DIDACTIC DESIGNING OF LEARNING OBJECTS

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Abstract. The problem of didactic designing of digital Learning Objects (LO) that allow students of engineering faculties to master the technology of knowledge in the context of professional activity is discussed in the article. Evolution of LO in the transition process of educational environment from traditional to information-communication level is considered. During the comparative analysis new didactic and psychological conditions and factors appearing in educational environment in connection with the use of digital LO were selected. We have shown the impact of these conditions and factors to support learning activities of students and changing the role of a teacher. There is essential difference between a digital LO and a traditional one on the level of discipline training module. Digital LO is represented by functionally complete elements (information-activity-management) of learning environment and is used in any existing models of learning. Based on the integration of the models instructional design ADDIE (Analyze-Design-Develop-Implement-Evaluate) and operation of objects of the engineering activities CIDE (Conceiving-Designing-Implementing-Operating) was received the cyclic model of LO designing MDCO (Modeling-Designing-Constructing-Operating). Functional-pedagogical, instructional-ergonomic, psychological-ergonomic and socio-economic requirements for designing LO were selected. An example of the developed LO for training module "Microcontrollers' Programming" and the criteria for its evaluation are given.

Keywords: engineering education, learning environment, learning object, didactic designing, MDCO model.

Introduction

The relevance of didactic designing of Learning Objects, allowing students of engineering faculties to master the technology of knowledge in the context of a professional activity, is explained by the following circumstances.

Firstly, transition of the system engineering training in rapid change conditions of technological structure of modern production (3-5 years) on the lifelong learning model. Each specialist will implement this model individually based on his personal professional requests, needs and opportunities. Moreover, more than half of time spent on training and retraining will be spent to self-directed learning without interruption of production. Already today in the process of formal education in higher school for self-directed work of students more than 50 % of learning time is allocated.

Secondly, success of the self-training process for new technologies in professional activity depends on the degree of ownership by a specialist the technology of cognitive activity, which he mastered as a student.

Thirdly, as has been proved by Edgar Dale and his followers, effectiveness of cognitive activity of students depends on their activity (involvement) in the learning process. The highest learning outcomes (from about 70 to 90 %) [1] are achieved by students in the process of applying new knowledge to solve specific problems and performance of practical actions on laboratory and practical classes during implementation of coursework and projects.

Fourthly, the core of practice-oriented learning technologies in engineering is LO as a system-forming factor of subject environment of professional activity, around which interactive cooperation of educational purpose among its members is built: students and teacher on the level of a lesson or a training module.

Methodological grounds

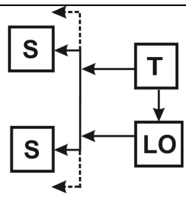
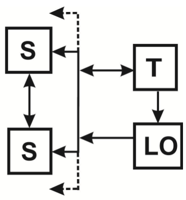
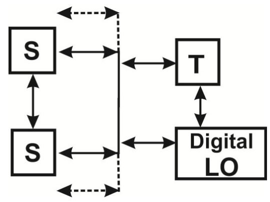
Modern *Information-communication Learning Environment* differs from *Traditional Learning Environment* by providing new tools, forming another space of interaction between students and teachers through the use of digital learning means that implement the information-communication technologies.

Learning means are man-made and nature-made objects used in the learning process as carriers of educational information and tools of activities of an educator and students for achievement of the learning, education and development goals [2]. In this article we are talking about a system of artificial means of training as a set of Learning Objects (LO), which is necessary and sufficient for learning the content of education at the level of the training module of the discipline. This level is selected in connection with the realization in the modern practice of higher professional education of modular technology learning. In addition, each LO, being an element of a system of learning means, is a complex independent subsystem [3].

Let us consider the structure of interaction of participants in the educational process in conditions of Traditional and Information-communication Learning Environments that are presented in Table 1. Channels of activity, i.e. interaction between the participants of an educational process, are designated in the patterns (a, b, c): one-sided → and bilateral ↔.

Table 1

Comparison of the interaction between a Teacher (T), Students (S) and Learning object (LO) in Traditional and Information-communication Learning Environments

Learning Environment	**Traditional**		**Information-communication**
Levels of interpersonal interaction	Direct		Direct and mediated
Patterns of interaction	 a)	 b)	 c)
Training Methods	Passive	Active	Interactive

In traditional learning environment when implementing of passive methods one-sided communication channel between all participants in the learning process is set, when active methods – between the teacher and students bilateral cooperation is established. LO in traditional learning environment mediates learning activities of students and has a one-sided channel of interaction with them. Educator simultaneously is a source of information and an organizer of educational interactions of students. He also selects and develops LO, organizes perceptual actions of students.

As can be seen from the patterns of Table 1, the main difference between Information-communication Learning Environment and Traditional one is that LO is converted to digital. It is active, that is expressed by bilateral channel of interaction with students and teacher. I.V. Robert allocates the activity of LO as an essential feature that defines the essence of innovation in Information-communication Learning Environment [4]. Thanks to features like processing large volumes of information, visualization, multimedia, providing interactive dialogue in the direction of information exchange between the users, digital LO is capable of performing the functions and source of information, and means of communication, and providing of interaction between the participants of the learning process. In other words, it can be functionally complete, which distinguishes it from a traditional LO, which generally performs one of the functions: information, management, training or supervising. In educational practice digital LO is often named "educational resource" on the basis that it is a system-formation factor of the learning technology at the level of discipline training module.

Thus, in Information-communication Learning Environment there are didactic conditions and factors such as: increasing intensity of interaction of information exchange and redistribution of functions among the participants of the learning process, which directly affect the change of organizational forms and methods of training. In addition, you must consider such psychological factor as internalization (interiorization): the formation of internal means of mental activity owing to active reflection in consciousness of the external means used in the context of learning activities. New LO owing to process of internalization creates new internal means of mental activity, i.e., expands the users' consciousness. Moreover, these internal means are not a copy of LO in the person's mind. They include many additional elements and links between them caused by knowledge, experience, thesaurus, psyche features and person's actualized mental processes. Thus, there is a system expansion of mental activity internal means of new LO users.

Didactic designing of LO on the level of discipline training module

Appointment of digital LO as an educational resource of a specific training module is creation of necessary and sufficient conditions for mastering specific professional technology in the process of students' interactive educational interaction. To do it, the projected LO must satisfy four requirements at least.

1. *Functional-pedagogical requirement*. Digital LO in engineering education should be designed as a system object in the context of engineering activity. To develop a model of such object it is necessary to integrate the well-known models of instructional design ADDIE (Analyze-Design-Develop-Implement-Evaluate) [5] and functioning of engineering objects CIDE (Conceiving-Designing-Implementing-Operating) [6] that is shown in Table 2. As a result, we obtain the model of LO development – MDCO (Modeling-Designing-Constructing-Operating) [7], which is represented in Figure 1.

Table 2

Comparison of the content of design stages

ADDIE (Analyze-Design-Develop-Implement-Evaluate) model				
Analyze	**Design**	**Develop**	**Implement**	**Evaluate**
A systematic exploration of the way things are and the way things should be. The difference is performance gap	The Design phase will outline the performance objectives	Using the information gathered in the Analysis and Design phase, the performance solution is created	Includes delivery of the performance solution	Measurement of how well the performance solution achieved the objectives
CIDE (Conceiving-Designing-Implementing-Operating) model				
Conceiving	**Designing**	**Implementing**	**Operating**	
Defines customer needs; considering the technology, enterprise strategy, and regulations; and developing conceptual, technical, and business plans	Focuses on creating the design, that is, the plans, drawings, and algorithms that describe what product, process, or system will be implemented	Refers to the transformation of the design into the product, including hardware manufacturing, software coding, testing, and validation	Uses the implemented product, process, or system to deliver the intended value, including maintaining, evolving, recycling, and retiring the system	
MDCO (Modeling-Designing-Constructing-Operating) model				
Modeling	**Designing**	**Constructing**	**Operating**	
Generalized-integral description of LO by a user's language	Designing of a project (plan, sketch, layout, algorithm, program) of LO	Development of an experimental sample of LO, its testing and correction	Implementation of LO, its work in the students' learning process and assessment of their learning outcomes	

Functioning of the MDCO model is carried out as follows. At the modeling stage, based on the analysis of changes in the requirements for training of engineers, changes in components of current LO-1 (prototype-1) are forecasted, i.e. object's and subject's signs of LO-2 (prototype-2) are clarified and its model is created. The object signs are identified on the basis of the answers to the following questions (*Conceiving phase of CIDE model*):

- what functionality will LO-2 differ from LO-1;
- what are the most promising of professional tools and systems appropriate to implement these features;

- what actions can be performed with LO-2;
- what is the algorithm of performing these actions? Questions that clarify the subject signs of LO-2, i.e. signs of the users (*Analyze phase of ADDIE model*), in the case of constant user audience and its target plants will be:
- what actions with LO-2 will allow the user to develop the necessary competence;
- what training-methodological components of LO-2 are necessary to support self-directed performance of these actions?

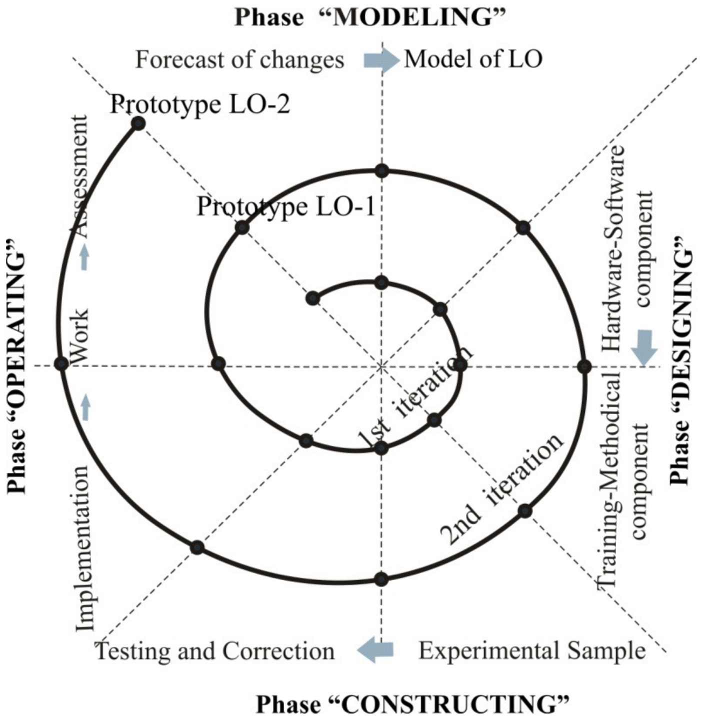


Fig. 1. **MDCO Model of LO development**

In the designing phase the basic components of LO-2: hardware-software *(Designing phase of CIDE model)* and training-methodical *(Design phase of ADDIE model)* are developed.

The constructing phase involves making of LO-2 experimental sample, its approbation and correction *(Implementing phase of CIDE and Develop phase of ADDIE models*).

The operating phase consists of stages: introduction of LO-2 *(Implement phase of ADDIE model),* work *(Operating phase of CIDE model)* and assessment of the student learning outcomes *(Evaluate phase of ADDIE model).*

2. *Instructional-ergonomic requirement*. The designed LO should be reusable which makes it possible to implement modular technology of education as a technology of development the relevant professional competence(s). Because substantively and organizational module is logically a complete part of training material followed by control of the students' knowledge and skills, then its technological implementation requires a functionally whole LO. This object must consist of functionally interconnected training-methodical and hardware-software blocks.

3. *Psychological-ergonomic requirement*. The designed object should form environment of advancing preparation (outstripping training). The designed object should form environment of advancing training that provides conditions for the formation of future specialists "zone of proximal" development (L.S. Vygotsky) [8]. We understand these conditions as external support of students' cognitive activity, which is organized by a teacher as a process of solving professional problems in interaction between the students and digital LO. Effective external support stimulates professional and psycho-emotional development of the individual student, reinforces his motivation to achieve goals and forms readiness for independent learning.

To achieve the effectiveness of external support during designing of LO's hardware-software block a teacher needs to orient on professional tools and systems that implement the most promising technologies in the manufacturing sector. When designing a training-methodological support of LO, you should: (a) develop a detailed and clear instructions guaranteeing the independence of student-user's work with LO; (b) take into account the target settings of LO's students-users in the formation of tasks and control tests to ensure their maximum engagement in the learning process.

4. *Socio-economic requirement – digitalization of LO.* Modern technological platforms in education are designed for digital LO. Firstly, they can be used in any existing training models (face-to-face, distance-learning, blended learning, etc.) in the framework of formal and informal education, i.e. to be available for people with different socio-economic status. Secondly, digital LOs reduce university costs. Once creating LO, it can be used repeatedly for students of all forms of learning, decrease expenses of a teacher time due to automation of knowledge control.

Parallel to the process of digitization of traditional LO the development initially of digital LO – simulators: physical objects, processes and systems is taking place. On the element base of digital LO various international Internet-projects are constructed in the field of engineering education, for example, RUBIGAS, MobiVET 2.0, AVARES, etc [9].

Results and discussion

In university educational practices the implementation of new LO is carried out at three levels: 1) *reproductive* – application of finished LO, created by a specialized company which develops training equipment and software; 2) *productive* – if LO has a prototype in industrial or social spheres, it adapts to the technology of the educational process either (a) by university teachers, or (b) by the specialists of manufacturing enterprises; 3) *scientific-research* – when teachers, conducting research in the subject area of professional activity, use new technical and technological solutions for the development and implementation of LO.

Interest for this study is represented by the second (a) and the third levels, because university teachers participate in them. On the productive level they build partnerships with the leading manufacturers of new techniques, focusing primarily on those who implement the program to support higher education institutions in the form of free supply of equipment for the educational process. In this case teachers of the department make the design and construction of LO from hardware and software provided by a company and also develop methodological supply to them. One of the examples of such enterprise is the company "OWEN" (Moscow) – the leading manufacturer of equipment for automation of technological processes on Russian market (http://www.owen.ru). More than 50 technical universities in Russia and CIS (Commonwealth of Independent States) participated in its program of support of higher education institutions. We have presented in the work [10] our experience of participation.

On the scientific-research level there are research and development (R&D) and psychology-didactic projects of the department teachers aimed to obtain new knowledge and practical application in formation new LO and technology of its use in the learning process.

We present the example of LO's development for electronics. Generalization of pedagogic experience of electronics teaching in different institutes shows that the main attention is paid to the semiconductive elements, analog and digital nonprogrammable devices. At the same time the modern production of electronic devices is based mainly on the microprocessors, it is also reflected in scientific and popular science literature. There is a paradox: a graduate studied electronics cannot understand the functioning system of a microcontroller-based device. By the way, the microcontroller (MC) is considered as the most outstanding achievement in electronics after the transistor. We add that scientific works with technical decisions based on MC win the competitions (according to the experts' responses). Analog and nonprogrammable digital devises lose their positions for perspective programmable systems – MC.

In our scientific researches and applied development in the information electronics field we carried out the analysis of the results in patent and information search and were convinced that the information and measuring equipment plays the leading role in the application of MK on frequency and efficiency. Therefore, a decision was made to project LO as an example of the constructing information- measuring system.

We used this Model as a tool for designing LO for the training module "Microcontrollers' Programming" [11]. We developed this LO as a training-methodical and hardware-software complex. LO is aimed to provide selected from many sources and systematically organized material to mechanical, electrical students, who do not have special skills in programming, to acquire the opportunities of modern electronics, which element base includes programmable systems located in one semiconductive crystal – Microcontrollers. The training-methodical unit of the LO serves as a source of information and monitoring tool. It is represented in a textbook [12], which has a paper and electronic versions.

There are a lot of manuals about AVR Microcontrollers now where you can find examples of structures of different devices. However, the majority of them do not implement typical functions of information and measurement systems. Examples of programming of such functions, like conversion of physical properties and quantities into digital code, data input from sensors and keyboard, data output on the indicator, formation of signals by executive devices, etc. are carried out in the training-methodical unit of our LO in order to fill this lack.

Hardware-software unit of LO consists from the developed programs and hardware for their realizations – Microcontroller's test bench [13]. The test bench is designed in two modules with digital and analog inputs. Each module has a slot for programming microcontroller with the help of AVRISP mkII programmer. The main purpose of the hardware-software unit of LO is realization of the practical component in studying Microcontroller programming, Figure 2.

Fig. 2. **Using Microcontroller's test bench in practical classes**

A student is given an engineering task – to develop a definite device. Solving this problem he should use fundamental and applied knowledge from various adjacent areas: physics, computer science, electronics etc. Obtaining a practical result in the form of an operating device develops in a student an understanding that using Microcontroller he can to solve various technical tasks of modern production as well as his readiness to perform the course and graduation works.

Assessment of student learning outcomes after using the LO "Microcontrollers' Programming" was performed according to the criteria detailed in [14]:

1. Indicators of changes in integrative qualities of students′ knowledge: K_e^{av} efficiency, K_s^{av} systemacity and K_r^{av} knowledge reliability and their selective dispersion σ_e^2, σ_s^2 and σ_r^2;
2. The parameter defining cognitive activity was the indicator of performance by a students' group of all kinds of educational work Π_a, which was calculated from the formula:

$$\Pi_a = \frac{A}{N \cdot T},$$

where A – quantity of the works executed by students;
N – quantity of students in a group;
T – time allocated for studying the training module according to the academic curriculum, hours.

As an example in Figure 3 the results of control of the knowledge systemacity factor K_s of students in the form of the extrapolation curves obtained by a method of the least squares are presented. From Figure 3 it follows that this factor for experimental and control groups essentially differs not only quantitatively (K_s^{av} in an average above), but also qualitatively (on distribution density).

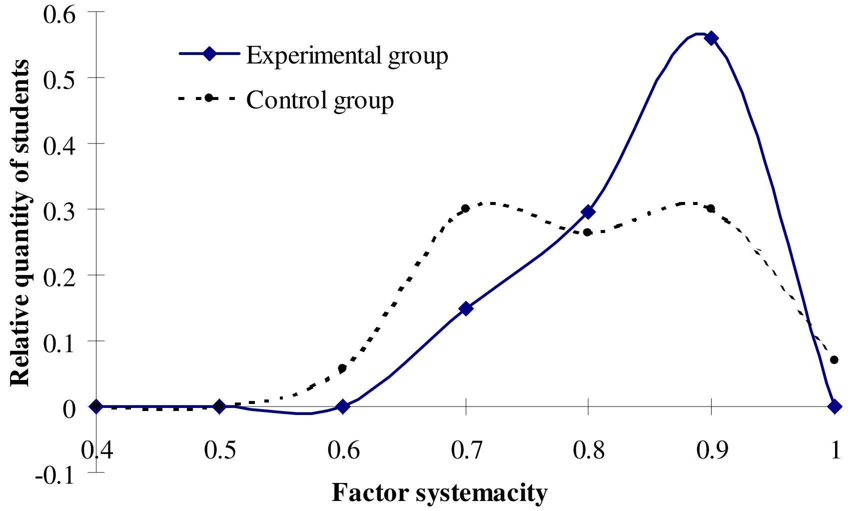


Fig. 3. **Density of students' distribution by K_s**

The sample averages of the cognitive activity indicator Π_a^{av} of experimental and control groups was equal to 0.84 hour^{-1} and 0.73 hour^{-1} respectively, that confirms significant improvement of this indicator. Having distributed all educational tasks executed by students by levels of cognitive activity: reproductive, productive and creative, we detected that Π_a^{av} increased due to the increasing number of works of productive and creative levels. Besides, 67 % of the respondents who participated in the experiment noticed, that "application of LO created convenient conditions for self-directed training, as well as stimulated desire to study new material more intensely".

The authors taking in account their own experience and world practice examples in engineering education prove that design and implementation of new LO on productive and scientific-research levels are in the conditions of integration between science, industry and education. So, there is a possibility in flexible synchronization of changes in these spheres of human activity.

Conclusions

In conclusion, we emphasize the key idea of social constructivism, which lies in the fact that knowledge cannot be transferred to the student in finished form, and you can only create pedagogical conditions for their successful construction and expansion:

3. These conditions are formed by the learning environment, which has moved to a new information-communication level now. In this regard, in it new didactic and psychological conditions and factors appeared that enhance the degree of its impact on the effectiveness of students' learning activities.
4. The system-formation factor of Information-communication Learning Environment at the level of discipline training module is digital LO. Around it a modular training technology in the context of professional activity is built.
5. Digital LO is designed as a functionally complete element (information-activity-management) of learning environment, which can be used in any existing models of training (face-to-face, distance-learning, blended learning, etc.), as well as to develop MOOC.
6. The basic requirements when designing LO: functional-pedagogical, instructional-ergonomic, psychological-ergonomic and socio-economic.
7. The model of LO development – MDCO (Modeling-Designing-Constructing-Operating) was obtained as a result of integration of the models of instructional design ADDIE and functioning of engineering objects CIDE.

8. Designing digital LO carried out on productive and scientific-research levels provides flexible synchronization of changes in production and scientific fields with changes in professional training of engineers.

Acknowledgement

LO-1 first prototype of the training module "Microcontrollers' Programming" was introduced in the educational process in 2010 in Stavropol State Agrarian University; LO-2 was participated in the contest "The best innovative project in educational technology field" at the International Exhibition-Congress "High Technologies. Innovations. Investments (Hi-Tech'2012)" in St. Petersburg, where it was awarded a diploma of the 1st degree and a gold medal.

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