https://doi.org/10.15407/intechsys.2025.05.066
UDC 303.721; 004.03142

S.P. KUDRIAVTSEVA, PhD (Engineering), Senior Researcher, Leading Researcher,
Institute of Information Technologies and Systems of the NAS of Ukraine,
40, Hlushkova Akad. ave., Kyiv, 03187, Ukraine
https://orcid.org/0000-0003-0450-3388
svetaa@irtc.org.ua
O.Ye. VOLKOV, PhD (Engineering), Senior Researcher, Director,
Institute of Information Technologies and Systems of the NAS of Ukraine,
40, Hlushkova Akad. ave., Kyiv, 03187, Ukraine
https://orcid.org/0000-0002-5418-6723
alexvolk@ukr.net
K.M. SYNYTSYA, PhD (Engineering), Senior Researcher, Leading Researcher,
Institute of Information Technologies and Systems of the NAS of Ukraine,
40, Hlushkova Akad. ave., Kyiv, 03187, Ukraine
https://orcid.org/0000-0002-7417-1748
ksynytsya@irtc.org.ua
Ye.A. SAVCHENKO-SYNIAKOVA, PhD (Engineering),
Senior Researcher, Leading Researcher,
Institute of Information Technologies and Systems of the NAS of Ukraine,
40, Hlushkova Akad ave., Kyiv, 03187, Ukraine
https://orcid.org/0000-0003-4851-9664
savchenko_e@meta.ua

DIGITAL TRANSFORMATION MODEL FOR SUSTAINABLE DEVELOPMENT EDUCATION

A new model for digital transformation of education to achieve sustainable development goals is proposed. It takes into account the input of stakeholder communities and an assessment of the current state of transformation. This enables the parallel development of tasks assigned to different stages, takes into account changes in technology and the regulatory framework, and plans training for participants in transformation processes, particularly based on the examples and results of other models. The elements that distinguish education for sustainable development from other models are identified. The model is built taking into account the dynamics of the environment in which change occurs and the network connections between participants.

Cite: Kudriavtseva S.P., Volkov O.Ye., Synytsya K.M., Savchenko-Syniakova Ye.A. Digital Transformation Model for Sustainable Development Education. *Information Technologies and Systems*, Kyiv, 2025, Vol. 5 (5), 66–82. https://doi.org/10.15407/intechsys.2025.05.066

Furthermore, the model demonstrates the principles of education for sustainable development in action – collaboration in the development of solutions and the implementation of technologies, a balance between local innovation implementation plans and centrally supported strategic directions.

Keywords: *digital transformation, sustainable development goals, educational transformation model, agile approach.*

Introduction

The Sustainable Development Goals (SDG) [1] were formulated as a response to the 21st-century challenges that humankind is facing in social, economic, ecological, and other spheres. Ecological disasters caused by climate change, the quick spread of disease due to the increased number of travelers, and the technological impact on ecosystems are just some examples of the global challenges that need to be addressed by coordinated efforts using multifaceted approaches. These problems are characterized by complexity and uncertainty; they require analysis of big data and usage of the latest technologies, and their solution could only be achieved in collaboration among large groups of participants from different fields and different countries. On the path towards global sustainable development [2], education is the basis for transforming and shaping possible options for the future of society by enhancing the balance between knowledge mosaic and global vision, individual priorities and social environment, immediate economic effect, and long-lasting consequences.

Educational models, approaches, and practices, to a large extent, still preserve traditions, values, and priorities of the past, which are not compatible with the SDG. Traditional approaches to learning and teaching have become ineffective and perhaps even counterproductive as the challenges and opportunities associated with transformations of learning and education extend beyond traditional thinking and strategies. Education in the digital age embodies an approach to learning that combines content with skills, makes use of digital technologies, and builds up abilities to analyze and integrate, rather than reproduce and remember. In the 21st century, along with knowledge and skills, competencies have become the most important acquisition and the result of education.

Evolutionary transformations [3] of education have been taking place along with industrial revolution stages as an attempt to react to knowledge and skills gaps in the workforce. The connection between educational and business models, as well as types and levels of technologies involved, is often considered a determinant for the stages of educational transformations, demonstrated by the rise of unified mass-scale education in connection with the 1st industrial revolution. However, the main difference between adapting education to the society's needs in the past and nowadays is in the understanding of the regimes, acquired competencies, and, as a result, a new social contract. In addition to mastering the key competencies of the 21st century [5, 6], educated people must be socially competent, adaptive, proficient in digital technology, and have a high level

of personal competence. Thus, education is a way of raising intellectually, socially, and emotionally strong people who are mindful of their health and personal development, participation in society, and maintaining their identity.

Problem Statement

Despite extensive studies of the educational models, educational demands and transformations, as well as skills and competencies required for the future [7], there is a lack of common understanding of the changes necessary to implement education for sustainable development, its core elements and dependencies, and the role of technologies in the digital transformation of education.

The purpose of this study **is** to consider dependencies between educational elements to introduce a model of digital transformation for the education domain that will be helpful in guiding educational changes in a systematic way. For this purpose, the main elements that characterize education are identified, and their evolution through the stages of transformation is demonstrated. Then, the digital transformation models and approaches in business are analyzed, and a new approach to modeling transformation is suggested. The suggested digital transformation model enables tracing the changes in particular elements during the transformation and their effect on the demand for change in the related elements. Therefore, it could be used as a tool for retrospective analysis of educational transformation and a framework for planning the transformation for sustainable development.

Approaches of Investigation

Most of the Digital Transformation (DT) research is focused on a specific way of changing business by incorporating ICT and other digital technologies. This change is aimed at achieving better operational efficiency by changing the business model, but it may also involve some modification of products or services to better meet the requirements and expectations of the customers.

In the business case, DT is considered a linear process of business change from its current state to the desired state within the period of time when other factors that influence its efficiency (such as economic, environmental, legislative, and related to customer demands, etc.) remain constant. Therefore, this process could be divided into some distinct phases, starting with an analysis of the current state and goal setting, then further continuing with planning of necessary interventions, development, and implementation of the desired business model. It is expected that the decisions made during this transformation project ensure the lasting competitiveness of the business. However, this approach may not work as expected in the case of dynamic environments, innovative technologies, or large-scale projects where participants are not bound by the same leadership.

As has been shown earlier, the changes in Education as a specific area are taking place incrementally and unevenly, and are often opposed or ignored by conservative people who do not take a risk of innovation unless it is critical. Educational transformations occur at different speeds and depths within a country and across countries, so the detailed planning of DT for the whole area in advance is counterproductive. The transformation model should take into account these irregularities and support continuous improvement of particular parts and components until a satisfactory level is reached.

The approaches to dealing with large systems projects and implementation demonstrate some similarities independent of the nature of these systems, such as a trend to substitute rigid hierarchical systems with distributed ones with different levels of self-regularity, or collecting user feedback for adaptation and personalization. One of them, the agile approach, first introduced as a new vision of software engineering for small projects, has further proved its efficiency in the case of large distributed systems and multiple teams [8].

The agile principles as declared in the Manifesto [9] emphasize dergulation in favor of flexibility, attention to customers, collaboration, and interaction. Expressed in general terms the idea of agility is in achieving certain flexibility to be able to adapt to changes inevitable in a dynamic environment. The flexibility relies on a system structure, provisions for incremental and iterative development (improvements, updates, adaptations), and collaboration that embraces customers into development teams.

The agile methodology expresses similar values and priorities to those of Education 4(5).0, i.e., the centrality of a client (learner), the need for adaptability, and co-creation (involvement in the process of obtaining the result). In [10], a detailed analysis of the agile principles and their reflection on teacher and learning methodology is discussed. In particular, the stress is made on collaboration as opposed to competition, the practicability of learning as opposed to formal theory and assessment, learners' involvement and freedom of choice, and adaptive teaching strategies for individual treatment.

Therefore, the agile principles may be applied to DT model development. The main components taking part in the DT are humans, business processes, and models/strategies.

Digital Transformation

Technological breakthroughs in the field of information technology have caused competition between entities implementing traditional ways of doing business and innovators operating in the digital world. In a historically short period of time, the world has moved from the use of digital technology "to support" traditional business processes (calculations, communication, statistics) to a new reality in which the virtual (information) world is an integral part of the physical one. In this reality, the final de-

cision-making is still up to the human being, but the analysis and processing of data, the tasks of ongoing management and monitoring, as well as many other "intellectual" tasks are taken beyond his direct participation. This phenomenon is called "digital transformation".

An analysis of the definitions of digital transformation [11–13] demonstrated that this concept is associated with processes that differ in specific goals, in their implementation, and the objects to which they are applied. However, their common background is their purpose corresponding to the implementation of progressive changes using various digital technologies (computer, information, intelligent, mobile, communication, etc.). For comparison, here are two definitions of digital transformation: the first focuses on the business efficiency of the organization, and the second emphasizes the creation of a new entity as a result of using the capabilities of physical and digital systems.

"Digital transformation is the use of technology to radically improve the performance or reach of an organization. In a DT business, digital technologies enable improved processes, engaged talent, and new business models" [14].

"Digital transformation is characterized by a fusion of advanced technologies and the integration of physical and digital systems, the predominance of innovative business models and new processes, and the creation of smart products and services." European Commission (2019) [15].

According to [16], the basis of the DT process is technologies, which, on the one hand, cause new needs and expectations of users (*disruptions*), requiring a response (action) from the organization, and on the other hand, form the basis and support of changes. DT requires the development of *a model and strategy* for implementing such changes, which ensures the formation of *a new business strategy* based on Value Chain analysis — a way to achieve results using the organization's resources under the current business organization model. Transformations concern both *structural changes* (organizational structure, roles and responsibilities, leadership style) and *processes* associated with the production of a product or obtaining a result. DT often faces *obstacles* in the form of inertia — lack of support and direct resistance to innovation, and, despite the positive effect, it can carry certain risks.

Research aimed at the identification of the specific topics studied in relation to the DT [12] identified three focus areas that can be described as follows:

- human factors: workforce &human potential, skills and competencies of personnel, potential and acceptance of changes, Leadership at different levels, interaction, stakeholders, and owners' prospects;
- business factors related to logistics and operational processes, management and data collection, marketing, etc., specific to a particular area;
- technology and information, which form the basis of the proposed changes, and ensure the ability to quickly analyze data, communicate and collaborate online, manage, and forecast.

In the field of higher education, the immediate disruptions are associated with a need for innovations in the educational processes and new economic models for obtaining education. Students' experience in using the latest technologies, such as virtual and augmented reality, gamification, elements of artificial intelligence, and personalization tools, creates certain expectations about the education delivery models [17–20]. To see a broader picture of the changes in education brought not only by technologies related to learning, instruction, and assessment but also by the evolution of society, we further consider the evolution of the educational goals.

Educational Transformations. Evolution of Educational Goals

To better understand changes in learning and education, it is useful to look at how the goals of education are transforming from "mastery of knowledge" to "mastery of oneself through knowledge" [2].

Education performs a function that enables achieving four universal goals at any stage of development for any society:

- to provide for finding a suitable job and thereby obtain a chance to *participate* in society,
- to use and develop *personal abilities* and exchange "*talents*",
- to *make decisions* based on the individual's awareness,
- to build and maintain one's *identity* based on one's own traditions and the wide variety of traditions around.

These four goals of education remain constant over time — much like the universal "hierarchy of needs" [7], which demonstrates progress from physical needs through safety and social needs, to respect and knowledge, and culminates in self-actualization and self-realization. However, the ways these four universal needs are satisfied vary greatly at different times and in different societies. The first educational goal in this comparison could be interpreted as a basic, "survival" need, the second, as the way to socialization and self-development, after that comes the one for leadership and responsibility, and finally, reaching a harmony with oneself and the world.

Mass-scale education (a non-discriminative education for all) [4] used to focus on achieving the first goal through knowledge, skills, and competencies provided for learners to tackle the tasks they face during their lives. Certainly, one of the main educational goals is to help people understand the times and society in which they live and find solutions to technical, economic, and social problems using relevant technology. Not long ago, educators could expect that whatever was taught would stay with the students for their lives. Nowadays, educational institutions must prepare students for economic and social changes happening faster than ever before, to use emerging technologies and solve arising problems that were unknown in the past. Therefore, besides learning "from the past" — from knowledge and experience in a specific field, there should be learning

"for the future" — learning to be prepared for future challenges. A schematic view of major educational changes is presented in Table 1.

As one can see, incremental changes in each of the features have led to significant revisions of the learning process, which has been gradually becoming engaging, participatory, and inclusive. Growing independence of the learners and their involvement in the learning process, as well as the development of self-regulation skills, provides a framework for successful learning throughout life. Instructional strategies evolve to support individual learning preferences and talents, preserving the achievements of project-based learning by balancing competitiveness with teamwork, learning from peers, and collaboration arranged around the group projects.

The choice of features to describe the educational model at different stages is determined by the need to emphasize the changes that characterize each new stage. These changes can be quantitative, as in the case of the use of technology or collaboration, or qualitative, as in the case of a learning environment demonstrating that the models of education have grown beyond the school limits to support learning anytime and anywhere. However, the main value of this comparison is in revealing the hidden links between the desirable result of the education and the methods used to achieve it.

If the goal of education is to prepare someone for a regular job, such as an industrial worker, then a drill and practice approach focusing on stuf-

Table 1. **Transformation Education from 1.0 to 4.0**

Features	Version of Education			
	1.0	2.0	3.0	4.0
Learning environment	Classroom	Elements of blended learning	Flipped classroom	Personalized
Instructional strategy	Lecturing Drills and practice	Elements of experiential learning	Student-centered learning	Peer learning, problem-based learning
Collaboration	Almost none	Limited collaboration	Collaborative learning	Social learning
Assessment	Formal testing	Tests and activities	Individual and team projects	Competency-based
Technology	None	Limited use	Integrated in the educational process	Immersive experience
Teacher's role	Authoritative, transmitting knowledge	Supervision and support	Guidance and mentoring	Arranging learning experience
Learner's role	Absorb the information	Interaction and engagement	Search, select, integrate information	Take a responsibility and make decisions

fing the person with facts, rules, and procedures may be sufficient and effective. However, if the goal is to support someone's creativity, unfold capabilities and individual talents, expecting a fresh look, out-of-the-box thinking, and innovative solutions, then the old school approach will not work. Thus, although subject-related knowledge and skills are still needed, a set of target competencies that one should acquire through education has changed considerably. Further, these new competencies are described, as well as their role in the implementation of sustainable development goals.

Competencies for SDG – 21st century skill. Education in the 21st century is focused on four important areas [17], namely:

• Knowledge — general and digital literacy, basic and contemporary knowledge;

• Practice — skills and competencies, enabling the application of the acquired knowledge;

• Character — personality, determining our behavior and interaction with the world;

• Learning to learn — reasoning, self-development, and adaptation.

Together, they constitute the space for implementation of all educational goals [21, 23]. The first two provide the basis for employability, which is also supported by learning and adaptability acquired within the fourth area. The third area supports most, if not all, goals of education, facilitating the development of skills for individual and collaborative decision-making and self-regulation, as well as competencies necessary for advancing in new physical and cultural environments, preserving personal identity.

To address the needs of the Education of 21st century an innovative framework has been adopted in Singapore [23]. This framework identifies a set of core values and competencies deemed necessary to better prepare students for the future and presents them in a way that unfolds through education, thus supporting the creation of the new curricula and assessment. The framework is intended for school children (from pre-school to post-secondary), thus its core focuses on the upbringing and character-building aspects. The core values include respect, responsibility, resilience, integrity, care, and harmony. The core provides a basis for social-emotional competencies, which are necessary to manage and position oneself in society. The respective skills are necessary to handle challenges, manage emotions, develop responsibility, build relations with others, and identify one's role and place in society. Based on that, the next set of competencies equips young students with skills to advance in highly dynamic, technology-rich, and culturally diverse environments. They include basic skills and awareness in civic, global, and cross-cultural domains (Literacy); a set of skills needed for dealing with information, communication, and collaboration (Collaboration); and Cognitive skills, including critical thinking, innovative and inventive thinking, and the ability to adapt to the situation and environment in problem-solving. Altogether, this frame-

work guides the raising of a confident person, a self-directed learner, a concerned citizen, and an active contributor.

More attention is being paid to skills and competencies to be developed at the HE level.

SDG outlined new problems requiring innovative approaches to their solution and thus new competencies, i.e., proficiencies and abilities based on knowledge, skills, and behavior relevant to attaining the goal. A recognized list of competencies includes: creativity, critical thinking, communication, collaboration, leadership and responsibility, self-regulation, and lifelong learning. When analyzing competencies for sustainable development, many researchers focus on skills associated with them. The levels of detail in the description of these skills vary, so several frameworks were proposed, with different principles of grouping.

In [24], digital literacy skills are gathered in a separate group, whereas the other two groups cover the rest. One of them contains so-called learning skills which are important for professional development, and another — a variation of self-management and collaborative skills (named life skills), as listed below:

- learning skills (creativity and innovation, critical thinking, and problem-solving; communication and collaboration);
- literacy skills (information literacy, media literacy, and ICT literacy);
- life skills (flexibility and adaptability; initiative and self-direction; social and intercultural skills; productivity and accountability; leadership and responsibility).

Another framework [22] suggests a better balanced grouping of competencies clustering those related to self-development and collaboration (inter-personal and intra-personal), cognitive and meta-cognitive (comprising learning, cognition, and understanding), as well as civic and social for a global positioning, and digital related to the activities in the technology-intense environment.

For curricula planning, it is important to discern professional competencies related to the knowledge and skills in a specific application area, such as accounting or pharmacy, and general *transversal* competencies, which are not specific to any field but are considered valuable for most activities. The transversal competencies include Language, Thinking (cognitive), Self-management, Social and communication, and Life competencies [25]. For some reason, this framework implicitly highlights language skills and ignores digital competencies, which are probably taken for granted as obtained through basic literacy.

A perception of the importance of specific and generic skills among employers and graduates was a topic of a longitudinal study [26–28]. Although the division between the generic and specific sets of skills differs from the previously mentioned analysis of transversal and specific competencies, it allows tracing back the important components of the curricula. In this research, the generic group includes the ability to interpret complex situations, to adapt to the communication environment for successful

collaboration, to think out of the box, to operate in unknown situations and different cultural settings and contexts, to understand data-based reasoning, to interpret and generate media content persuasively, to understand concepts across multiple disciplines, to overcome cognitive load by using various tools, to transform tasks into actions adjusted to the work environment, and to collaborate virtually and engage large communities. The second group includes skills considered specific in the context of the sphere of employment, such as diversity management and social skills, professional background skills (formal education and work experience), as well as self-management and IT skills. The results of the study show that background skills are becoming less relevant for employability, whereas the skills from the generic group are considered to carry more weight in the evaluation for some work positions.

Although work experience and formal education have become less relevant for employability [29], this means that other important competencies were not in demand previously and thus were not addressed by the educational programs.

Twenty-first-century learning embodies an approach to learning that combines knowledge with skills and the formation of a systemic understanding rather than the collection of knowledge from the studied disciplines. It implies a learner's curiosity about advances in the field, new approaches, methods, and technologies to stay relevant, and the ability not only to integrate innovations but also to produce them. This requires learning and innovation skills — these are what separate trainees who are prepared for the more challenging work environments of today's world from those who are not. These skills include: creativity and innovation, critical thinking, problem solving, communication, and collaboration.

There is no doubt that two core skill sets — the ability to quickly acquire and apply new knowledge — will remain on the list of requirements for any job.

Achieving the goals of education in the 21st century is determined by the availability of digital technologies for communication, collaboration, and learning. Know-how to apply core skills — problem solving, communication, teamwork, technology, innovation, etc. — ability to use on every project (job).

MetaSkills. To make learning relevant, personalized, and engaging, to engage learners through skills (life and vocational, learning and innovation, information and technology), knowledge (21st century core subjects and cross-cutting themes), and relevant technologies, learning activities require an expansion of the existing educational development model.

And since the problems are associated not only with limited resources and funds, but also with the way teachers teach and how training is organized. Students must learn deeper and broader, beyond the "3R paradigm (the concept of 3R — recall, retrieve, refine) and traditional tests. They should have the opportunity not only to master the learning content of-

fered to them, but also to understand how they can expand and produce new knowledge themselves, using the the potential of modern digital technologies. In other words, move from 3R to 4C and an independent search for obtaining the missing knowledge. To do this, use communication, collaboration, critical thinking and problem solving, creativity, and innovation, that is, to go from 3R to 4C (communication, collaboration, critical thinking, creativity) [9, 10, 29, 30]. The role of the teacher is to help them with this.

The 4C skills are the key to helping learners achieve a deep understanding of knowledge and are essential to facilitating the transfer of learning to a digital environment. These skills are inextricably linked to content knowledge, since it is impossible to teach skills independently of the content knowledge base — for example, it is impossible to think critically about anything. In the digital age, knowledge and skills develop together in such a way that the knowledge students use in the classroom becomes a source of creativity, a subject for critical thinking and communication, and an incentive for collaboration. At the moment when skills (communication, cooperation, the ability to use the potential of new technologies) "work" with new interdisciplinary knowledge (computer science, bioengineering, modern manufacturing, etc.), students interact in a global network of economic, technological, social and ecological relationships (and this is the main thing, this did not happen in the 20th century). Learning is becoming hybrid.

Self-development and grouping. Self-development is the process of acquiring new skills and knowledge for the purpose of self-improvement. In recent years, countries have been increasing investment in education, and as a result, more and more students are gaining access to digital technologies in educational institutions, at home, and in community centers around the world. This provides new opportunities for learning and skill development. Digital technologies are a powerful tool for developing personal abilities (self-improvement) and sharing "talents" in a group. Ensuring universal access to technological tools and closing the digital divide provides learners with more opportunities to realize their potential [12]. Grouping — learning from others. You can learn self-development by being in the same group with students who have experienced this before. These learners tend to be knowledgeable about the process of self-development in different contexts.

Purposeful development of information technologies in the field of quick decision-making. Through the range of social networks and instant messengers, human potential for informed participation in decision-making has never been so successful. Learning to work digitally, harnessing the power of social media to solve a problem together in a community, and applying the critical thinking and information literacy skills needed to effectively use the wealth of information available are clear challenges for the 21st century. In many cases, learners are just beginning to understand how to use the information around them. Digital technologies have made

it easier to connect with those who share interests (social media) and also coordinate learning activities.

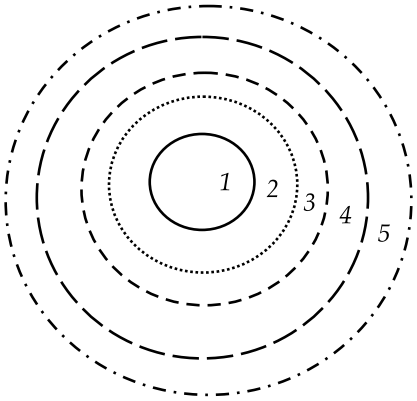
Culture. In the digital age, one of the in-demand skills is the ability to connect traditional and interdisciplinary knowledge, which provides an incentive to create and use new knowledge, services, and technologies. Increased mobility, immigration, and access to job opportunities around the world have led to yet another type of connection and addition—communities around the world are becoming increasingly culturally diverse. The challenge for each individual is to build and maintain his identity based on his own traditions and the wide variety of traditions around him (the task of maintaining social harmony).

So, if earlier the achievement of the learning goal consisted in the fact that the student must adapt to new living conditions, new work requirements (a person went into the environment), then with the change in technologies, methods, and models of updating knowledge, the achievement of learning goals also changes. This is an adaptation to various "social scenarios" (an intellectual environment rich in resources provides its capabilities to the learner through interactive technology using intellectual content). In all of these cases, digital technologies, infrastructure, and platforms can be critical, but they are tools, not ends in themselves. There needs to be a chain that connects digital and technological knowledge with social and emotional skills.

Digital technologies are driving huge changes in the way we communicate and interact with each other, and increasingly in the way we learn and solve problems. Thanks to the use of digital technologies on the one hand and various types of learning activities on the other (i.e., the ultimate combination of technological and didactic aspects), learners can access learning anytime and anywhere. Rethinking the goals of education in the digital age, learning must be organized in such a way as to *understand* that today a greater harmony with the environment (society) is required, and this requires new scientific knowledge, competencies, and technologies.

DT Model

Following the agile principles, the core of the model is represented by the stakeholders of the digital transformation of Education. Thus, the core is represented by those who are involved in the transformation and benefit from it. Taking into account that the same person could play one or several roles from a set R (a learner, a teacher, a supervisor, a developer, an administrator, a manager, an owner of an educational business, an employer) simultaneously depending on the scenario, we further refer to the role when discussing the transformation or use the term "user" where appropriate. One should keep in mind that a learner could be considered a recipient of an educational service, in which case his satisfaction with the service as a client is a measure of its quality. On the other hand, a learner is a product of the educational process, whose features are eva-



The layers of the DT model:
1 — Core — stakeholders involved in development and implementation
2 — Goals, plans, ideas, concepts, strategies
3 — Business implementations, processes, and structures
4 — Technologies and information space
5 — Institutionalization of norms, values, culture, and traditions of the new reality

Fig. 1. DT Model

luated by a potential employer — competencies, values, attitudes, views, and abilities. According to agile methodology, Stakeholders are involved in setting requirements in a collaborative way, evaluating intermediate and final results, providing feedback, and participating in the process implementation.

Therefore, the next layer contains a transformation framework represented by a concept, a hierarchy of goals, as well as related ideas, plans, and strategies. It describes a current model of Education, the purpose and expected results of the digital transformation, and outlines the approaches to its implementation. This is the source of the specific, and the starting point analyzed and corrected.

The next layer corresponds to the business structure and processes affected by the transformation. In the case of Education, it corresponds to the educational organizations as providers of educational services, producers of educational content, certification and accreditation& agencies, on the one hand.

A learner as a product is formed by an instructional process arranged by a teacher personally or through intelligent learning content as an implementation of instructional strategies; therefore, the model components closest to the core would be “instructional strategies”, “learning content”, and “learning environment” within which teaching and learning occur.

The next layer is represented by supportive tools and resources necessary to populate the learning environment, to develop learning content, to support assessment and learning analytics, etc. Finally, the outer layer determines culture, values, and norms that regulate the application of digital and non-digital instructional and learning processes and the recognition of their results.

The model in Fig. 1 could be used to describe the Education state. For instance, Education 1.0 may be described as follows:

- Learning environment: a classroom setting for unified group learning, a laboratory;
- Teaching strategy: “knowledge-transfer” through lecturing, non-differentiating;

- Assessment: test-based, 3R type;
- Learner: passive recipient;
- Learning content: textbook;
- Learning strategy: memorization, repetition, reproduction;
- Culture and Values: following the guidelines, obedience, perfection, teacher as an ultimate authority, organizational regulations, and documented process.

Conclusion

As a result of the discussion, a new model for digital transformation of education to achieve sustainable development goals was proposed. This model takes into account the input of stakeholder communities and an assessment of the current state of transformation. This allows for the parallel development of tasks and the of the current state of transformation. The model is built taking into account the dynamics of the environment in which change occurs and the network (decentralized) connections between participants. The model demonstrates the principles of the SDGs in action — collaboration in the development of solutions and the implementation of technologies, a balance between local innovation implementation plans and centrally supported strategic directions.

REFERENCES

1. 17 Goals to Transform Our World. URL: https://www.un.org/sustainabledevelopment [Accessed 08 Sep. 2025]
2. Report on the 2022 Transforming Education Summit, Convened by the UN Secretary-General January 2023, 49 p. URL: https://www.un.org/sites/un2.un.org/files/report_on_the_2022_transforming_education_summit.pdf [Accessed 08 Sep. 2025]
3. Gritsenko V.I., Manako A.F., Sinitsa E.M. Digital Transformations and Mass Continuous Learning. *Control Systems and Computers*, 2018, Vol. 277 (5), 47–61. https://doi.org/10.15407/usim.2018.05.047
4. Defining Education 4.0: A Taxonomy for the Future of Learning. *World Economic Forum*, Jan. 2023, URL: https://www3.weforum.org/docs/WEF_Defining_Education_4.0_2023.pdf [Accessed 08 Sep. 2025]
5. *UiTM Academic Compass. Education 5.0 @ UiTM. Navigating the Future.* Academic Affairs Division, UniversitiTeknologi MARA, 2019, 95 p. URL: https://penang.uitm.edu.my/images/hea/EDU5.0/Education_5_at_UiTM_-_UiTM_Academic_Compass_352019-min.pdf [Accessed 08 Sep. 2025]
6. Grytsenko V.I., Kudriavtseva S.P., Synytsya K.M. Learning Task Models in the Context of Education for Sustainable Development. *Control Systems and Computers,* 2020, Vol. 289 (5), 3–16. https://doi.org/10.15407/csc.2020.05
7. *Four-Dimensional Education.* The Center for Curriculum Redesign, Boston, 2015, 121 p. URL: https://www.researchgate.net/publication/318430582_Four-Dimensional_Education [Accessed 08 Sep. 2025]
8. Maslow A.H. Higher needs and personality. *Dialectica*, 1951, Vol. 5 (3–4), 257–265. https://doi.org/10.1111/j.1746-8361.1951.tb01056.x
9. Hohl P., Klünder J., van Bennekum A., Lockard R., Gifford J., Münch J., et al. Back to the future: origins and directions of the "Agile Manifesto"–views of the originators. *Journal of Software Engineering Research and Development*, 2018, Vol. 6 (1), 15. https://doi.org/10.1186/s40411-018-0059-z

10. What is a 21st century education? URL: https://www.battelleforkids.org/Insights/learning-hub-item/what-is-a-21st-century-education. [Accessed 08 Sep. 2025]
11. Education in the 21st century – think strategy. URL: https://thinkstrategicforschools.com/education-21st-century [Accessed 08 Sep. 2025]
12. Delors J. et al. *Learning: The treasure within*. UNESCO, Paris, 1996. 266 p. URL: https://unesdoc.unesco.org/ark:/48223/pf0000109590 [Accessed 08 Sep. 2025]
13. Verina, N., Titko, J. Digital Transformation: Conceptual Framework. *The 6th International Scientific Conference Contemporary, Issues in Business, Management and Economics Engineering*, 2019. 721–724. https://doi.org/10.3846/cibmee.2019.073
14. Development: The 8 Ways You Need to Start Working on It. URL: https://www.clockster.com/az/blog/self-development [Accessed 08 Sep. 2025]
15. Digital transformation. URL: https://reform-support.ec.europa.eu/what-we-do/digital-transition_en [Accessed 15 Jun. 2025]
16. Vial G. Understanding digital transformation: A review and a research agenda. *Managing digital transformation*, 2021,13–66. https://doi.org/10.4324/9781003008637-4
17. Gillpatrick T. Innovation and the digital transformation of education. *The Journal of Limitless Education and Research*, 2020, Vol. 5 (3), 194–201.
18. Holmes W., Bialik M., Fadel C. *Artificial Intelligence in Education – Promises and Implications for Teaching and Learning*. Independently published, Boston, 2019.
19. *AI for Learning*. Carmel Kent, Benedict du Boulay, 2022, Publisher CRC Press. https://doi.org/10.1201/9781003194545
20. Ouyang, F., Jiao, P. Artificial Intelligence in Education: The Three Paradigms. *Computers and Education: Artificial Intelligence*, Vol. 2, Article 100020. https://doi.org/10.1016/j.caeai.2021.100020
21. Binkley, M. et al. Defining Twenty-First Century Skills. In: Griffin, P., McGaw, B., Care, E. (eds) *Assessment and Teaching of 21st Century Skills.* Springer, Dordrecht, 17–66. https://doi.org/10.1007/978-94-007-2324-5_2
22. The Partnership for 21st Century Skills. URL: https://www.teacherpowered.org/guide/resources/partnership-21st-century-skills [Accessed 08 Sep. 2025]
23. 21st Century Competencies. URL: https://www.moe.gov.sg/education-in-sg/21st-century-competencies [Accessed 08 Sep. 2025]
24. OECD. An OECD Learning Framework 2030. In: Bast, G., Carayannis, E.G., Campbell, D.F.J. (eds) *The Future of Education and Labor.* Arts, Research, Innovation and Society. Springer, Cham, 2019. https://doi.org/10.1007/978-3-030-26068-2_3
25. Gog T., Kester L., Nievelstein F., Giesbers B., Paas F. Uncovering cognitive processes: Different techniques that can contribute to cognitive load research and instruction. *Computers in Human Behavior*, 2009, Vol. 25 (2), 325–331. https://doi.org/10.1016/j.chb.2008.12.021
26. Artuz J.K.A., Roble D.B. Developing students' critical thinking skills in mathematics using online-process oriented guided inquiry learning (O-POGIL). *American Journal of Educational Research*, 2021, Vol. 9 (7), 404–409. https://doi.org/10.12691/education-9-7-2
27. Irwanto I., Saputro A.D., Rohaeti E., Prodjosantoso A.K. Promoting critical thinking and problem solving skills of preservice elementary teachers through process-oriented guided-inquiry learning (POGIL). I*nternational Journal of Instruction*, 2018, Vol. 11 (4), 777–794.
28. Liebowitz J., Frank M. (Eds.). *Knowledge management and e-learning*. CRC press, 2016, 367 p. https://doi.org/10.1201/b10347
29. Transformative Competencies for 2030. URL: https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/concept-notes/Transformative_Competencies_for_2030_concept_note.pdf
30. *Reimagining our futures together. A new social contract for education*. Report from the international commission on the futures of education UNESCO, 2021, 188p. https://doi.org/10.54675/ASRB4722

Received 10.09.25

С.П. КУДРЯВЦЕВА, канд. техн. наук, старш. наук. співроб., пров. наук. співроб.,
Інститут інформаційних технологій та систем НАН України,
просп. Акад. Глушкова, 40, Київ, 03187, Україна
https://orcid.org/0000-0003-0450-3388
svetaa@irtc.org.ua
О.Є. ВОЛКОВ, канд. техн. наук, старш. дослідник, директор,
Інститут інформаційних технологій та систем НАН України,
просп. Акад. Глушкова, 40, Київ, 03187, Україна
https://orcid.org/0000-0002-5418-6723
alexvolk@ukr.net
К.М. СИНИЦЯ, канд. техн. наук, старш. наук. співроб., пров. наук. співроб.,
Інститут інформаційних технологій та систем НАН України,
просп. Акад. Глушкова, 40, Київ, 03187, Україна
https://orcid.org/0000-0002-7417-1748
ksynytsya@irtc.org.ua
Є.А. САВЧЕНКО-СИНЯКОВА, канд. техн. наук,
старш. наук. співроб., пров. наук. співроб.,
Інститут інформаційних технологій та систем НАН України,
просп. Акад. Глушкова, 40, Київ, 03187, Україна
https://orcid.org/0000-0003-4851-9664
savchenko_e@meta.ua

МОДЕЛЬ ЦИФРОВОЇ ТРАНСФОРМАЦІЇ ЗАДЛЯ СТАЛОГО РОЗВИТКУ ОСВІТИ

Вступ. Освіта задля сталого розвитку (ОЗСР) відповідає реалізації Цілей сталого розвитку, зокрема Цілі 4 «забезпечення якісної доступної освіти для всіх». Перехід від традиційної освіти до ОЗСР потребує значних змін не тільки у змісті навчання, але й у стратегіях та методах навчання та тренування, що пов'язано зі зміною головної мети навчання — від опанування знань та навичок минулого до навчання та підготовки до розв'язання нових, комплексних та мультидисциплінарних проблем, зокрема, шляхом роботи в групі. Така підготовка також потребує розвиненої технологічної підтримки, тому трансформацію традиційної освіти в освіту задля сталого розвитку доцільно здійснювати під час цифрової трансформації. Під цифровою трансформацією зазвичай розуміють перехід до інтенсивного застосування інформаційно-комунікаційних технологій з метою підвищення ефективності виробництва, керованості процесів, спрощення адміністрування, розширення клієнтської бази або запровадження нових продуктів чи сервісів. Досліджені моделі цифрової трансформації стосуються здебільшого окремих організацій, які централізовано переходять до нових умов функціонування. Оскільки ОЗСР призводить до змін у системі цінностей та культурі суспільства, бажаним є залучення представників зацікавлених спільнот до планування, реалізації та оцінювання результатів цифрової трансформації на кожному етапі. Таким чином, потрібно створення нової моделі.

Метою статті є розгляд залежностей між освітніми елементами для запровадження такої моделі цифрової трансформації в освітній сфері, яка буде корисною для систематичного управління освітніми змінами. Для цього визначено основні елементи, що характеризують освіту, та продемонстровано їхню еволюцію протягом етапів трансформації.

Методи дослідження полягають у визначенні основних характеристик ОЗСР у порівнянні з традиційною моделлю освіти та створенні гнучкої моделі трансформації освіти для досягнення цілей сталого розвитку з застосуванням цифрових технологій для організації освітніх процесів, підтримки пізнавальної діяльності, розроблення інтерактивного навчального контенту тощо.

Результати. Запропоновано нову модель цифрової трансформації освіти для досягнення цілей сталого розвитку, яка враховує внесок зацікавлених спільнот та оцінку поточного стану трансформації, що дає змогу паралельно відпрацьовувати завдання та оцінювати поточний стан трансформації, які описують різні її етапи, враховуючи зміни технологій і нормативної бази, а також планувати тренінги для учасників трансформаційних процесів. Визначено елементи, які відрізняють ОЗСР від інших моделей.

Висновки. Модель побудовано з урахуванням динаміки середовища, в якому відбуваються зміни, мережевих (децентралізованих) зв'язків між учасниками. Окрім цього, модель демонструє принципи ОЗСР у дії — співпрацю у підготовці рішень та впровадженні технологій, баланс між локальними планами впровадження інновацій та стратегічними напрямами, що підтримуються централізовано.

Ключові слова: *цифрова трансформація, цілі сталого розвитку, модель освітньої трансформації, гнучкий підхід.*