Fundamental Problems in Computer Science

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LEARNING TASK MODELS IN THE CONTEXT OF EDUCATION FOR SUSTAINABLE DEVELOPMENT

Education for sustainable development is based on the implementation of the concept of life-long, high-quality and inclusive learning, aimed at acquiring the competencies necessary in a knowledge society. The paper describes task models for learning tasks related to the acquisition of general skills and knowledge for collaborative problem solving, information analysis and evaluation, and management of one's own learning. A learning process is considered as a collaborative problem solving implemented through an interaction between a learner and an open learning environment. The specifics and requirements to the open learning environment for sustainable development support are discussed, and the role of digital technologies is outlined.

Keywords: lifelong learning, digital technologies for teaching and learning, sustainable development goals, digital didactic, education for sustainable development, learning environment.

Introduction

The concept of sustainable development and its three components — economic, social and environmental — constitute the basis of the 2030 Agenda for Sustainable Development [1], the document in which the 17 Sustainable Development Goals (SDGs) were identified as the way to address global challenges for the survival of humankind. The rationale behind the identified goals is that achieving them provides everyone with the opportunity to live a balanced, peaceful, prosperous and just life nowa-days without compromising the ability of future generations to meet their own needs in the future.

Education is at the core of the Agenda: evolution and enhancement of education is one of the key elements in achieving all the SDGs. Recognizing the important role of education, this document highlights it as a separate goal (SDG 4) stating "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". To address this goal, UNESCO adopted the Education 2030 Framework for Action [2], which is focused on expanding access to education, with a

particular attention to inclusion, equity and quality at all levels in lifelong learning.

The idea of lifelong, high-quality and inclusive learning, as a new paradigm of education, is rapidly spreading all over the world. It suggests the possibility of changing the very nature of learning due to the availability of information, flexibility of learning experiences, and, consequently, the possibility of acquiring new competencies necessary in a knowledge-based society. This trend entails the introduction of emerging digital technologies, the use of innovative educational and pedagogical methods and capitalizes on the growth in amount and changing nature of information and knowledge. Knowledge and education, being the most valuable renewable resources available to humanity, empower people to respond to emerging challenges and find non-standard solutions.

However, the role of education is not limited to responding to changes in the world, it can be proactive to its transformations.

A variety of action items in line with [2] has been proposed as specific steps towards achieving the SDG 4 focusing on political, financial, governance and other aspects at various educational levels [3]. This study is aimed at addressing the essential changes in learning and teaching that are related to implementation of the SDG 4 and the requirements to learning environment for lifelong learning in the context of sustainable development. For this purpose, learning and teaching, as two sides of the educational process, are considered as a problem-solving activity.

Core Features of the ESD

The emerging context of social transformations requires a revision of the goal of education and approaches to learning. To address the challenge of ensuring sustainable human capital and social development, UNESCO is building a new concept of learning for the future by rethinking the goal of education. Transformation of education according to this concept requires understanding by the participants of the educational process the need for harmony with the environment, both nature and society; and this understanding could be achieved by interdisciplinary studies, by introduction of new disciplines and curricula, by gaining new competencies and by using new approaches.

The concepts of education and learning, their role for society wellbeing and place in a human's life, have been a subject of scrutiny analysis in the past decades, resulting in the idea of lifelong learning, or learning through the life, as opposed to education that precedes and prepares for the rest of life. Thus, in the report [4], two interrelated concepts of a learning society and lifelong learning were introduced, and lifelong learning has been identified as a key element of education policy both in developing and developed countries. In [5] a comprehensive concept of education based on two key ideas — "lifelong learning" and "four basic principles of education: learning to be, to know, to do and to live together" is suggested. The purpose of education is considered to be in support for learning, exploring and experimenting with knowledge and generating new knowledge that society needs.

The concept of learning has been extended beyond the borders of formal learning. Nowadays, any activity is interpreted as learning activity if it is aimed at changing the understanding, attitudes, or behavioral models of individuals by acquiring new knowledge, developing new skills, or introducing the desired behavior for the particular situation. Therefore, lifelong learning could be implemented as a combination of formal, non-formal and informal learning, all of them facilitating the professional and personal development of the individual.

Education for Sustainable Development (ESD) can be considered as a way of implementing quality education corresponding to the concept of lifelong learning. ESD is a multi-disciplinary education which can be seen as a new facet of education in terms of curriculum content, learning outcomes, teaching methods and technologies used. The ideas of sustainable development can be addressed at all educational levels in various depths. So, ESD is considered as a way to change humans believes and modus operandi through consistent educational impact, through lifelong learning that addresses the future needs and prepares for challenges. ESD is a holistic and transformative education that affects learning content and didactics, enriches learning

outcomes by general competencies, enhances motivation for learning through the life, and extends and reconstructs interactive learning environments for learners and ultimately achieves its goal by transforming the society.

The main difference between ESD and traditional education is in the development of key general competencies that enable the learners to analyze their own actions in terms of their social, cultural, economic and environmental impact on the present and future. Key competencies represent cross-cutting abilities crucial for all learners of all ages (however, developed at different age-appropriate levels) that are necessary for promoting sustainable development. They can be understood as transversal, multifunctional and context-independent. Key competencies for sustainability are systemic, strategic, forward-oriented and critical thinking, ability to recognize one's own role and collaborate with others, and integrated problem-solving [6]. These competencies can only be developed through conscious efforts of the learners themselves. They are acquired through learning experience, through real life activities and experience, and critical analysis [7] of the above. People in possession of these competencies could be called "citizens of sustainable societies" [8], as they are empowered by abilities to formulate their point of view, to make efforts in the interests of positive change, to collectively deal with emerging challenges.

Another difference is in the didactic and pedagogy behind the ESD processes. ESD requires a shift from teaching to learning, from "consumption" to "conscious activity" model. ESD is implemented by didactic approaches, which support self-directed learning, participatory learning and collaboration, explorative and problem-oriented learning, which enable inter- and trans-disciplinary studies, incorporation of the andragogy principles and the combination of formal and informal learning methods. The ESD requires the use of methods that encourage independent study of the learner, facilitate group and team work over a common problem, develop communication competencies and promote their use for trans-disciplinary solutions.

In terms of a systemic approach, ESD is reorienting the entire learning process for sustainable development. It means that the focus of attention is shifted from the formal concept of sustainable development towards a study of the processes leading to stability or instability, their causes and effects. Systemic view enables consideration of each of the SDGs as a part of the inter-related set of goals in order to get a comprehensive view of the plan for sustainable development.

Learning and Learning Problems/ Tasks for Achieving the SDGs

The detailed analysis of the SDGs shows that education in the 2030 Agenda for Sustainable Development is not restricted to the SDG4. Education is specifically mentioned in the tasks of the five goals: Health and Well-being (SDG3), Gender Equality (SDG5), Decent Work and Economic Growth, Responsible Consumption & Production (SDG12), Climate Change Mitigation (SDG13), but also linked to almost all of the other SDGs in one way or another.

SDG 4 [3] formulates three major requirements for achieving the goal: education should be continuous, inclusive, and of high quality. We further consider the implications of these requirements and resulting features of educational processes, primarily, teaching and learning.

Learning happens throughout our life: we master cognitive skills, develop our attitudes and acquire new behavioral skills in the course of everyday life. Learning cannot be limited to a certain period of time, it is a continuous process, since the information environment is constantly changing by generating, receiving, processing, restructuring information, archiving, reusing and deleting it [9]. Therefore, lifelong learning is a proper way to address these changes, so formal education should be reconsidered to prepare the learners for further learning, and new forms of learning and training should be developed.

As noted above, in a sustainable society, education should be of a qualitatively new level. This is understood as the correspondence of the characteristics of the process and the learning outcomes to the needs of the learner in the digital age. In a review of quality assessment processes for online

and distance learning institutions [10], it is recommended to use a systemic approach to ensure quality and consider learning outcomes as the main measure of quality. Studies [11, 12] have shown that barriers to quality education are still too high for many learners, and that more efforts are needed to develop quality standards that address design, development and implementation of educational programs, especially those delivered using hybrid, blended and online modes.

Inclusive education is understood as a process of education and upbringing in which the entire society is included through its individuals aiming at providing the necessary special support. Inclusiveness is achieved through the process of addressing individual learner's needs and as a social model, envisages that the learning system changes for the sake of the learner (and not the vice versa). The goal of inclusion (as opposed to integration) is the formation of a learning and developing environment for learners. A simple example could be seen in a BYOD (bring your own device) approach [13] when the learning content and process is arranged around learners' mobile devices.

It is important to note that there is a close relationship between all three imperatives for to ESD (lifelong learning, quality and inclusiveness) as well as the mechanisms for their implementation as illustrated by the following example.

One of the specific learning objective for SDG 4 "Quality education" may be formulated as follows: "The learner is aware of the important role of education and lifelong learning for all as the main factors of sustainable development that contribute to improving people's lives". Instead of reading the learning material, a learner could conduct a case study on lifelong learning for all., thus, contributing to the development of the systemic thinking competence. As a key competence, systemic thinking facilitates understanding the complexity of problems and the way their solution will assist on the path to a sustainable society.

As demonstrated by the example, the learning process takes place in three domains: cognitive, affective and psychomotor [14], and includes several levels overarching a range from basic, superficial assimilation to more complex, deeper learning.

The cognitive domain includes the development of mental skills and knowledge acquisition related to information processing, knowledge application, problem solving, and research, as well as the ability to integrate different elements or concepts and come up with judgments about the importance of concepts. The affective area includes our feelings, emotions, and relationships. The psychomotor area includes the use of motor skills and their coordination.

Usually learning is considered as pertained to the intellectual functions and cognition, whereas physical skills are considered a subject of training. Here we emphasize on learning as a general term for acquisition and enhancing knowledge, cognitive and physical skills, attitudes, believes, and behavior. Considering learning from a problem-solving perspective, learning is a process aimed at solving a learning problem, which is formulated in terms of attaining a learning goal. In a context of learning, a teacher and a learner interact with each other to solve a learning problem. The methodological basis of the approach to analyze this interaction is representation of participants as problem-solving systems endowed with a certain structure and working according to certain rules [15].

ESD is the foundation for building key interdisciplinary sustainable development competencies relevant to the achievement of all SDGs. In addition, ESD can contribute to the development of specific knowledge, skills and competencies required in order to achieve specific SDGs. Specific learning objectives focused on achieving SDG 4 can be grouped as follows: learning-cognitive, socio-emotional and behavioral [6].

Learning — cognitive problems include building the knowledge and cognitive skills needed to better understand SDG 4 and its challenges. Socio-emotional learning problems include the development of social skills that enable learners to interact, negotiate, justify, reach the agreement and exchange information. This also includes the formation of introspection skills, values, attitudes, and aspirations that will contribute to the self-development of the learner. Behavioral problems are focused at the formation of the activity competences. Examples of different types of learning problems (learning-

cognitive, socio-emotional, behavioral) for developing the key interdisciplinary competencies according to the particular SDG 4 requirements are given in the Table.

Digital Technologies and Learning Environment for ESD

Education is a driving force for sustainable development, which will be successful only if the opportunities to develop critical thinking, independence of judgment and the ability to conduct debate brought by the digital revolution [16] will be fully employed. The development of technologies imitating various aspects of artificial intelligence related to human abilities to summarize information, recognize objects, identify emotions can lead to cardinal changes in the field of education. The use of holography, instant transcription, voice and gesture recognition, identification of attention, mood or tone of a message are just some examples of technologies that have a great potential for enhancing virtual and augmented reality for education. Introduction of digital technologies into the educational system brings complex changes to the pedagogical, methodological, and technological approaches and the culture of learning as a whole [17].

Provision of comprehensive and equitable quality education and lifelong learning for all is associated, first of all, with the use of approaches to education based on the open educational resources (OER) [18], new opportunities for dialogue, perception and information processing. Modern digital technologies, OER and global computer networks are becoming powerful tools for accessing information from any corner of the world. At the same time, diversity and continuity is viewed not only as a promising trend, but also as a condition for achieving a new quality of education. The main idea is that lifelong learning becomes a fundamental principle of the educational system, that is manifested in an open environment, comprising an educational informational, professional, and entertaining elements. This change from prescriptive teaching and learning procedures to ubiquitous learning has led to the emergence of innovative platforms for supporting learning activities and entailed; changes in approaches, organization, models, methods and technologies of learning [17].

Traditional learning environments are specially created for processing of learning tasks. They are considered as containers, therefore all their content is known, accounted, and prepared for consumption. This model does not of the modern world, and will be inevitably substituted by open eco-systems models, evolving through a chain of transformations, stimulated by socio-economic conditions that set new goals for education. Building upon ubiquitous "any time, anywhere" learning, open learning environments can be illustrated by home-based learning, massive open online courses (MOOCs) [19], social learning — from friends, family and colleagues, study of the nature changing both the knowledge and attitude towards it, personal learning environments, formed according to the needs and preferences of a particular person, as well as high-tech environments of virtual and augmented reality [20].

Dialogue is arguably one of the most important components of any learning. Moreover, dialogue is often understood as a general requirement leading to an improvement in the quality of education. The well-known formula of Vygotsky L.S. [21] "learning is ahead of development" only in recent years has begun to gain meaning in digital didactics inherent in the concept of lifelong learning. Developing a dialogue structure and understanding the behavior of learners in the process of online communication requires consideration of two aspects: interaction with OER and interpersonal interaction. Studies show [22] that interaction with OER is not enough to achieve a set of ESD learning goals, as targeted feedback is needed to teach the learners how to analyze, synthesize and evaluate the information received. Interpersonal interaction while solving a problem in a group has a number of advantages, such as learning about other approaches and methods, dividing the problem into parts and obtaining the solution faster, acquiring management and teamwork skills. Therefore, many learners are motivated to work by other learners, especially when solving joint problems. As the SDGs are achieved, the problems being solved by the learner

become more complicated, since ESD is a process of continuous learning, the result of which is the ability to envision the consequences, predict the future and look ahead. To implement learning activities within the framework of achieving the SDGs (as opposed to traditional learning), an open environment needs the instruments for solving learning problems aimed at developing critical and creative thinking, the ability to solve problems, analyze, make decisions, learn something together, develop sociability. Since the description of the functioning of two dissimilar parts of the environment — "social" and "technical" is based on the concept of a problem, the approach based on the problem theory [15] can be used as a conceptual basis for description of dialogue interaction within ESD. The methodological prerequisite for the use of the problem theory was the idea of identifying basic learning task models for interactions within an open environment.

Dialogue Interaction Tasks in the ESD Support Environment

We further will consider a special type of interaction, a dialogue interaction, a process of exchanging messages between two or more subjects, caused by their need for sequential or parallel execution of some actions to achieve the joint solution of a learning problem. Dialogue interaction while solving the learning problem implies the existence of:

▪ objectives of interaction between the participants of problem-solving process which initially might be not in full concordance;

▪ activity of all participants focused on achieving SDG 4 and manifested through the change of a lead (interaction control) or distribution of routine and non-routine actions among all the participants;

▪ mutual understanding concerning the actions the participants perform and decisions they make;

▪ enhancement of knowledge and skills of one participant through the assimilation of knowledge and skills of another.

Considering problem solving in an open environment, both a learner and environment as his/her partner expand their capabilities by performing a variety of actions associated with problem sol-

ving. Particular tasks delegated to the partners correspond to certain objectives. The methodological basis for constructing dialogue interaction task models is to consider this interaction as a process of collaborative solution of one problem by two (or more) problem solving systems PSS_j and PSS_i. In this case, various types of (dialogue) interaction are presented as procedures for solving certain classes of problems.

Learning and Teaching Tasks. Let the environment (problem solving system PSS_i) is able to solve N sets of tasks and PSS_j (another problem solving system, a learner) seeks to solve a task from this set, using PSS_i, which has certain instruments (methods, algorithms, procedures) for solving the task. The purpose of the interaction between them is to give the learner an opportunity to develop concepts, think critically, apply and evaluate what has been learned using the instruments and experience that is relevant to solving the task. Let PSS_{ij}^* — a partner model of the PSS_i, available for the PSS_j. $PSS_{ij,k}^*$, is a model of the PSS_i, which is available for the PSS_j within the K-th subject area (achievement of the SDG4) and includes knowledge about the means of interaction task (IT_k) solving. $PSS_{ij,k}^*$ — knowledge of the PSS_j about its own mechanisms for solving the IT_k. LO_j is the interaction objective which is available for the PSS_j (to transfer the task to the partner for solution, to solve it by joint efforts, to improve its own knowledge and skills by itself or by knowledge and skills of a partner, etc.).

Then, by the problem of dialogue interaction in the process of solving the learning task from group N, focused on achieving the SDG 4, we mean a set $IT_k = \{B, B_{cs}, B_r^*, PSS_j\}$, where $B = \{K, PSS_{ij}^*\}$; $B_{cs} = \{K_{cs}, PSS_{ij,k}^*, PSS_{ij,k}^* \subset PSS_{ij}^*\}$; $B_r^* = \{K_{r,j}, LO_j\}$.

Each system in the process of goal-setting for solving the IT_k should:

1) form an adequate current representation of an open environment, i.e. $K_{cs,i}^*$;

2) have a model of the subject area K_i^*;

3) have information about itself, about its own properties and capabilities, i.e. have a PSS_{ii}^* model;

4) have a learning management procedure;

5) be able to distribute the functions for the implementation of the learning procedure among all participants in the learning (e.g., in case of learning community);

Table. **Examples of learning tasks for achieving SDG 4**

Task types / Kind of learning	Lifelong earning	Quality	Inclusive
Learning-cognitive	Assemble resources on lifelong learning technologies. Explain what knowledge is required for lifelong learning implementation. Build verbal lifelong learning models.Choose the best examples to help you understand the concept of lifelong learning.	Explain your understanding of the key principles underlying the Quality Learning program. Analyze the relationship between quality learning and sustainable development goals. Suggest some models to achieve quality learning. Select the most efficient way to implement the above model.	Describe your understanding of the principles of inclusive learning. Analyze various facts and opinions about inclusive learning in the experts' reasoning. Create a plan to achieve gender equality in some area (for example, education). Explain why your approach to solving the problem of inclusive learning will work.
Social-emotional	After watching the lecture, assess and describe the educational needs to achieve the SDGs Actively participating in group discussion, propose a plan for fulfilling the needs in harmony with interests, abilities, and beliefs. Share your ideas about recruiting skilled people to better meet the needs of your community. Working in a team, discuss, refine, and reconcile the needs and objectives.	As you observe the growth and change in the nature of information and knowledge, describe your feelings about the relevance of quality learning. Present and discuss training programs in ESD for different stakeholders (teachers, educational leaders and management). Describe how you value quality learning for improving the quality of your life. Suggest a plan to improve team-building and collaborative skills through a goal-oriented activity (e.g. startup proposal writing) Reconsider your judgment and change the way you achieve the results in light of new circumstances.	Provide examples supporting the feasibility of inclusive education. During group discussions, present a broad approach to inclusiveness, equity and gender equality. Evaluate someone's awareness of the fact that individuals should be appreciated independently on their abilities and achievements. In discussion, offer recommendations for ensuring more equitable access to some levels of education and training. Demonstrate that everyone has a right to communicate and to be heard.
Behavioral	Choose an environment in which EDS tasks will be addressed based on your knowledge of lifelong learning. Following the instructions, create a lifelong learning model. Implement a learning process according to the model using selected technologies. Create new models according to a new situation or new task.	Create a presentation showing examples of quality learning. Extend your lifelong learning experience to different areas. Show communication skills in conflict resolution that can be used in professional fields to achieve quality learning. Focus on acquiring competencies and achieving relevance for quality learning.	Build a structure or pattern from various elements of diversity that enhances some aspects of a person's life Apply what you have learned to new situations in the workplace. Modify the instructions to suit the needs of the students. Motivate a learner to perform the planned exercises. Adjust the learning environment for the needs of a particular learner.

6) be able to interact for the implementation of various procedures;

7) select or create resources to achieve the SDG_s;

8) assess the degree of achievement of the SDG_s and the effectiveness of progress towards the implementation of the model of the required state of the subject area ($K_{r,i}^*$).

Within the framework of the problem approach, the construction of a dialogue interaction task model includes the development of a learning management procedure and a description of the learning control actions.

Since the solution of the problems of searching and analyzing information, improving knowledge, jointly solving, providing access to resources is necessarily present when solving the problems of teaching and learning, we will further consider the models for solving these problems within the framework of achieving the SDG 4.

According to the 7th condition, the implementation of dialogue interaction requires the availability of instruments to ensure effective teaching and learning of partners.

Each task solved by a system is defined as a triplet $T = \left(K^*, K_{cs}, K_r^*\right)$, where K^* is a model of the problem domain, namely, $K^* = \left(\{A\}, \{\omega\}, \{R\}, \{A\}\right)$, $\{A\}$ — a set of learning objects; $\{\omega\}$ — set of operations on $\{A\}$; $\{R\}$ — set of relations on $\{A\}$; K_r^* — model of the required state of the problem domain K_r; K_{cs} — current state of the problem domain. Changing the current state of K_{cs} to the required K_r is called a procedure for solving the task T.

A procedure for solving the problem may include operations of both the first and second type [15]. Operations of the first type affect the original data and transform them into a result (change the objects of the subject area).

Operations of the second type control the application of the operation of the first type (they do not directly affect the data).

A program Ω^* is a model of a procedure for solving the task, which contains only descriptions of operations of the first type. Operations of the second type are intended for the programs formation using models of operations $\{\omega^*\}$.

Since interaction in the environment can be represented in the form of procedures for solving

various kinds of problems, we will consider learning as a procedure for solving a cognitive problem and the associated control problem. According to [15], the learning task is a pair of tasks $<CT, AT>$, where CT is a cognitive task, and AT is an assessment task, the solution of which gives an answer to the question "whether the objective (goal) has been achieved in some parameters." In our case, the CT has a complex structure and includes an imperative with or without information search and analysis, or is solved jointly by PSS_j (learner) and some social environment (community, society).

Let us expand the concept of a cognitive task, given in [15], by including skills of PSS_i in the subject of the cognitive task, i.e. components from the sets of operations $\{\sigma\} = \{\vartheta\} \cup \{\omega\}$ and procedures $\{\Sigma\} = \{\Theta\} \cup \{\Omega\}$, where:

ϑ — intelligent operator of the second type,

ω — routine operator of the first type,

Θ— procedure of the second type,

Ω— procedure of the first type.

Skills and knowledge of the second type is an important component of general education whereas skills of the first type (editing, searching, and distribution of materials) is a component of professional specialization.

The Main Types of Training Procedures for Interaction Tasks in Achieving SDG 4. Let us assume that PSS_j (the learner) can solve the task T_k, involving to this solution another solving system PSS_i (an open environment). To do this, PSS_j must determine its own capabilities and the capabilities of a partner in solving the task T_k, the goal of attracting PSS_i to the solution P_k, i.e. the goal of interaction with PSS_i. The fulfillment of these conditions leads to the expansion of the PSS_j (learner) of the components T_k. In this case, in the learning problem, the role of T_k is played by the problem of learning or self-learning, i.e. pair of tasks $<CT, AT>$. Therefore, the solution of the learning task, as well as the process of solving any interaction task, includes: procedures for solving the set of learning tasks by the learner $\{<CT, AT>\}$; a procedure of interaction between the learner and the environment, aimed at achieving the objectives of "obtaining new knowledge, skills and abilities."

Considering the learning tasks focused on achieving the SDG 4, it is necessary to highlight:

1. Teaching according to a pre-compiled training program Ω^*, the implementation of which is completely entrusted to the learner, operating with the learning objects available to him. In this case, the components of the program Ω^* (a set of formulations $\{F_{ji}^*\}$ of the task of learning, a set of models $\{PSS_{ji}^*\}$ of states of the solving system PSS_i, a set of relations $\{R_j\}$ defined on the sets $\{PSS_{ji}^*\}$ and $\{F_{ji}^*\}$) are formed in the process of performing the procedure (adaptability), i.e. goal-setting related to the achievement of SDG 4 is being carried out. This makes it possible to form a CT, an AT and a model of the task that PSS_j will solve, which opens up additional opportunities for learning management. The ability to generate a solution assumes that the environment has operators of the second type $\{\vartheta\}$ or a "meta-learning procedure" that ensures the formation of a program Ω^*. Such operators can be operators of assessment and decision making, operators of forming a plan for solving a problem, operators of changing the model of the required state of the subject of the problem being solved, etc.

2. Learning in the process of solving a problem. Let the learning task LT_{ji} be a subtask of some task T_k, which is not a teaching task or a learning task and is referred to PSS_j. In this case, two kinds of the relationship between the procedures for solving the learning task LT_{ji} and the task T_k, can be indicated:

a) the control procedure for learning $\Omega_{l,ji}$ is carried out before performing the procedure $\Omega_{k,i}$ of solving the task T_k;

b) the components of the decision procedure $T = \{LT_{ji}, T_k\}$ are the set of tuples $\{\pi\}$ such that each π includes one component of the procedure $\Omega_{l,ji}$ and a component of the procedure $\Sigma_{k,i}$.

Case *a*) corresponds to the educational process "from the instruments of solution to the task", and case *b*) — to the learning in the process of solving a task. If in the tuples $\{\pi\}$, at least one component from $\Sigma_{k,i}$ precedes the components $\Omega_{l,ji}$, the process is called learning "from tasks to means of solving them", it motivates the learner to search for the instruments and "extract" means of solu-

tion, by the formation of a social-emotional task.

3. Interactive learning. Learning is interactive if the goals LO_l and LO_t are achieved during managed interaction and each of the participants performs at least one of the operations of the second type. In interactive learning, partners often change their interaction management functions so that the learner can formulate and solve the tasks independently.

The first type of learning procedures is typical for learning with OER, the second — for adaptive learning systems and problem solving support systems, the third — can be considered as lifelong learning. Thus, it is shown that the solution of learning and teaching tasks are crucial for achieving SDG 4, and the teaching task is to form a personal environment for performing the learning task. The latter, in turn, needs to provide the following sets of tools:

▪ routine or executive operations of the first type $\{\omega_k\}$, for acquisition of specific experience by performing actions and thus changing T_{cs} towards T_r. These actions can be completing assignments, solving problems, viewing illustrations, reading, watching videos or conducting experiments, and most importantly, these actions could be discussed;

▪ intelligent operations of the second type $\{\vartheta_k\}$. These meta-operations are needed to comprehend and reflect on the mastered material. Learners get an opportunity to analyze their knowledge, feelings and impressions, to recognize problems that do not have a prepared solution;

▪ procedures for solving a set of learning tasks by the learners. After executing the operations, a learner needs some general theory to explain the facts and find patterns, to determine cause and effect, implications of the results. In this way, learners get the opportunity to incorporate their own experience to form a systemic view, find an application for the concepts and phenomena learned;

▪ procedures for interaction between the learner and environment aimed at achieving the goals of G_t and G_l. Application of the acquired knowledge and skills in a new situation, when partners work together on the problems that have arisen to achieve the goal and learn from each other. At the same time, this stage is also a first step to a new level of learning (development).

Requirements to the Environment for ESD Support

In the previous section, we considered the solution of the learning/teaching and dialogue interaction problems within an open learning environment that are central to ESD.

Currently, technologies enable creating a variety of learning environments that can be a virtual copy (a Digital Twin) of a traditional educational organization, but can also differ significantly from it. However, the use of technology alone does not guarantee quality. Taking into account the basic principles of ESD, the ESD support environment should provide sources of new knowledge and information that meet the needs of various users, should offer a wide range of digital technologies for organizing users' work and actually processing structured information, presented in the form of various media, and should meet the needs of users in the development of their abilities to solve new problems. Thus, such an environment should contain a set of tools for an independent learner for decision-making, informed choice and control of the learning process, as well as assist him/her by individually adapted advice and support. In addition, there should be tools for planning the learning (what, when, why, how), scheduling the learning sessions, tools for analysis and assessment, as well as communication and dialogue interaction tools for all of the above tasks.

As described above, a successful dialogue interaction is possible in a situation when both partners have a certain model of each other and some common (similar) models of the problem, context, and subject area. In addition, the participants of interaction must understand and accept the roles — their own and the partners' — in the process of interaction.

When designing, choosing or using a learning environment, it is necessary to take into account (1) the distribution of roles and associated problems, and (2) the possibility of updating and developing the environment and its components. The first, in particular, concerns the role of the Teacher, attention should be focused on the needs of the Learner, which are identified and specified in the process of dialogue interaction.

The second premise is that the learning environment needs to be continuously evolving to support lifelong learning. The objectives of ESD, in contrast to the classical (retrospective) learning, are aimed primarily at preparing for new situations, conditions, methods, technologies; at recognizing and formulating new tasks; at the development and integration of their solutions.

In ESD, the teacher's job is not to directly transfer knowledge to the learner, but rather to organize and use a functionally rich learning environment facilitating learning, scaffolding, communication with experts (teachers) and peers, which will empower learners to develop concepts, think critically, apply and evaluate what they have learned by providing instruments and learning experience assisting in achieving individual learning and teaching goals.

Within the framework of this environment we further indicate groups of information objects (entities) which need to be supported by technologies for achieving a qualitatively new approach to learning — ESD. Among them, we highlight:

Learning and Teaching Objectives. In the traditional curriculum, the educational goals and the means of achieving them are set in advance, therefore, the coordination of learning and teaching objectives is reduced to the learner's choice of the objectives from the list. When considering the problem of learning in the framework of ESD, it is necessary to envisage a variety of possible objectives and understand the goals of the learner to determine the educational content and select adequate learning strategies supported by certain teaching methods. Understanding the goals of each learner enable planning of the optimal learning path for each individual by choosing the learning content in the required volume using examples and explanations from the area close to the learner, choosing the appropriate types of learning activities, presentation methods, as well as using other types of adaptation [23] based on the knowledge of the characteristics of the learners and the problems they solve or the tasks they perform.

Information About the Learners. Besides the learning objectives, information about the learner, his knowledge, skills, and preferences is needed for

the effective organization of his learning process. Educational programs intended for wide coverage of the users — mass-scale education — ignored individual differences being oriented at the "average" learner. With the development of the technical capabilities of individualization of the learning process and research in the field of the student's educational preferences (styles and strategies of learning, the use of certain technologies and media, the duration and frequency of training sessions), technologies appear that provide a certain degree of individualization of learning through the use of the model [24], reflecting the characteristics of the student. In an ESD context, it is important to provide access to information about the learner for all learning technologies that he uses, as well as to ensure that this information is updated and, based on it, the learner's model is improved. Changes in the characteristics of learners in the digital era must be taken into account in the formation of educational resources, namely: the need for highly interactive courses, the availability of digital educational material in multiple formats, its structuring in the form of micro-lessons and small modules (as opposed to long-term programs and lecture courses), the possibility of choosing modules, meeting individual needs, obtaining assistance in solving their practical problems.

Available Resources. Modern education is impossible without a variety of resources — educational (textbooks, curriculum, distance courses), technical (equipment, specialized technologies, software), information (recommended literature, various data sources), communication (interaction and collaboration technologies, support services). Access to learning experience has been expanded by offering a variety of digital sources, making it easier to create, combine and share multimedia, constructing virtual environments and interactive models, and facilitating enhancement of digital skills. The learners obtained more freedom in choosing both the curriculum and the resources for its study. At the same time, they are facing new tasks to evaluate resources available for their experience level and make decisions regarding the quality of the proposed resources and correspondence to their expectations and needs. From an ESD

perspective, learners must learn to work in an open information environment, so it is especially important to develop general skills such as analyzing and evaluating information, knowledge management, problem solving and decision making. Intelligent technologies of filtering and searching for resources and sources of information in accordance with the characteristics of learners can contribute to solving the problem of learning in an open environment, such as technologies based on web-mining, case-based reasoning, intelligent agents, that are able to make personalized recommendations [25].

Criteria and Evaluation. In a traditional learning environment, the behavior of students directly depends on assessment criteria, e.g. how the achievement of the learning objectives will be assessed when solving the learning problem. Assessment strategies, the type and format of assessment affect students' motivation and their mastery of the material, such as, the priority of comprehension over memorization, a conceptual understanding rather than fragmented knowledge, development of problem solving skills using the acquired knowledge. The digital toolkit for assessing learning outcomes is constantly evolving, allowing expanding the range and improving the quality of assessment. It is possible to assess not only knowledge or attitude, but also skills and competencies of learners, and integrate assessment elements into digital educational content. In the context of ESD, the learners often have to make their own decisions regarding the criteria for assessing their achievement of the learning objectives, in accordance with which the evaluation strategies should be formed. In addition to assessing their own achievements, the learners must be able to form criteria for evaluating the quality and relevance of educational, informational and, to a certain extent, other resources.

Activities for Learning Support. Activity, in contrast to passive consumption, is the basis of learning. A successful choice of the learners' activities maintains interest in learning, promotes deeper understanding and strong memorization. In an ESD context, learning activities, rather than information, influence learning outcomes, encouraging learners to go beyond their current level of knowledge and practice to achieve deeper understan-

ding or higher levels of competence. Various types of educational activities are implemented in a variety of digital environments, including virtual learning environments [26]. Support for the individual learning activity can also be implemented in an open environment, by technologies and participants, including support for the problems of content choice, planning and scheduling, assessment and evaluation, monitoring and management. Formation of a personal learning environment, individual choice of a platform for its implementation and interaction technologies is a step towards lifelong learning providing some "continuity" of learning services and integrating learning and training with other (e.g., professional) tasks. This list indicates major requirements to the learning environment arising from the ESD objectives and outlines the transformations needed to meet these requirements. Besides technological and didactical changes, the culture of the learning environment, understood as the dominant values and beliefs that influence decision-making [20], will evolve to embrace ideas of equity, respect, tolerance, privacy, ethics and global responsibility. In general, ESD's open environment is designed to help learners develop understanding of and attitude towards learning in a society where knowledge is constantly evolving and learners' competencies are constantly increasing.

Conclusion

Addressing the sustainability targets set out in the SDGs requires significant changes in society, including knowledge, practical skills, attitudes and behaviors, to engage its members in the sustainable development process.

Therefore, education becomes the most important factor in sustainable development. The research results show that education should be considered as both an independent goal (SDG4) and a means for achieving all the SDGs thus leading to reconsideration of the learning tasks.

The learner within ESD framework needs to develop skills for independent search and critical assessment of information, participation in planning and management of one's own learning, as well as skills for interaction and communication with other actors in the process of solving new problems.

Mastering of these and other meta-skills is implemented through specific learning procedures. Consideration of tasks associated with ESD learning processes enables identification of objects and operations as components of these procedures which need to be supported by an open learning environment.

A personal learning environment which is able to adapt to the individual needs of the learner and to evolve over time by incorporating emerging technologies for intelligent processing, evaluation and visualization of information can play a role of a learning partner in the development of learners' key competencies in the field of sustainable development necessary to achieve any of the SDGs.

A learning environment for ESD support will integrate a range of digital technologies and modern didactics, knowledge structuring and presentation mechanisms, address social and organizational issues to transform the society and help people develop knowledge, skills, and behaviors needed for sustainable development.

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ЗАДАЧНІ МОДЕЛІ В КОНТЕКСТІ ОСВІТИ ЗАДЛЯ СТАЛОГО РОЗВИТКУ

Вступ. Концепція сталого розвитку є основою прийнятої ЮНЕСКО глобальної програми, в якій особливу увагу приділено освіті як засобу формування компетенцій, необхідних для досягнення конкретних цілей сталого розвитку (ЦСР). Освіта з метою сталого розвитку (ОСР) заснована на реалізації концепції безперервного, якісного та інклюзивного навчання, що передбачає створення умов для навчання і розвитку кожного члена суспільства, можливість придбання ним компетенцій, необхідних у суспільстві знань. Забезпечення якісних можливостей навчання протягом усього життя для всіх учнів на всіх рівнях і у всіх освітніх спільнотах є основою для поліпшення життя людей і сталого розвитку. Зміст і засоби реалізації ОСР мають суттєві відмінності, зумовлені соціально-економічними умовами, укладом і рівнем технологічного розвитку країн і регіонів, тому важливим і актуальним є аналіз особливостей ОСР і характеристик освітнього середовища для підтримки ОУР.

Мета статті — проаналізувати, яким чином ідеї сталого розвитку можуть бути інкорпоровані в зміст і процес навчання шляхом інтеграції методів цифрової дидактики, структурування знань і цифрових технологій. Використовуючи задачний підхід, показати, що визначальним для досягнення ЦСР є рішення задач навчання, вивчання і діалогової взаємодії у відкритому середовищі, функціонування якого спрямовано на розширення доступу до безперервного, якісного і інклюзивного навчання.

Методи. Системний підхід, теорія задач, задачний підхід.

Результати. Показано, яким чином безперервне навчання, як основа реалізації освіти в інтересах сталого розвитку (ОСР), і доступ до знань в епоху цифрових технологій можуть сприяти досягненню ЦСР. Досліджено особливості завдань навчання, вивчання і діалогової взаємодії для досягнення ЦСР в освіті, сформульовано відповідні задачні моделі. Описано вимоги до функціоналу і технологій формування відкритого середовища, взаємодія учня з яким дозволяє досягти поставлених цілей при вирішенні завдань навчання в рамках ОСР.

Висновки. Результати проведеного дослідження показують, що освіта — це одночасно самостійна мета і засіб для досягнення всіх ЦСР. Вона є не тільки невід'ємною частиною, а й ключовим фактором сталого розвитку з точки зору досягнення ЦСР, що вимагає розгляду завдань навчання, відмінних від традиційних. Виникає потреба у формуванні навичок самостійного пошуку і критичної оцінки інформації, участі в плануванні та управлінні своїм навчанням, а також здатності до взаємодії в процесі вирішення нових завдань. Вирішення цієї нової задачі пов'язано з навчальними процедурами, вплив яких посилюється при діалоговій взаємодії учня і відкритого навчального середовища. При цьому задача навчання виступає як засіб створення особистого середовища для виконання задачі вивчання, що сприяє розвитку в учнів ключових компетенцій у сфері сталого розвитку, необхідних для досягнення будь-якої з ЦСР.

Ключові слова: навчання протягом життя, нова освітня парадигма, цифрові технології викладання та навчання, цілі сталого розвитку, цифрова дидактика, освіта для сталого розвитку, навчальне середовище.