Educational engineering: the technological basis for creating educational products

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Abstract. The article proves and substantiates the necessity of introducing the concept of educational engineering into the educational process. Various definitions of the terms ‘engineering’ and ‘educational engineering’ are analyzed and considered. The main task of engineering in the educational process is determined in the article along with the reasons that stimulate the introduction of educational engineering into pedagogy. The definition of educational engineering is formulated determining the considered term as a model with certain characteristics. The article proposes the concept of educational engineering, which is based on the categories ‘Educational product’ and ‘Educational product life cycle’ and includes a system of principles for implementing an engineering approach to creating such products. The definitions of basic terms are proposed and the structure of the educational product life cycle is characterized. The phases of the educational product life cycle and its phasic states are described. The principles for educational product developing are formulated. The article contains a conclusion about the possibilities for implementing the presented concept of educational engineering.

1. Introduction
The current stage of the education system development is characterized by the intensive introduction of modern tools and technologies into pedagogy and teaching practice. At the same time, insufficient attention is paid to improving and structuring the process of creating educational innovations. It, in many cases, does not allow to ensure the proper effectiveness of creative activity, leads to the appearance of overlapping developments and irrational expenditure of intellectual, financial and other resources.

In our opinion, the above mentioned and other similar problems can be overcome within the concept of educational engineering which consists in implementing tested and proven engineering approaches used in other design areas into the educational process.

2. Engineering in education
Engineering as a form of constructive activity dates back to ancient times and appears in the creation of the Acropolis, the Colosseum, the Great Wall of China, etc. One can note a steady interest in engineering in the first two decades of the 21st century, especially in the higher education system [1].
At the same time, it is necessary to mark that there is still no unified interpretation of the term ‘engineering’ due to the lack of well-defined structure of this activity in the context of modern pedagogical issues [1]. Engineering as a type of activity is a general term, and its various definitions (‘constructional’, ‘financial’, etc.) can be found in the titles of various academic courses [1]. The term ‘engineering’ being derived from the verb ‘to engineer’ with the ending ‘ing’ can be interpreted as ‘creation’ or ‘design’ [2].

Engineering can be defined as a process of applying scientific principles for designing systems that lead to the achievement of desired results [3]. Engineering allows to accumulate knowledge through systematic and provable introductions into the real world with the use of hypotheses based on theory and practice which can be theoretically and empirically confirmed [4].

The International Chamber of Commerce (ICC) ascribes the term ‘engineering’ to the production and technological spheres. ‘International engineering is aimed at design, research, construction, and also includes consultations that make it possible to reduce capital expenditures on creation and reconstruction of production facilities and their sites’ [5].

In publication [6] educational engineering is understood as the purposeful activity of a teacher aiming at creation, introduction and testing modern educational products. In publication [7] educational engineering is defined as the process of applying evidence-based principles to create educational and technological projects that meet the needs of learners and enable them to achieve the set goals. Educational engineering can be viewed as a model for designing learning environment, as an innovative strategy and a modern research method [8].

The main task of engineering in the pedagogical process is ‘the creation and promotion of an educational product’, which is the result of a scientific and pedagogical activity [6]. Educational engineering is being actively introduced into the educational process along with engineering thinking and engineering approach in teaching [6]. As rightly noted by E.Z. Vlasova, this is determined by the current rapid pace of development and, in particular, the development of the educational process, which necessitates modernization as well as adjustments and changes into educational strategies so that educational institutions can remain competitive, meet the needs of educators and students [9].

Thus, the introduction of educational engineering into pedagogy is associated with:

- project orientation of the educational process;
- the necessity to use modern educational products;
- implementation of modern digital educational environment;
- requirements to make ‘a new type’ of students - “drivers of economic and social development” [6].

3. Educational engineering concept

We consider educational engineering as an operating model focused on the process of creating an educational product. This model is distinguished by its orientation not only on design, but also on other stages and phases of the process, such as analysis, implementation, introduction and quality assessment. Educational engineering focuses on the accumulation of knowledge on the process through a research-based approach, so every decision within the process must be justified [10].

The proposed concept of educational engineering is based on the terms 'Educational product', 'Educational product life cycle' and a framework of principles for implementing the engineering approach in the creation of such products.

We presume that an educational product (EP) is the outcome of a result-oriented activity in education intended for systematic use in the educational process. Various products can act as EPs, including educational systems, technologies, methods, teaching tools, tools for curriculum implementation, educational resources, methodological documentation, etc. (figure 1).

The educational product life cycle is a set of interrelated processes of creation and sequential alteration in the state of this product from specifying initial requirements for it to a complete rejection to use it in the educational process. The structure of the EP life cycle should be characterized by
versatility necessary and sufficient for application to any type of an educational product. This structure should be invariant to the methods of designing and applying the EP, to the training courses being taught, to the types and forms of interaction between the participants of the educational process. The EP life cycle must be complete, i.e. cover all periods of the educational product existence - from the inception of its concept to its exclusion from the educational process. A very important element of the life cycle structure is the EP reproducibility, which allows the repetition of all necessary actions in case of making a correspondent decision. Another most important property of the EP life cycle is helicity, i.e. the ability to carry out the next cycle not only from the initial stage, but by means of developing or modifying the existing educational product and, thus, to use the experience and potential accumulated by previous developers and users at a higher level.

![Figure 1. Typology of educational products.](image)

The EP life cycle consists of five stages, each of which corresponds to a specific so-called phasic state of the EP predetermined by the content of the phase and the goals of a product developer (figure 2). At the “Substantiation” phase, the educational product is in a state of a concept, i.e. consistently detailed idea of its development (figure 3).

![Figure 2. The EP life cycle.](image)

![Figure 3. Structure of the ‘Substantiation’ phase.](image)

The initiator of this idea makes efforts to identify, analyze and substantiate the necessity of the EP development, to formulate its goals and objectives, to determine the field and scale of its possible application, to assess the necessary resources and to resolve other issues related to substantiating EP development and formulating design specifications. In education this activity, in the overwhelming majority, is of proactive nature. For this reason, the stage of preparation and concluding a contract for the EP development is rarely performed – in case there is a specific orderer.
In the ‘Development’ phase the educational product is the subject of an activity, sequentially going through the stages of planning, pedagogical design, implementation and documentation (figure 4).

![Figure 4. Structure of the ‘Development’ phase.](image)

There are several options for implementing the ‘Development’ phase:

- **Creation** of a fundamentally new EP, not existing before, with unique properties and qualities absent in other similar products;
- **Development** of the existing EP, involving expansion of its functionality, replenishment of the information, resource and other bases, implementation of new didactic tools and technologies in addition to those already used in the product;
- **Modernization** of the existing EP by updating obsolete or useless components or elements of the product by means of their substitution with similar modern means without changing the product functionality or application field;
- **Development and modernization** of the existing EP, i.e. combination of the ‘Development’ and ‘Modernization’ options.

Regardless of the type of the ‘Development’ phase implementation, the main content of the above mentioned stages remains fundamentally the same. At the planning stage, a plan for the EP development should be drawn up specifying the time of the necessary actions and activities, as well as the resources (human, financial, material, information, etc.) required to perform each operation. The absence of such a plan or the inability to ensure its implementation leads, as a rule, to chaotic and fragmented EP development and failure in achieving the target result.

At the stage of pedagogical design, a project of the product under development is created. This project should constitute a set of documents which describes specific proposed solutions in terms of the structure, content, implementation method, technology and methodology of the EP application. An obligatory stage of pedagogical design is an expertise of the proposed solutions for compliance with the current legislation, as well as their coordination with the administrative staff of the educational institution in which the EP is planned to be applied.

At the ‘Implementation’ stage a prototype of the educational product, suitable for being tested under real-life conditions in an educational organization, is created. At the ‘Documentation’ stage methodological documentation is developed for regulating the EP application.

During the ‘Testing’ phase the educational product is in the state of a workable prototype. It potentially possesses target properties and qualities, however, they should be proved experimentally, and the possibility of its systematic use in the educational process should be confirmed in the prescribed manner.

Within the ‘Testing’ phase there can be distinguished a number of stages: organizing and conducting a pedagogical experiment, certification of the educational product and integration of the EP into the educational process (figure 5).

![Figure 5. Structure of the ‘Testing’ phase.](image)
At the stage of pedagogical experiment organization, participants, timing, place, conditions and methodology of the experiment being conducted, as well as the form of fixation, criteria and procedure for analyzing the obtained results are determined. The stage of conducting a pedagogical experiment is, in fact, an analogue of a trial operation stage compulsory for identifying the real properties and qualities of any product in engineering. We should note that the results of a pedagogical experiment can reveal the need to augment the educational product that implies an opportunity to return to the previous phase of the EP development and the implementation of the necessary actions with the following re-testing.

On receiving positive results in the pedagogical experiment, at the stage of EP certification there should be carried out a verification of EP compliance with the current legislative and other regulatory acts in terms of sanitary-biological, medical, informational, etc. safety as well as documenting the possibility of its appliance in the educational process in the corresponding level of education. In fact, such a document creates a regulatory framework for the introduction of a newly developed product into the educational process.

At the stage of EP integration into the educational institution, measures are taken to document the EP appliance directly in the educational process or in its management system. For example, if the EP is represented in the form of a didactic toolkit (an educational resource, a technical training tool, etc.), then the need for its use is indicated in the training course syllabus. If the EP is a tool for managing any type of educational activity (for example, a means of organizing distance learning), then the need for its use is indicated in the job description of a corresponding specialist and in the technological regulations for the implementation of a corresponding process.

Particularly noteworthy is the situation when an educational product developer is considering the possibility of its commercialization. In this case the EP developer has to register the copyright and other rights to the product, prepare its commercial versions, sign agreements for its replication and/or commercial distribution, or independently arrange this activity.

The state of the educational product at the “Application” phase can be characterized by the term ‘functional element of the educational process’. The EP is legitimately and persistently used for its intended purpose in accordance with the academic calendar. At the same time, such values as the number of users, the number of educational organizations that use the EP, and the duration of its use can be considered as indicators of its relevance and usefulness for teaching purposes.

At the “Application” phase as the experience of educational product appliance accumulates, the information on its advantages and disadvantages is collected. And in case there is a contact between the developer and users of the EP, proposals for its adjustment or improvement can be formulated. This process can be quite long-lasting, but sooner or later the user comes to the conclusion that it is inexpedient to continue using the EP. The reasons for such a decision may be of different nature: substantial or physical obsolescence of the EP, the impossibility of restoring or replacing the necessary equipment, changes in the regulatory framework of the educational process, etc.

Awareness of the necessity to abandon the educational product can be considered as the beginning of the ‘Decline’ phase which completes the EP life cycle and creates conditions for the development or selection of a new product free of identified shortcomings. The state of the EP at this phase can be characterized by the term ‘Agony’. The use of EP is still possible for some time but its effectiveness approaches zero or becomes negative. Refusal to use the end-of-life EP, which ‘clears’ the educational environment for introducing a new EP, can occur at any time. An educational organization has an objective need to attract and use a new educational product.

Let us formulate the main principles of EP developing [11].

- **Consistency** - EP development should cover all phases and stages of its life cycle taking into account the interaction of all participants and components.
- **Purposefulness** - the EP development is aimed at achieving specific goals determined by the goals and objectives of the educational process.
- **Criteriality** - the results of the EP application should be assessed or measured according to the criteria significant for the relevant educational system or pedagogical activity.
- **Technology orientation** - the EP development should be based on advanced educational technologies with the application of design approaches used in engineering.
- **Plan orientation** – the EP development should be carried out according to a pre-developed plan under conditions of control over the allocated resources.
- **Documentary support** - the educational product must be provided with design, specification and methodological documentation that ensures its acquisition by users and integration into the educational process.
- **Eligibility** – the EP must have documentary evidence of the possibility of its application in the educational process.
- **Safety** - the EP must comply with the legislative, content, medical and sanitary, informational and other criteria for its safe application in the educational process.
- **Intellectual property consideration** - the EP developer’s authorship and ownership must be documented in accordance with the applicable law.

4. Conclusion
In our opinion, the implementation of the presented concept of educational engineering will make the processes of educational product development and introduction, similarly to processes of modern engineering, coherent and structured [12, 13, 14].

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