SECTION 2. EDUCATION

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2.1 Digital learning resources: problems of definition, classification and design

Currently, in pedagogical research, the concept of “digital learning resource” is in the area of heterogeneous multi-vector interpretations. The problem of classification of such resources is inextricably linked with the issue of their nomenclature and is one of the most difficult and ambiguous to solve [6]. The concept itself has several synonymous designations: “electronic educational resource”, “e-learning resource”, “computer-based training tools”, “educational software”, “computer learning tool”, “digital education tools”, etc., the simultaneous rotation of which leads to terminological inconsistency and confusion. Redundancy and disorder of terms actualize the need for systematization of concepts.

Today, scientists do not have a single point of view on the classification of e-learning resources and their nomenclature system. Despite some differences, these concepts have a lot in common. Many scholars (I. Krevskiy, T. Glotova, M. Deev, S. Matyukin et al.) define the concept “electronic educational resource” or “e-learning resource” as an educational resource represented in digital form and included structure, subject content and metadata about them. ELR may include data, information, and software necessary for its use in the learning process.

The term “digital learning resource” is more recent and “refers to digital resources such as applications (apps), software, programs, or websites that engage students in learning activities and support students’ learning goals” [7].

Issues of classification of such resources (under various names) were highlighted in the works of O. Alekseev, O. Balykina, O. & I. Bashmakov, M. Belyaev, A. Gurzhiya, V. Demkina, L. Zainutdynova, B. Kryvytsky, V. Lapinsky, Y. Mashbyts, V. Osadchy, C. Rakova, I. Robert, M. Shishkina and al. Despite the relatively large number of works, devoted to various aspects of this problem, it remains relevant for today's pedagogy. In particular, there is a lack of research on this phenomenon from the standpoint of the theory of classification in the modern pedagogical literature.

Hierarchical and faceted classifications of digital learning resources

In a broad sense, classification is a system of subordinate concepts (classes, objects) of any field of knowledge, presented in the form of schemes (tables) and used as a method to determine links and relations between these concepts or classes of objects, and also for exact navigation in a variety of concepts or relevant objects. The classification should fix the regular relations between the classes of objects in order to determine the place of the object in the system, which determines its properties.

Today, the dynamics of the process of information technology development, the creation of new learning tools based on them is increasing every year, their didactic potential is growing, at the same time other electronic tools, which were considered progressive, are becoming morally obsolete. It is quite problematic to expect in such fleeting conditions until the definitions of concepts crystallize for their further systematization. We believe the processes of nomination and classification to be interrelated and interdependent aspects of research, and we consider classification itself as a powerful factor in the formation of new knowledge [8].

The practical need for classification stimulates the development of theoretical aspects of science, and building classification is a new stage (“leap”) in the development of knowledge.

Classification based on scientific principles not only give a detailed picture of the state of science or its fragment but also allows us to make informed predictions about the still unknown facts or patterns.

The first classifications of electronic educational resources were built on a hierarchical method, in which a given set is successively divided into subordinate subsets, gradually specifying the object of classification. The basis of the division is a certain feature or criterion. The set of obtained groups forms a hierarchical tree structure in the form of a branched graph, the nodes of which are groups. Hierarchical classifications of electronic educational resources have a strong tradition in the theory of pedagogy. Among the most famous are the classifications by function in the educational process, pedagogical purpose, didactic purpose, etc. Let's illustrate the application of the hierarchical method on the example of the original classification of electronic learning tools by the type of activity, proposed by Shyshkina [9].

The group of terms of the upper level of the hierarchy includes those that characterize these tools in general: "computer-assisted learning tools", "electronic learning tools", etc.

There are two groups of tools at the next level of the hierarchy:

1) tools with elements of artificial intelligence, which include modeling environments and intelligent systems for educational purposes, which, in turn, are divided into intelligent knowledge control systems, intelligent simulations, knowledge bases and expert systems for educational purposes (educational dialogue systems, proof systems theorems, classification systems, language learning systems, problem-oriented systems);

2) tools without elements of artificial intelligence (multimedia manuals and encyclopedias, knowledge control tools, databases, virtual laboratories, multimedia interactive environments).

Dimitracopoulou describes 10 categories of educational software:

1) Simulation systems (that simulate the behavior of a phenomenon, of an apparatus or a machine);

2) Modelling systems (that allow expressing and exploring models in one or multiple modelling formalisms and symbolic languages);

3) Educational Robotics and Media Based Laboratory (that captures the data from real experiments and visualize them);

4) Programmable system (that allow students to program with a set of basic entities and);

5) Virtual Reality applications (specificities are due to the 3D graphics);

6) Educational games;

7) Hypermedia-based learning systems;

8) Drill and practices software;

9) Intelligent tutoring systems or intelligent problem solving systems;

10) Collaborative Distance learning systems (have specific components and tools that allow collaboration through action and dialogue by distance, in a synchronous or asynchronous way) [10].

However, categories of this classification overlap. As the author admitted, virtual reality applications may be included in various other systems (e.g. simulation or modelling one), collaborative distance learning systems may belong in different previous categories, etc.

Nagata describes 11 types of educational software:

1) Authoring System;

2) Graphic Software;

3) Reference Software;

4) Desktop Publishing;

5) Tutorial Software;

6) Educational Games;

7) Simulations;

8) Drill and Practice Software;

9) Math Problem Solving Software;

10) Utility Software;

11) Special Needs Software [11].

Undoubtedly, such classifications have their advantages, the main of which are their traditionalism and relative simplicity of building. However, according to many researchers, the disadvantage of hierarchical classification is the poor flexibility of the structure due to the fixed basis of division and a predetermined order, which prevents the inclusion of new objects and classification groups – therefore, change in the composition of classification objects requires rebuilding the whole classification scheme.

New findings easily fit into a good classification, as well as into a good theory, without affecting its stability, but on the contrary, stabilizing it even more. Classifications based on one or a few features often lead to the building of artificial groups, which are sooner or later abandoned; while complexes based on many essential properties of objects have objective flexibility and, allowing for improvement, are preserved.

A certain limitation of hierarchical classifications arises from the very principle of the hierarchy, according to which each object can be assigned to only one class, as a result of which classifications are ambiguous or excessive.

Mashbyts consider that the most significant limitation in attempts to build a scientific classification of computer training systems is due to the fact that the authors of such classifications seek to find one basis for them. The most important requirement for classification is that it must be multifaceted, as learning technology includes a variety of ways to implement [12].

Classifications, based on several features of objects, are built on the faceted method, which involves the parallel division of many objects into independent classification groups. At the same time, there is no rigid classification structure and pre-constructed closed groups. Classification groups are built by a combination of values taken from the facets. Thus, faceted classification is several independent classifications that are built simultaneously on different grounds; it is a set, the elements of which are sets, the concepts in it are represented as the intersection of a series [13].

Consider the faceted classifications of electronic educational tools. One of the first attempts to systematize computer-based training tools was made by Kryvytskyi, who proposed classification on two grounds: the type of educational activity and pedagogical purpose. By the first criterion, computer educational tools are divided into intended for group work (face-to-face, classroom) and individual work; by the second – for informative, control and training tools. The most important for the practice of higher education, the scientist considers the tools for individual work, among which distinguishes the following ones:

1) electronic textbooks, which perform the traditional didactic functions of the textbook, but have additional capabilities provided by computer technology;

2) commercial subject-oriented educational software;

3) electronic (computer) models for the development of research skills;

4) specialized computer programs designed to provide certain parts of training courses;

5) tools for the development of subject-oriented didactic programs;

6) packages of application programs

7) personal online learning tools;

8) computer distance learning tools [14].

In our opinion, this classification is difficult to call scientific, because it is impossible to identify clear criteria for division (we have counted at least three: pedagogical purpose, commercial conditions of software distribution, technology). The essential characteristics of objects and the principles of their contraposition are unclear. Thus, electronic textbooks, specialized computer training programs, electronic models, packages of application programs are widely used in distance learning, can have both free and commercial software, etc.

Antonova et al. also offer two criteria for the classification of educational electronic resources:

1) the contingent of students;

2) place in the educational process and identify following ones: informative and referral sources (encyclopedias, manuals, dictionaries, etc.) that provide general information support, not linked to a concrete course program or didactic scheme and intended for use in solving creative learning tasks; for supporting the educational process (electronic textbooks), designed to study the subject “from scratch” to the limits of the subject area defined by the curriculum, which includes all types of educational activities: obtaining information, practice, testing; general cultural nature, designed to expand the cultural environment, the worldview of students [6].

A detailed analysis of electronic (software) tools for educational purposes and their classification was undertaken by Robert, who identifies problem-oriented, object-oriented and subject-oriented tools. Scientist identifies following software tools by a functional purpose:

1) pedagogical, designed to organize and support the user's educational dialogue with the computer, the purpose of which is to provide educational information and guide learning, taking into account the student’s individual capabilities and preferences;

2) diagnostic, testing;

3) instrumental, for the design of educational software;

4) subject-oriented software environments;

5) for the development of a culture of educational activities and information culture;

6) for processing the results of the experiment;

7) for managing the actions of real objects;

8) learning programming environments;

9) performing of some teacher’s functions;

10) for automated process of information and methodological support in the educational institution;

11) service engines;

12) educational games.

By methodological purpose, the following types of educational software are identified:

1) learning, the purpose of which is to provide knowledge, develop skills of educational and (or) practical activities;

2) simulations to practice skills, educational activities, self-training;

3) for monitoring and control (self-control);

4) informative and retrieval, informative and referral;

5) imitation, representing a certain aspect of reality to study its main characteristics;

6) modeling tools;

7) demonstrative;

8) educational games;

9) recreational [15].

The classification proposed by Robert is adopted by many scholars. No less popular is Zaintudinova's classification, which identifies the following three types of educational software by their purpose:

1) pedagogical software (service, tools for monitoring and testing the level of knowledge, for mathematical and imitation modeling, simulations);

2) information retrieval systems designed for input, storage and presentation of information (databases, knowledge bases);

3) learning systems (automation software, electronic textbooks, expert-educational systems, intelligent educational systems).

Zaintutdinova also offers a four-level typification of educational software by the form of providing information to the user:

1) containing educational information only in verbal form;

2) containing educational information in verbalized and two-dimensional graphics the form;

3) multimedia, containing information in the form of three-dimensional graphics, sound, video and partially - in verbal form;

4) virtual reality, which provides not only sound and visual but also tactile information, creates the illusion of presence in a stereoscopically represented screen world [6].

Alekseev proposes five classification categories, according to which he distinguishes the following electronic educational editions:

1) according to the model of physical and industrial objects and processes: an object of artificial reality, multimedia laboratory, calculation model, graphic form, symbolic form;

2) by the form of work: remote, deferred access, face-to-face;

3) by a methodical purpose: descriptive and illustrative, demonstrative, training, testing and diagnostics, methodical, regulatory, reference, auxiliary;

4) by the method of providing access to materials: local, locally distributed, corporate and unrestricted access;

5) by the technologies of formation of professional competencies: modular, project, problem, multilevel, programmed, brigade, reproductive training [15].

Belyaev and al. consider computer teaching aids as components of educational electronic editions and identify the following main types: general service software, software for monitoring and measuring the level of knowledge and skills, simulations, software for mathematical and simulation modeling, software for remote access and virtual laboratories, information retrieval reference systems, automated educational systems, electronic textbooks, expert systems, intelligent systems, automation of professional activity.

The classification of educational electronic editions is based on ten criteria. In particular, for the classification of educational electronic editions by methodological purpose, the already mentioned Robert’s classification of educational software was adapted. Educational electronic editions are also classified according to such criteria as training methods, education system, didactic focus, a form of presentation, distribution technology, type of interaction.

According to the level of didactic potential, four main groups of educational electronic editions are described:

1) declarative editions – printed materials and its electronic copies, audio and video, etc., the main didactic function of which is the introduction into learning material;

2) declarative tools – electronic textbooks, virtual classrooms, testing systems, the main didactic functions of which are comprehension, consolidation and control;

3) virtual simulations, learning laboratories and other computer systems, the main didactic purpose of which is to form and develop an unarticulated part of knowledge and skills;

4) computer systems for automation of professional activity or their educational analogs in the form of application packages, with using which the learning process takes place in the mode of research. According to the logical framework’s character, electronic educational editions based on deduction, induction, abduction, analogy are distinguished [16].

Some of these criteria are discussed some scientists, who believe that the classification of educational electronic editions can be based on conventional methods of classification of educational editions, electronic editions and software and offer the following criteria: functional feature, structure, organization of the text, the nature of the information provided, the form of presentation, purpose, the presence of the printed equivalent, the nature of the basic information, distribution technology, the nature of interaction with the user [6].

Osadchy & Sharov, in addition to the classification of electronic educational editions by purpose, mentioned twelve other classification criteria, namely: application, number of users, methods of presenting information, methods of feedback implementation, structure, method of individualization, scope, level of information culture of the user, interactivity, complexity, universality, cost of technology [17].

Warner et al. identify 3 categories of Digital Learning Resources: Digital academic content tools, Digital productivity tools and Digital communication tools [8].

Digital academic content tools offer academic content resources and/or engage students in activities to learn academic content or skills, including, but not limited to, language and literacy content or skills:

- Designed learning activities: interactive tutorials or lessons (adaptive and other), practice and assessment tools, dynamic modeling or simulation tools, virtual worlds;
- References/resources: dictionaries, encyclopedias, e-books, topic blogs, and/or topic-focused websites; visual and auditory topic-related resources;
- Language resource tools: translation and articulation tools.

Digital Productivity Tools include software, applications, programs, or websites that students use to plan, document, organize, and analyze content:

- Presentation tools;
- Word processing tools;
- Information analysis tools: spreadsheet and data analysis tools;
- Information organization tools: concept-mapping tools and story templates.

Digital Communication Tools include software, applications, programs, or websites that students use to communicate, collaborate, network, or present information:

Asynchronous/ synchronous text communications: discussion boards or forums, emails, text messaging, chats;

- Reflection tools: blogs or student journal;
- Videoconferencing/meeting tools;
- Project collaboration tools.
- And multiple individual DLRs can be combined in an integrated set [8].

Thus, all classifications of Digital Learning Resources and their predecessors have both advantages and disadvantages. The positive aspects of the hierarchical classification are traditionalism and relative simplicity of structure, the negative – its inexhaustibility, ambiguity and rigidity of the scheme, so the method of hierarchy is better applied to objects with relatively stable features [18].

In contrast to the hierarchical, faceted classification does not provide a rigid structure, there are several independent classifications that are carried out simultaneously on different grounds [13].

The advantages of faceted classification are the ability to create a classification of great depth by creating a large number of features for the formation of groups, the possibility of a simple modification of the entire system. Despite the shortcomings of the faceted method of classification, which include the complexity of construction and incomplete use of capacity, we consider it promising for further systematization of digital learning resources, which are developing dynamically.

Summarizing the above, we believe that the main advantage of faceted classification is the flexibility of its structure, which causes good adaptability to the changing nature of the issues, which is especially relevant for the classification of digital learning resources, which due to relative novelty and rapid development have not stable features, the very concept of which is constantly clarified and concretized in content and scope.

Modern scholars consider the systemic approach as a general scientific paradigm. As Gabrolino, Chéry & Guarnieri note “it offers a generic way to construct and present valid, relevant and rational representations of the most diverse, changing situations” [19].

According to Gutiérrez et al. “The point is that through systems approaches, those problems that before were restricted to the sphere of philosophical reflection now become a matter of methodological work in the field of social and organizational sciences. Systems approaches are the window through which philosophy enters science and, at the same time, they are the mirror that opens science to a self-reflective movement” [20].

Design and implementation of quality digital learning resources are some of the most pressing issues.

Experts from UNESCO Institute for Information Technologies in Education believe, that the development of the online EERs with interactive multimedia content necessitated the design of new system architecture, unification of the structure of digital educational products and elaboration of a unified software framework [21-22].

Of all the many different aspects of EER development, this study focuses on the design of electronic learning resources based on a systemic approach.

The expediency of applying the systemic approach in design is discussed in the works of O. Balalaieva, V. Bykov, L. Gryzun, A. Dokuchaeva, O. Zair-Beck, I. Kolesnikova, I. Konovalchuk, V. Kraievskiy, Y. Mashbits, I. Robert, N. Surtaeva and others.

However, the issues related to the definition of specific characteristics of the EER design it in terms of structure, organization, dynamics, remain understudied in modern scientific works.

The general theoretical focus of the paper led to the choice a complex of research methods: analysis of scientific literature to study the state of the problem and clarify the conceptual apparatus of the study, system analysis to determine the structural and procedural characteristics of design, generalizing and systematizing scientific experience.

Structural characteristics of EER design

The development of EER design relates to the development of systems engineering and design theory and methodology came from technical fields. One has to agree with researchers who emphasize the need to maintain the essence of the design concept existing in the technical sciences, for using (with appropriate specification and modification) in the new context, that let it be in the same conceptual group with the generic concept of design on the one hand and to apply the results of scientific research and experience in the design on the other.

One of the main advantages of this position is the possibility of applying the methodological basis of the systemic approach to the design of pedagogical objects and phenomena. The basic provisions of the systemic approach to design are specified in hierarchical, structural, object-oriented approaches, which apply of structuring, decomposition and composition methods, provide the determination of structural (aspects, levels) and procedural (stages, phases) characteristics of a design [6].

Decomposition is based on the breakdown of the description of the design object into components and elements and could be carried out by the nature of the object properties and by the abstraction degree of the description of the object characteristics. In the first case, it deals with the determination of the aspects of design, in the second one – levels of design.

The design aspect is a description of the system from a certain perspective defined by the relationships between elements and properties. Aspects are also called vertical levels of design. In the EER design, we can distinguish functional and structural aspects.

Since in system analysis a priority is given to functions and structure is considered as secondary, the functional aspect related to the features of system functioning is described first. Thus, the functional aspect encompasses the functions of the electronic educational resource, that is, properties that allow achieving the goal expressed as some characteristics of the elements, subsystems or system as a whole. An important point in this definition is the emphasis on the goal-oriented nature of functions.

The structural aspect encompasses the internal structure of the system, describes its constituents and the relationships between them. Often, the structure of a system is interpreted as its organization, orderliness, and interdependence of elements and connections. An element is understood as the simplest, conditionally indivisible component of the system.

System components that can be divided into elements are called subsystems, and those for which it is unknown whether they are divisible are called components. Elements and subsystems can be components. Unlike subsystems, characterized by integrity and capability to perform functions aimed at achieving the main system purpose, components do not have such properties.

The elements and components are bound by certain relationships – associations that determine their interdependence and maintain the integrity of the system. There are relationships differentiated by direction (directional and non-directional, forward and reverse), localization (internal and external), character (subordination, origin), etc.

Decomposing the system by the degree of abstraction of the object's characteristics let to distinguish design levels as such, also called horizontal or hierarchical levels.

According to the hierarchy principle, in the design of the system, it is appropriate to bring a hierarchy of its parts and their ranking, which simplifies the design of the system and its elements with a progressive increase in the complexity of the design object description.

To determine the levels of EER design it’s necessary to resort to the design theory. There are three basic levels of design in systems engineering: the meta-level, or system level, at which the most common goals of system design are dealt with in general, the macro-level at which subsystems are designed, and the micro-level at which system elements are designed.

In modern pedagogy, there is no universal viewpoint on the levels of design. The approaches of some scholars [27] to the subject are given in given in Table. 1.

Table 1.

Levels of design

	V. Kraievskiy	Ye. Mashbits	I. Kolesnikova	I. Konovalchuk
Level	*model of project* (fixation of the general content, principles and training methods in general and specific subject in particular)	*conceptual* (development of a model of training system as teaching and learning activity, description of mechanisms, principles, a way of management of learning activity)	*conceptual* (creating a concept of an object or its predictive model representation as a methodological basis for creating products at other levels)	*structural* (description of the components of a pedagogical system, characterizing its content and status in statics)
	project-model (selection of educational materials, training rules, regulatory description)	*technological* *(*description of the project in the form of specific instructions on the management of learning activity, selection of teaching and learning methods)	*content* (development of a product with properties that match its range of potential use and functionality)	*functional* (functional modeling reflecting the sequence and characteristics of the design stages, interaction of systems components and its dynamics)
	final project (description of a set of ideal and material learning tools for the specific subject)	*operational* (determining the degree of generalization of a training fragment, individualization, type of dialogue, type of management)	*technological* (algorithmic description of the way of operating in a specified context: technology of learning, situation modeling)	*technological* (development of the basic technological actions and operations for the further transformation of structural components of the pedagogical system)
		implementation (pedagogical and software implementation, the realization of principles and methods of manage-ment in pedagogic impact)	*procedural* (implementation of a project in the real process, creation of a ready-to-use product)	*productive* (project of technology of educational activity)

Generalizing the experience of scholars, we consider it reasonable to take approach of Maschbits as basis with the appropriate modifications and to distinguish four levels of EER design: conceptual, technological, operational and implementation.

At the conceptual level, the overall concept of the EER is developed, its purpose, target audience, global goal and the ideal result of learning activities using the EER are determined, and accordingly, functions are predicted and the structure is outlined in general; appropriate approaches and principles of concept implementation are selected; preliminary content selection of educational material is carried out; a predictive operating model representation of a design object is formed; the type of learning activity and the way of its management are determined, a student “field of independence” is defined, the type of dialogue, the degree of interactivity, adaptability, and individualization are determined.

Thus, at the conceptual level, some system of initial theoretical foundations based on the choice of ideas, approaches, principles on which further design will develop, is formed, alternative solutions are considered, the choice of the optimum effective one is made, and the conditions for achieving the goal are clarified.

At the technological level, EER basic didactic functions aimed at the realization of the common goal are determined, the selected educational material is structured, the EER subsystems are designed, its macrostructure is built, the optimal methods of teaching and learning are specified.

At the operational level, the functions of specific components and elements are determined, their assemblage is made, the EER microstructure is built, the necessary training effects are designed, the software is selected, databases are created.

At the implementation level, the software implementation of EER is developed, the technical solutions are clarified and specified, the functions of the interface are prescribed, the design is developed, the software is debugged, the functionality of the software is tested, the user guide is drafted and the methodology for using EER is developed.

The characteristics of the projected design results by aspects and levels are presented in Table 2 [23].

Table 2.

Characteristics of EER design results by aspects and levels

Level	Aspect	
	functional	structural
conceptual	predictive operating model of a design object, purpose definition, formal description of EER as a black box	design of general architecture of EER
technological	determination of subsystems functions, design their interrelations	design of EER macro-structure and subsystems
operational	determination of functions of components and elements, design their interrelations	design of EER micro-structure and elements
implementation	determination of interface functions, debugging software functionality	design of interface elements

Thus, at the conceptual stage, the functional aspect can be represented at the level of determining the EER purpose and its dominant function. Since the performance of functions is a process, their study could be carried out based on the analysis of flows of different types – information, energy, material (the structure in this aspect acts as a set of restrictions on flows in space and time). At the outset, a black-box method can be applied for functional modelling of the system without analyzing its structure and internal relationships. The system is represented as a black box, the internal structure and mechanisms of operation of which are unknown or unimportant at this stage, instead of its components and properties the system's response to the input data is studied. The system has an input for different flows and an output for displaying the system reaction and operational results, the processes taking place during the operation of the system to transform the input data to the output are unknown to the researcher.

The system description looks like a black box with an input (information or material that is used or transformed by the system to produce a result) and an output (the result of transforming the information) that reflects the goals of the designed system. Inputs for the system are information flows – academic content to be learned, outputs are knowledge, skills and competencies. Therefore, designer’s challengers are: what functions should be determined for EER, how to structure the academic content and training material to organize the effective tutor and student’ activity to achieve the goal based on the didactic potential of EER in line with the requirements of the State educational standard. Taking account aspects and levels, it might be useful to choose a top-down design style (stepwise design), when the process of searching and making design decisions is carried out from higher to lower hierarchy levels with an increase in the degree of specification.

Procedural characteristics of EER design

In addition to aspects and levels that are structural characteristics of design, an important issue is to determine the stages of design that characterize it as a process.

In engineering disciplines, design as a time-consuming process is divided into stages, phases, procedures and operations. In general, there are stages of research work (pre-design study, technical assignment and proposition), draft, technical and work projects, testing of prototypes and implementation.

The design stages are divided into phases – components of the stage, associated with a certain kind of work. Phases consist of certain procedures, which are a formalized set of actions or operations result of which is a design decision (for example, object modelling). The views of the systems engineering classics [27-28] on stages and phases of design are given in Table 3.

Table 3.

Stages and phases of design in system engineering

J. Jones	P. Hill	J. Dixon
divergence (extending the boundary of a design situation to have a large enough, and fruitful enough, search space)	identification the need	goal recognition
	goal definition	task specification
	search	
transformation (problem boundaries are fixed, critical variables are identified, constraints are recognized, decisions are made)	generation of ideas	concept formation
	concept formation	
	analysis	
convergence (reducing the field of options to the single design solution)	decision	solution specification
	experiment	
	production	production
	distribution and use	distribution, servicing

Most researchers agree that designing, in general, has three main stages: analysis (breaking a technical task into parts), synthesis (combining parts in a new way), and evaluation (implementation and evaluation of consequences), which are repeated iteratively and each subsequent cycle is different from the previous one in greater detailing.

The expediency of applying the methodology of the system approach in pedagogical design has been proved in the works of many scholars. In particular, V. Bykov et al. recommend applying the model ADDIE (Analysis, Design, Development, Implementation, Evaluation) used in instructional systems design. Researchers also emphasize the conditional sequence of these phases, since designing is a single process with many iterative cycles [24].

Generalizing the experience of scholars and taking into account the specifics of the subject of this study, we consider it expedient to determine the stages and phases in ERR designing [24].

The stage is interpreted as the most generalized part of the design as a process that reflects the change in its states. In the EER design, analytical, actual design, experimental and reflexive stages are distinguished. The design phase is part of the design process that involves describing one or more aspects or levels of design. General characteristics of the stages and phases of EER design are given in Table 4.

Table 4.

Characteristics of stages and phases of EER design

Stage	Phase	Characteristics
analytical	diagnostic	analysis of the situation, identification and diagnostics of the target group
	goal-setting	problem identification, definition the global goal, object, subject ideal final result of the design
design	conceptual	formulation a general concept of the EER as a system and development of a model
	technological	determination of basic didactic functions and their interrelations design of EER subsystems and macrostructures, structuring an academic content,

Continuation of table 4

		selection of an optimal training methods and way of management of educational activities
	operational	definition of components and elements functions, their interrelations, design of EER microstructure, choosing the optimal software to solve the tasks, creation databases
	implementation	software implementation, interface design, debugging software functionality, development of the model and methodology of using EER
experimental	ascertaining	analysis and determination of the students training level in the subject, diagnostics of students' need to use EER
	formative	testing, pre-implementation of EER in the educational process, verification of the methodology effectiveness
	control	quantitative and qualitative analysis of empirical data, indicators of methodology efficiency by certain criteria, systematization and generalization of the results of pedagogical experiment
reflexive	corrective	evaluation of project functioning, identification and elimination of shortcomings, introduction of necessary changes to the structure of the EER
	adaptive	creation of the final product, project adaptation to the real conditions of the educational process

At the analytical stage, the real situation in the educational practice in a specific subject is analyzed, the diagnosis or monitoring of the target group is provided, the contradictions are identified and the problem is defined, the object and the subject of design are determined, the possibility, necessity and feasibility of EER creation and development are stated, its general purpose is determined. At this stage, the global goal and ideal result of the EER design are formulated. The main phases at the analytical stage are diagnostic and goal-setting.

An actual design stage at certain levels includes conceptual, technological, operational and implementation phases, aimed at searching and implementing rational design solutions in functional and structural aspects.

At the experimental stage, testing is carried out, preliminary implementation of the EER in the educational process takes place and the effectiveness of the training method using EER in comparison with traditional or alternative methods is verified. The experimental stage consists of ascertaining, formative and control phases.

The reflexive stage consists of the corrective and adaptive phases, which provide for making necessary changes, eliminating deficiencies in the EER functioning, adapting the project to the real conditions of the educational process in a particular educational institution, evaluating the achievement of the declared goal, summarizing the results, creating the final product and outlining its further development.

Such approach reflects the logic of design as a process, involves changing its states (stages differ in the tasks, results and type of activity of the design subject – analytical, design, experimental, reflexive).

At the same time, we emphasize the conditional nature of the separation of these parts, since the design process does not have a linear sequence of stages and phases, which are interrelated and interdepended.

Thus, the diagnostic phase of the analytical stage involves the results of the ascertaining phase of the experiment; projecting and designing the main functions of the EER begins at the goal-setting phase; mistakes made at different phased of the design stage, even in the design concept can be found at the reflexive stage, etc.

Thus, a systemic approach to the design suggests considering EER as a complex system that is separated from the environment but interacts with it, has an integral structure, which is a set of relations between the elements in their interaction and the composition of these elements with their specific functions.

EER design should be considered as a multidimensional, multi-level and multi-stage process. In particular, there are functional and structural aspects, conceptual, technological, operational and implementation levels and analytical, actual design, experimental and reflexive stages, consisting of several phases.