project supervisors who would formulate workplace-related design and technological tasks (cases, projects) and take part in development of joint research projects, industrial initiatives and startups.

Secondary schools should promote active participation of pupils in various competitions and contests in engineering and art. However, the basic priority for pupils is to take part in All-Russian Pupil Olympiad in Technology JuniorSkills, regional youth contests and projects aimed at developing design art, project thinking, and entrepreneurial skills.

The research is carried out within the framework of the governmental contract with the Ministry of Education and Science of the Russian Federation no. 2016-02.04-08-№79-F-8.03 "Research on developing of innovative teaching-methodological support in the context of implementation of the subject-oriented concept"

REFERENCES

1. Oreshkina, A.K. [i dr.] Podhody k modernizacii soderzhaniju i tehnologij obuchenija v predmetnoj oblasti "Tehnologija" [Approaches to revicing content and teaching methods in the subject area "Technology"]. Shkola i proizvodstvo [School and industry]. 2016, no. 8, pp. 14–18. (In Russ., abstr. in Engl.).
2. Mahotin, D.A. Tehnologicheskaja gramotnost' obuchajushhihsja kak rezul'tat obshhego obrazovanija [Technological literacy of pupils as a result of secondary education]. Profil'naja shkola [Specialized school]. 2015, Vol. 3, no. 2, pp. 8–15. (In Russ., abstr. in Engl.).
3. Novikov, A.M. Postindustrial'noe obrazovanie [Postindustrial education]. Moscow: Egves, 2008. 136 p. (In Russ.).
4. Novikov, A.M. [i dr.] Metodologija: slovar' sistemy osnovnyh ponjatij [Methodology: dictionary of system basic notions]. Moscow: Librokom, 2013. pp. 110–113. (In Russ.).
5. Mahotin, D.A. [i dr.] Sovremennye podhody k razvitiju tehnologicheskogo obrazovanija v obshheobrazovatel'noj organizacii [Modern approaches to developing technological education at schools]. Mir nauki, kul'tury, obrazovanija [World of science, culture, education]. 2015, no. 4, pp. 65–68. (In Russ., abstr. in Engl.).

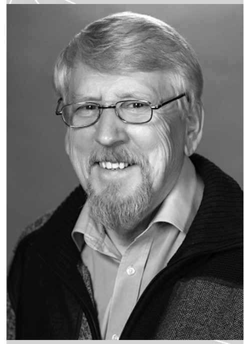
UDC 378.4, 372.862

Innovative Technology for Mass Training: Case Study of e-Course "Mechanical Engineering"

Ural Federal University named after the first President of Russia B.N. Yeltsin
S.A. Berestova, N.E. Misyura, E.A. Mityushov

S.A. Berestova

N.E. Misyura



E.A. Mityushov

The paper describes a course "Mechanical engineering" set up on the National Open Education platform. The course has a well-balanced system of authors' solutions, special practice-oriented tasks that encourage students to learn and develop engineering thinking. The disguising features of the course are weekly-based structure that allows controlling students' independent work, a practical-cognitive module, and an interactive programming module.

Key words: e-course, open education, engineering thinking.

According to the current Federal Education Act [1], when implementing educational programmes the universities may use e-learning beyond the traditional educational technologies. The State Programme of the Russian Federation "Education Development" for 2013–2020 [2] has determined the priorities of the state policy in the higher education sector. Among the major priorities there are introduction of open learning; wide application of information-telecommunication technologies; ensuring information transparency of education system for the society; development of high-tech educational environment.

The technologies and priorities mentioned in the Act and described in the State Programme reflect the international trends of education development [3, 4]: mass character and internationalization which entails: changes in learning technologies taking into account modern engineering and social-humanitarian achievements; significant transformation of lecture-seminar learning model; wide use of on-line courses; implementation of active learning methods.

With the launch of the National Platform of Open Education openedu.ru there appears an opportunity for students to transfer credits supported by a certificate on the suggested on-line courses in Russian universities when learning programme of Bachelor's or Specialist's degree. The focus on engineering learning content is a path that the course authors have chosen. The authors did not only use technical potential of the National Platform at the most, but also changed the course content in many aspects due to its filling in with practice-oriented problems.

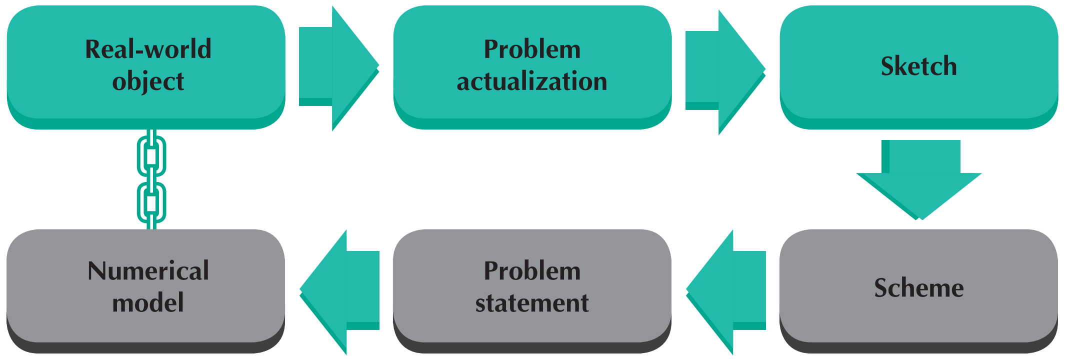
Designing the course to form the bases for engineering thinking, the task was set to motivate students to use all the variety of methodical innovations and potentials of information-telecommunication technologies. For this purpose, modern electron methodical content was developed in a wide range of information formats: lectures and examples of problem solutions accompanied by visual materials of actual process and phenomena; interactive learning manuals with comments of incorrect solutions; theoretical test questions and context problems on calculation of real constructions and mechanisms with a wide range of parameters; home assignments supported with stage-by-stage solution and stage-by-stage automated check; basic projects including several course sections. The pool of practice-oriented problems, tests, home assignments, basic projects with videos of real processes and phenomena, their sketches was formed. Multi-optional resource of testing and assessment materials was collected to perform weekly unbiased assessment of learning outcomes independently and automatically. Project-based technology was adjusted to e-learning using the basic project with implementing the authors' research results into learning activity including works of the course authors performed with students.

The concept of electron learning resource development on "Engineering mechanics" results from the existing problems in the sphere of engineering training, namely, the disbalance between stake-holders' demands and potential of traditional engineering staff training in universities that, in most cases, exists in implementing educational programmes based on the Federal State Standards of higher education. The need to confront those difficulties results in demand for the transfer from traditional education which can be compared to filling-in the repository with knowledge accompanied by a set of exercise on brain jogging towards active content interaction with the realities of today's world. Considerable progress towards the reforms of basic engineering education can be made under the condition of organic integration of best traditional practices with cognitive-applied methods widely using information-telecommunication technologies.

The reform concept of Bachelor and Specialist general engineering training chosen by the authors on the basis of their experience is focused on motivation of students' learning activity to train them both for studying the profession and self-education and self-development. The key authors' solutions are aimed at applied training to learn the world around, its spatial and quantitative relations.

A visual representation of cognitive-applied module connection with its traditional structure is given in fig. 1 showing students' learning activity in the training process. Following the traditional integrated unity of learning form and content, the additional cognitive-applied module allows a student to be involved in motivated active creative cognitive activity starting from basic training. In this case, students are to develop individual work skills to acquire knowledge using different information sources: traditional textbooks, electronic textbooks, Internet resources, mutual consultations, and teachers' consultations. The context problems included in the course allow transferring the real world processes and phenomena into numerical models with clear understanding of practice-oriented problem statement. The course problems (analysis of forces in bridge rods, jib crane construction, racers' and pilots' overloading, positioning of laser lathe knife with numerical programme control, etc.), and particularly individual tasks of basic project with the elements of real engineering

Fig 1. Traditional connections ( ) and new additional cognitive-applied module ( )



solutions provide harmonic continuous shift to the study of professional disciplines.

Apart from traditional teaching, the section of fundamental training is added with a module shown in fig. 2 to make it more practice-oriented.

The potential of inversion is applied as a form of theory delivery. Fundamental knowledge is either visualized by illustrating real world processes and phenomena or illustration is followed by theory delivery. Change in conception of mechanics teaching contributes to the increase in efficiency of learning outcome achievement.

"Engineering Mechanics" course is aimed at implementing educational programmes for the profile of "Engineering and technical sciences". The course contains structured presentation of main concepts and principles of mechanics, description of numerical modelling techniques of engineering constructions and typical models and mechanisms. The course content is focused on students' preparation for learning other disciplines of the education programme profile. The course considers equilibrium and motion of mechanical systems in combination with mathematical rigor based on key concepts and theorems of mechanics. Traditional theory is accompanied by analysis of only practice-oriented problems with construction of 2D and 3D analytical models.

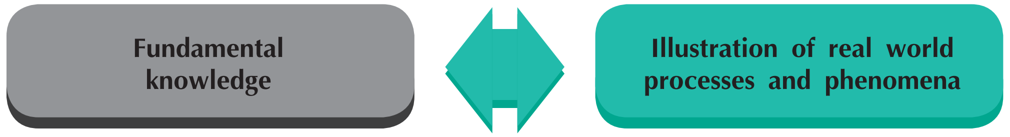
After learning this course a student will be able to: describe equilibrium and motion of a single mass point, system of mass points, and a rigid body system using the key concepts, laws, and theorems of mechanics; construct 2D and 3D analytical models describing the equilibrium and movement of typical engineering bodies; select a numerical model to determine geometrical parameters and power loads in the problems of engineering body's equilibrium and motion; study motion of parts in typical machines and mechanisms; determine kinematic characteristics of parts in the typical machines and mechanisms in their motion; apply mathematical operations in generation and solution of equations describing equilibrium and motion of engineering bodies in terms of designed mathematical models.

The methodical innovations are based on the teaching experience in one of the leading universities, namely, Ural Federal University named after the first President of Russia B.N. Yeltsin. In 2006, the authors of the course published the textbook [5] approved by the RF Ministry of Education and Science. In 2011 the second edition of the textbook was issued for Bachelor's syllabuses [6], in 2012 – book of problems [7]. The authors have upgrade certificates including those of on-line courses on mathematics, physics, and mechanics on Coursera international platform. The authors continue their professional development introducing the concepts of modern engineering education in learning process, for example, Conceive – Design – Implement – Operate (CDIO). The results of authors' practical research are aimed at increasing the efficiency of learning in the sphere of engineering education.

The technological means of increasing the learning efficiency are provided by maximal using of tools on openedu.ru platform and potential for its filling-in with original software (interactive problems) on "Engineering mechanics" course taking into account its specificity.

The successful course completion is ensured by regularity of students' work and their active participation in on-line

Fig 2. Traditional forms of learning ( ) and new additional cognitive-applied module ( )



discussion of specific challenges with each other and with teachers.

When designing the on-line course on "Engineering mechanics", the original authors' techniques aimed at potential of openedu.ru platform were implemented in learning process.

To make an emphasis on the key learning concepts, differentiate learning process in terms of students' level of skills, motivate students for regular learning, the learning material is equally divided into chronological parts (weeks) according to its workload and time consumption of doing learning and monitoring tasks. There is a uniform delivery of learning material and students' study time per a week cycle.

Motivation for cognitive-applied learning activity is supported by the content of theoretical learning material with the illustrations of purely practice-oriented content presented by video of real processes, animations, photos, and sketches of engineering bodies that precede the problem statement. The research problem parameterization is carried out with specific consideration of the range of possible changes in geometrical, physical, constructional, and engineering characteristics of real engineering objects and processes with their participation. This approach provides the shift in students' minds from solution templates and fragmented information towards integrated perception of real problems with the focus on engineering tasks within the basic training. Context problems and creative tasks are included into basic projects that, together with possibility of training individualization, promote the students to actively search for additional information, simulation and full-scale modeling, learning the world, its spatial and quantitative relations. Each task is aimed at development of practical skills in numerical calculations using developed mathematical models with assessment of error output that envisages calculations using scientific calculators. To apply the results of problem solution into further practice, a student is to choose a unit system which, in each case, is related to a definite research object. The course contains only examples or problems in which model parameters correspond to its physical meaning or engineering content.

The means of modern information-communicative technologies are widely used in 'student-learning material' interaction. The special software is designed to verify the accuracy of graph construction of a free solid body. As a result of intensive interaction with the virtual environment and interactivity, a student acquires the skills in graph construction (external forces and constrained forces) when performing monitoring tasks. Solving the learning problems a student has a possibility to obtain a correct answer without limitation due to the developed automated system and work with comments of possible error register. The designed software is used to present kinematic magnitudes graphically.

To develop student research skills and engineering thinking, the on-line course comprises a basic project of simulation model development of a real engineering body. Problem statement of the project can vary in compliance with educational programme profile. The basic project is performed step-by-step during several weeks. The final stage of basic project implies students' independent assessment of their creative section.

The course implementation has shown that a teacher can supervise the class of 500 students owing to students' involvement into tutorial activity.

To scale-up the monitoring and individualize their performance, a data selection system was developed for control-assessment materials. Nearly unlimited variability of control-assessment material is achieved through the software designed to change parameters by means of built-in randomizer. In this case, the changes in variable parameters are defined by analysis of real processes and phenomena, the mathematical models of which have been developed. It also relates to geometrical parameters, kinematic, dynamic, and other magnitudes. In some cases the model parameters were obtained from dynamic problem solutions not included in the given course, but providing the adequate image of engineering problem statement. The examples are the selection of: steering angle of an automobile, automobile motion law when doing a looping-the-loop, automobile motion parameters along a highway, parameters of plane aerobatics operations etc. Selecting the data for the problems set, the course authors sought for constructional, geometrical, technological, physical parameters in references, engineering literature, patents, standards, in research journals and Internet.

The course provides the connections with pre-requisites and co-requisites as well as a unity of basic education. The earlier acquired knowledge on many natural and engineering disciplines is organically built in the course. Besides, the possibility of using the information in post-requisites is described. The examples are skills used in generating curves, differentiation and integration of composite functions, engineering graph skills in pictorial projection construction, physical knowledge of common concepts of speed and acceleration, competence of using information technologies, such as 3D-modeling, motion animation, transfer from mathematical model to process programming, use of on-line calculators in engineering calculation and on-line tools to plot graphs of the function parametrically set, etc.

In January, 2016, at the Gaidar Forum German Gref in his report told about on-line learning and education: "I generally do not believe in on-line education of the previous century. On-line learning has to be radically changed. Now it is still the same as traditional one, i.e. we have transferred traditional education into on-line. In our opinion, both the former and the latter…, are losers. On-line course will be used, but the learning content will be completely different and teaching methods will be completely different. We need to change the model of education")[1].

The launch of "Engineering mechanics" course on the National Platform of Open Education has shown its efficiency in training second-year students of Ural Federal University. At mid-year exams the students' performance indicators far exceeded similar indicators of the previous year. The examination of electronic learning (table 1) took place on-line with personal identification without direct teacher's participation in examination.

The main result is radical changes of content and form of traditional material delivery on mechanics. For educational programmes of "Engineering and technical sciences" profile "Engineering mechanics" course lays the foundation for achieving the learning outcomes of engineering modules [8], which involves interdisciplinary project [9] and demonstrates the unlimited potentials of on-line techniques.

Table 1. The number of students taught by different methods

	Students of on-line course, 2015	UrFU traditional learning, 2014-15	UrFU electronic learning, 2015-16
The total number of students	517	323	186
Students with high learning outcomes	292	213	179

[1] The Gaidar Forum. 2016:report by German Gref URL: https://www.youtube.com/watch?v=Tkj3sE492To

REFERENCES

1. Ob obrazovanii v Rossiiskoi Federatsii [Elektronnyi resurs]: fe-der. zakon ot 29 dek. 2012 g. № 273-FZ. [On education in the Russian federation]. Moscow, 2012. 404 p. URL: http://minobrnauki.rf/documenty/2974/file/1543/12.12.29-FZ_Ob_obrazovanii_v_Rossiyskoy_Federatsii.pdf, (Accessed: 19.12.2016).
2. Gosudarstvennaya programma Rossiiskoi Federatsii «Razvitie obrazovaniya» na 2013–2020 gody [Elektronnyi resurs]: utv. rasporyazheniem Pravitel'stva Ros. Federatsii ot 15 maya 2013 [State Program of the Russian Federation 'Development of Education' approved by the Government of the Russian Federation]. №792-p. [Moscow, 2013].700 p. URL: http://minobrnauki.rf/dokumenty/3409/file/2228/13.05.15-Gosprogramma-Razvitiye_obrazovaniya_2013-2020.pdf, (Accessed: 19.12.2016).
3. Livanov D.V., Volkov A.Ye. Stavka na novoe soderzhanie [Elektronnyi resurs]. Vedomosti [Bulletin]. 2012. № 3179. URL: http://www.vedomosti.ru/opinion/articles/2012/09/03/stavka_na_novoe_soderzhanie, (Accessed: 19.12.2016).
4. Konanchuk D., Volkov A. Epokha «Grinfilda» v obrazovanii [Epoch of 'Greenfield' in education] [Elektronnyi resurs]: SEDeC; Center of education development of Moscow Management School SKOLKOVO (SEDeC). Skolkovo, 2013. 52 p. URL: http://www.skolkovo.ru/public/media/documents/research/education_10_10_13.pdf, (Accessed: 19.12.2016).
5. Mityushov E.A., Berestova S.A. Teoreticheskaya mekhanika: ucheb. [Theoretical mechanics]. Moscow: Akademia, 2006. 320 p.
6. Mityushov E.A., Berestova S.A. Teoreticheskaya mekhanika: ucheb [Theoretical mechanics]. 2-e izd. Moscow: Akademia, 2011. 320 p.
7. Belayeva Z.V., Berestova S.A., Denisov Yu.V. et al. Teoreticheskaya mekhanika v primerakh i zadachakh [Theoretical mechanics in examples and problems]. Mityushov E.A. (eds.). Moscow: Akademia, 2012. 176 p.
8. Berestova S.A. Proektirovanie obshcheinzhenernogo modulya programm proizvodstvenno-tekhnologicheskogo bakalavriata [Project of general-engineering module of production-technology Bachelor programs]. Inzhenernoe obrazovanie [Engineering education]. 2014. № 14. P. 100–105.
9. Rebrin O.I., Sholina I.I., Berestova S.A. Interdisciplinary project for Bachelor Engineering Program [Electronic resource]. Sharing successful engineering education experiences: 10th Int. CDIO Conf., Barcelona, Spain, June 16–19, 2014: Proc. Barselona, 2014. [9 p.]. URL: http://www.cdio.org/files/document/cdio2014/14/14_Paper.pdf, (Accessed: 12.12.2016).

UDC 378.146

Monitoring Math Competency of IT Students

Tver State University
S.M. Dudakov, I.V. Zakharova

The paper studies a method to develop testing and assessment materials, which is based on splitting "classical" parts of mathematics into smaller disciplines. It reveals the opportunities of the method in terms of competency-based approach.

Key words: competency approach, testing and assessment materials.

S.M. Dudakov

I.V. Zakharova

Introduction

Competency approach implemented into educational standards challenges many education programme designers. One of the challenges is competency mapping and developing relevant testing and assessment materials, which can be used at each stage. This paper describes how to overcome this challenge and simultaneously solve many other tasks and difficulties, which education programme designers normally face.

Mathematical disciplines for IT students

Training high-qualified IT professionals is impossible without profound mathematics education. Unfortunately, in the Russian language we still lack an appropriate term to call this section of mathematics. English "Computer Sciences" can be interpreted in different ways – either literally or transforming into "theory of IT", "IT fundamentals"; "math fundamentals for IT", etc. Nevertheless, one can identify the key subfields which are consistently incorporated into this mathematical course: different areas of discrete maths (theory of graphs, theory of Boolean functions, theory of coding, etc.), formal languages and automata theory, mathematical logic, algorithms, some topics of general algebra. Other disciplines incorporated into this course are optional and depend on a particular education programme, for instance, calculus of probabilities or numerical mathematics (see [1, 2]). Other mathematical subfields, if included, are regarded as supportive (for instance, calculus), since relevant knowledge and skills are also developed within other disciplines but rarely used in professional activities.

The incorporated disciplines are interrelated: either one discipline follows the other discipline or they are mutually influence each other. In this latter case, the contents of two disciplines are interdependent, which challenges programme and curriculum design. A typical example is mathematical logic and algorithm. On the one hand, fundamentals of both disciplines can be taught independently, but if to go deeper, one can see that these disciplines are strongly connected and can be taught as one subject. However, this method does not always work and a dozen of disciplines can never be taught as the only one. The probable decision is to teach several subjects simultaneously, but this is quite challengeable in practice. Another option is to split the discipline into smaller sections, which can be taught in different time. First, fundamentals, which are essential for other disciplines, are taught, and later it is possible to go deeper. However, the problem is that by the time, when the subject is learned in detail, students will have already forgotten some of the fundamentals, and the teacher and students have to spend extra time revising.

Another challenge is to motivate student to learn theoretical subjects. It is no secret that many students want to quickly acquire professional skills without learning fundamentals. It is particularly true for the first year students due to the decreased level of training at schools and no occupational