities. The project will become an important part of the student's portfolio.

The interdisciplinary project is to be completed within 4-5 semesters. The stages of the project are detailed design based on the device application, which implies component design and specifications; static, kinematic, dynamic and structural analysis, which includes analytical models, choice of solution methods, mathematical models, solving of the simplest optimization problems. In the result of decision analysis the geometry dimensions of the product are specified by means of the terms of references, the materials and components are chosen (power, rolled stock, bearing parts, cable etc.) While calculating and preparing specification, component drawings and the assembly drawing are produced by means of a computer-assisted drawing system (AutoCAD, COMPASS, Autodesk Inventor etc). The design documents are prepared in accordance with the standards of USDD. Engineering documentation connected with metrology, engineering law, standardization and conformity assessment is prepared. The choice of material is based on specified operation conditions with due regard to technological and economical requirements, as well as the product being reliable and long-life. The student's high level of knowledge and skills is obvious through 3D-modeling and dynamic visualization of detailing and assembling.

It is important that the number of practical and student individual tasks is constantly increasing throughout the module. The amount of hours spent on theory and illustrating examples should be minimal but sufficient, while more time should be devoted to creating analytical models and getting information of those calculation methods which will be applied during the interdisciplinary project. It is noteworthy that in the curriculum the hours necessary to get acquainted with information technologies and programming software are not compiled within a separate discipline but included into diverse modules.

If there is lack of time and it is impossible to pass though all stages of product design, the project may be reduced to component design and the team-based method of work may be applied (when subassemblies are designed by different students). This way students acquire an important competence – team work abilities and skills. There are two ways to organize team work: different tasks for five or six teams or three sub-tasks for united teams.

Let us turn to the interdisciplinary project the goal of which was a simple mechanism of electric hoist. There was a group of 25 students. 19 students actually participated in the project. There were five teams with different numbers of students; from two to six members in a team. The roles were distributed on the basis of students' relevant skills. Some students made accurate calculations, others gathered and analyzed the information, yet others prepared presentations and reports. The students were not eager to appoint the project manager since management is not an easy thing for them.

There were different approaches to solve the problem. The levels of complexity were determined by the students. For example, designing the bar which hold the electric hoist, one team reduced the hoist and the load it lifts to the concentrated force; the other team made the task more complicated having substituted the electric hoist with load by evenly distributed load and considered the components parameters and dispositions. The third team took the electric hoist as evenly distributed load plus additional load in terms of the concentrated force. There was an attempt to consider the electric hoist moving: there were several calculations depending on the position of the hoist on the holding bar and the most critical value was chosen.

The results of the work fulfilled within the interdisciplinary project were checked by means of production programs provided for educational purposes (calculation of coiling length of the drum, engine displacement and other parameters). The tutor of the group, professors of the graduating department and the employer representatives were invited for the projects defense. The students made presentations, answered the questions and got the experts' feedback. The experts made a note of team interaction and distinguished the leaders. The students were offered to fill in the form to assess their personal contribution to the project, the contribution of the team players and other teams' presentations. The final conclusion was made through the integration of these assessment lists.

The project is time-consuming: it takes the teacher much more time than a traditional course does. Working with the project the teacher has to analyze information gathered by students, monitor studying pathways, check the calculations, which were made through individually created formulas, work with assessment lists and the rating system , provide e-learning; the latter means creating a new form of materials representation and impossibility of materials direct conversion, "student-teacher" system of interaction being immature, students' being careless of time limits and, as a results, often shifts of the project deadline. The project increases the time of students' individual work as well: information search and analysis, preparing presentations, team work (team players transferred from one group to the other several times during the semester).

Implementation of these projects into practice-oriented bachelor's curriculum will broaden students' horizons, help them comprehend the disciplines being interconnected and also clarify some aspects of their professional activity.

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