DOI: 10.2478/jtes-2022-0023

sciendo

Journal of Teacher Education for Sustainability,
vol. 24, no. 2, pp. 166–179, 2022

Is Sustainable Development Really Sustainable – Theoretical Reflections, Statistics and the Need for Changes

Elita Jermolajeva and Inese Trusina
Latvia University of Life Sciences and Technologies, Jelgava, Latvia

Abstract

The aim of the article is to explain holistically the main provisions of sustainable development in the nature-society-human system based on the methodology for analyzing changes in energy flows and the power of socio-economic systems. The authors consider the development of society as a creative process aimed at changing the direction and speed of free energy flows (useful power) in *Space* and *Time*. They also consider sustainable development in the nature-society-human system to be consistent with the laws of the global evolution of living nature and the laws of the historical development of humankind. The paper focuses on key questions concerning the new concepts of sustainable development; the methodology for designing the sustainable development using the concept of energy flows in open, non-equilibrium stable systems and power change analysis approach. The results of the main positions of the models and their interpretation are presented based on the statistical data of United States of America (USA) in the period of 1960–2021.

One of the most important primary things in order to bring about changes in people's thinking, understanding and attitude towards sustainability issues is their education in different forms – formal education and non-formal education opportunities. Creating an interdisciplinary approach and explaining sustainability as a set of economic, social and ecological factors also play a crucial role in raising public awareness of sustainability issues.

Keywords: education, energy flows, sustainability, sustainable development

Introduction

History is made by people pursuing their goals and interests. This process is contradictory, leading to a clash of opposing interests and goals, which has manifested itself many times in history in the form of crises, conflicts, and wars. Nevertheless, despite conflicts and wars, *the growth of the possibilities* of humankind as a whole has been preserved, and, consequently, its development has also been preserved.

What is the process of turning *the impossible into the possible*? This process is purposeful work, which is called creative work or creativity. Creativity is any process of

finding and implementing solutions to complex problems. The process of searching, adopting and implementing solutions to economic, financial, social, legal, political and other problems is a creative process or a single holistic process of designing and organizing the future world. The purpose of this design is to make certain changes in the world around us. Ideas are the source of this process, and the goal is the material embodiment of the idea into a working structure that gives society new opportunities to satisfy its needs, both current and future. But then creativity is the process of development and its preservation throughout the existence of humankind, which is demonstrated by the whole history. This process is contradictory, leading to a clash of opposing interests and goals, which has repeatedly manifested itself in the form of crises, conflicts and wars. Nevertheless, the growth of the possibilities of humankind as a whole has been preserved, and, consequently, its development has been preserved.

This continuous, chrono-holistic process is called the historical process of development. The preservation of the historical chrono-integral process of development means that there is sustainable development of society. A necessary and sufficient condition for the continuous development of society is people who are able to put forward and implement ideas that, when implemented, ensure the growth of society's possibilities. At the same time, the growing possibilities of society are used most effectively if the society forms a person capable of putting forward and implementing ideas.

The authors consider the development of society as a creative process aimed at changing the direction and speed of free energy flows (useful power) in *Space* and *Time*. They also consider sustainable development in the nature-society-human system to be consistent with the laws of the global evolution of living nature and the laws of the historical development of humankind.

The aim of the article is to explain holistically the main provisions of the project management of sustainable development in the nature-society-human system based on the methodology for analyzing changes in energy flows and the power of socio-economic systems.

The paper focuses on key questions concerning the new concepts of sustainable development; the methodology of designing the sustainable development by using the concept of energy flows in open, non-equilibrium stable systems and power change analysis approach.

The authors of the article are convinced that it is possible not only to adequately explain the world around us, but also purposefully change it, design its development without violating the fundamental laws of the nature-society-human system. Future specialists should know, understand and be able to use the opportunities opened up by science for the transition to the sustainable development of society in close relation to the laws of human environment. The concern of living generations for future generations is to help educate people who are capable and realize their ability to be creative for the benefit of Humanity, in the name of the development of life on the Earth. We need to prepare students not only for employment in a sustainable economy, but also to equip them with the skills and values that will allow them to live sustainable lifestyles on the planet. This entails encouraging strong personal development as well as promoting responsible citizenship (Bell, 2016). Scientists have reasonably studied and clarified the competences related to the sustainable development goals (SDGs), which can be developed in higher education (SDR, 2019). State policy makers can propose relevant education regulation, because SDG 4 – Qualitative Education 4.7 – envisages that by 2030, all

students acquire the knowledge and competences necessary for the promotion of sustainable development. Not only universities, but also corporate society should participate in this process, trying to match the competences offered by education and those required in the labor market (Dias et al., 2022). Human rights education can also promote a universal and global attitude and can be practiced in schools together with an inclusive attitude towards religions and worldviews. Combined with social sustainability, it could help students understand how the world can be shaped locally and globally, with serious concern for each person and humanity as a whole (Miedema & Bertram-Troost, 2015). The reorientation of teacher education towards sustainability is revealed as the interaction of three phenomena – the interdependence of science development, integration and anthropocene phenomena. It can be considered as a set of complex interacting phenomena that demonstrate complex progress towards the goal of sustainable development or unsustainable development. The attitude towards the phenomena of development and integration of science and its formation, as well as the interrelation of changes, is the basis and also the cause of the gradual development of the Anthropocene (Salīte et al., 2016).

Basic Concepts and Principles of Sustainable Development Design

In the definition of sustainable development adopted by the world community and approved by the United Nations (UN), two concepts are fixed (Bolshakov et al., 2019): an opportunity and a need necessary for the preservation and development of systems of any nature and purpose. The pair "opportunity – need" denotes a contradiction, the resolution of which is carried out by minimizing the difference between needs and opportunities with the help of more advanced ideas, projects and technologies. In the next cycle, the process is repeated with other increased characteristics of opportunities – needs. Considering the relationship between needs and opportunities, we begin by answering simple questions of sustainable development design: What is the initial state of the system? What is the goal of sustainable development? Why is the transition to sustainable development necessary? What problems exist? How is sustainable development defined? Who, where and when implements sustainable development? How sustainable development is measured?

In general, the main stages of designing sustainable development are as follows:

- Definition and calculation of the existing state or definition of opportunities – "Model parameters for the initial time";
- Definition and calculation of the required state or definition of needs – "Parameters of the model in accordance with the development criteria";
- Definition, calculation and formulation of problems;
- Formation of a strategy and forecast of critical situations;
- Defining parameters and methods from calculation;
- Formation of the management system – decision planning, parameter measurement, measurement control.

The modern real world is a system of nested cycles, accompanied by crises and conflicts of various scales, tearing apart the chrono-holistic process of development into separate 'pieces' of rise and fall. These 'pieces' are difficult to link to sustainable development. Moreover, it is impossible to give an example of the sustainable development of any living socio-economic object throughout the entire time of its life. And yet, the life

of the Earth as a continuous process over 4 billion years demonstrates an amazing ability to maintain continuous development, despite a huge number of factors of negative, and sometimes catastrophic external and internal impact. This ability to resolve contradiction is the fundamental law of the cyclical conservation of the development of living systems (Bauer, 2002). The consequences of this law and its projections are many other laws – the law of the cyclical change of biological species, the law of the cyclical change of generations, the law of the cyclical change of technologies, the law of cyclical economic development, and others. All of them make it possible to manage the process of transition from one quality to another, the process of overcoming the crisis in order to maintain the further development of a living system in the long term.

Under the conditions of negative influences, the development of life is preserved at each cycle of its existence, if there is an integral non-decreasing increase in the efficiency of using the consumed power (resources). Development is sustainable in a certain cycle of the existence of a living system, if during this period there is a non-decreasing increase in the efficiency of using the consumed power (Shamaeva, 2019). In the transition between cycles, the chronointegrity of development is destroyed, dimensional (spatio-temporal) gaps arise – crises that require breakthrough management technologies, when sustainable development becomes a strategic goal of managing the way out of the crisis. Without management and outside of management, it is fundamentally impossible to move into a new quality and ensure sustainable development in the long term, covering the system of cycles – crises of modern world civilization (Karibaev et al., 2019). Any science-based strategy must use scientific knowledge based on universal laws. Comprehension and correct application of these laws in practice will allow effectively implementing the strategy.

Today, there is a fear that the current idea of sustainable development may lead to the repetition of strategic mistakes in choosing the development trajectory of individual countries and the world community as a whole.

Experience of Designing Sustainable Development in the World

The first attempt to move the world community to an integrated approach to considering the interaction of society with the environment was the international conference on environment and development, convened by the UN (1972). Participants recognized the existence of a relationship between the need to create a safe environment for humans and economic development (UN, 1972). In 1987, at the 42nd session of the UN General Assembly, the basic principle of sustainable development was adopted (UN, 1987). Sustainable development was defined in the Brundtland Report as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Brundtland, 1987). In 1992, the UN convened the second international conference on environment and development in Rio de Janeiro, where it adopted a number of fundamental documents outlining the ideology of sustainable development (UN, 1992).

The Club of Rome's report "The Limits to Growth" (Meadows et al., 1972) was the first to model our planet's interconnected systems and made clear tendencies in population, industrialization, resource use and pollution. "The Limits to Growth" contains the follow main messages: *First,* the environmental impact of human society had become heavier between 1900 and 1972 due to both an increase in the number of humans

and the amount of resources consumed and pollution. *Second*, our planet is physically limited, and that humanity cannot continue to use more physical resources and generate more emissions than nature is capable of supplying in a sustainable manner. *Third*, the human ecological footprint will soon overshoot the carrying capacity of the planet. *Fourth*, we will have to move back into a sustainable state, either through 'managed decline' of activity, or through 'collapse' of nature or the market. *Fifth*, humanity must act now and today. As a result of the work of the Club of Rome, an interpretation of sustainable development has arisen, which is often called the 'triune concept of sustainable development', highlighting the interdependence of the three pillars of sustainable development: environmental, social and economic. Sustainable development becomes achievable only when the stability of each of the three listed components is formed. Later on, the concept of economic development without growth or zero economic growth has become widespread. In addition, the supporters of this concept believe that economic growth leads to disruption of the biosphere of human life and is limited due to the planet's lack of raw materials and fuel resources (Pestel, 1989).

The conclusions of the report are based on the idea that the mission of human civilization on the Earth is not positive, it is destructive, and therefore it is necessary to limit its birth rate and reduce human activity. The second important point of the report is that a single picture of the world is considered at the level of three separate systems (Economics, Ecology and Society) and their separate reference cannot give an idea and understanding of the performance results and development perspectives of the whole socio-economic system. This is not in line with a *systematic approach*. The report has become the basis for further development of the concept of sustainable development.

The UN has endorsed the 2030 Agenda, which is a call to action to protect the planet, end poverty and guarantee human well-being. According to the United Nations Communication Group (UNCG), the SDG is a world call to action to end poverty, protect the planet in peace and prosperity by 2030. In 2016, SDGs were adopted by 193 countries to promote economic growth, to ensure social inclusion and environmental protection.

Club of Rome leaders Ernst von Weizsäcker and Anders Wijkman in 2018 presented a joint report titled "Come On!" (Weizsäcker & Wijkman, 2017). The report deals with the decline of capitalist civilization in the form in which it exists at the moment – with its own guidelines for expanding production and making a profit. It has been criticized that GDP reflects spending rather than well-being or subjective happiness, and does not see the benefits that exist outside the market. It has been determined that the only thing that measures GDP is the speed at which money moves in the economy.

A breakthrough in understanding the sustainable development of the world was the ideas that served as the starting point for drawing up the report:

- the concept of 'full world' proposed by the American ecologist and economist Herman Daly (Daly, 2015). Human civilization was formed in the conditions of an 'empty world' – a world of unexplored territories and an excess of resources;
- concepts of living socio-economic systems proposed by F. Capra (Capra & Jakobsen, 2017).

According to H. Daly (2015), the economy is an open subsystem of a larger ecosphere, which is finite, non-growing, and materially closed, although open to a continual, but non-growing, throughput of solar energy. When the economy grows in physical

dimensions, it incorporates matter and energy from the rest of the ecosystem into itself. All these populations, both living and non-living, are what physicists call "dissipative structures", that is, their maintenance and reproduction require a metabolic low, a throughput that begins with depletion of low entropy resources from the ecosphere and ends with the return of polluting, high-entropy waste back to the ecosphere. This disrupts the ecosphere at both ends, an unavoidable cost necessary for the production, maintenance, and reproduction of both people and wealth.

It can be argued that for 50 years the formulated theoretical basis of sustainable development and the projects implemented on this basis have not been successful in achieving sustainable development goals. It can be stated that today we have not come close to understanding sustainability and sustainable development. This failure was very accurately described by the famous thinker and mathematician of the 15th century N. Kuzansky, who stated, "Everything that is measurable is achievable, everything that is achievable is measurable" (Dart, 2022).

Alternative Design Approaches for Sustainable Development

Returning to the definitions of the natural sciences, all living systems – nature and society – are open, stable, unbalanced and dynamic systems. Therefore, it is natural to use the laws of living systems to create technologies for sustainable development. In nature, there is no closed living system in which there would be no inflow and outflow of energy with zero power (energy flow) (Podolinsky, 2004; Vernadsky, 2006). According to E. S. Bauer, a feature of living systems is that they work against the expected equilibrium using free energy (Bauer, 2002). The main characteristic of energy flows circulating in living systems is their ability to perform external useful work or create external useful power. Human activity can be described in terms of flows of energy and matter, and since the 1980s and 1990s, some systems ecologists and economists have begun to pay more attention to economic issues (Costanza, 2004; Georgescu-Roegen, 1986). A direct continuation of this classical thought is the teaching of Vernadsky about the restructuring of the biosphere into the noosphere – a qualitatively new state, which is a historically inevitable process (Vernadsky, 2006). The human economy exchanges materials and energy with the larger Earth system. Only energy flows have no boundaries, and these continuous flows provide and support the processes of the Earth system (Odum, 1968).

Based on the conversion of biomass units into energy units, Lindemann (1942) formulated a new methodology for studying ecosystems using the analysis of energy flows. At present, the inconsistency or inconsistency of the measures of heterogeneous systems (social, economic, environmental, etc.) is the reason for the rupture of ties, as a result of which social systems are managed in isolation from the general patterns of living systems, which ultimately leads to a global systemic crisis (Kuznetsov, 2015). When economic and ecological systems are conceptualized in the same language of energy and matter flows, it is natural to state that the human economy is rooted in the Earth's geobiosphere. In the model, the total throughput of a system is the sum of all flows in the system and is a measure of the speed at which flows are processed by the system (Fang & Chen, 2019) and depends on the structure of the system. Thus, like GDP, it reflects the size and overall performance of the system. System growth can be defined as an increase in the total exchange of flows (Ulanowicz et al., 2014). These models can become the basis for the concepts of social justice and limited economic optimization to understand better

the problems that arise. Based on the quantitative and qualitative assessment of smart rural development in Latgale region (Latvia), the concept of smart specialization can be used to promote sustainable development in rural areas (Šipilova et al., 2017).

Methodology of the New Approach

In contrast to the proposed models of sustainable development, the authors create the model based on the following provisions:

- Our system – the biosphere – is not closed and has the ability to perform external work, that is, it has the ability to evolve.
- The evolution of inanimate nature, which preceded the emergence of life, was dominated by the processes of reducing free energy, which took the form of the second law of thermodynamics.
- The evolution of living nature is dominated by processes that lead to an increase in free energy, which is true for all forms of life. Both of these processes determine the multidirectional evolution of inanimate and living nature and are controlled by the law of conservation of power.
- Living systems (nature, society) with constant exchange with the environment should not be in equilibrium, that is, they must be capable of doing external work. The measure of the distance of a system from equilibrium is its free energy. For a living system, balance is death.
- Any system cannot exist without interaction with its natural environment and combines two associated processes: an active flow of environmental impacts, which determines the capabilities or capacity of the system, and the use by society of the flow of resources resulting from this impact to meet needs.
- The highway of evolution is an accelerating wave dynamic process from unstable equilibrium to stable non-equilibrium.
- Sustainable innovative development of socio-economic systems is a chrono-holistic process of growth in the useful capacity of the system with no increase in the rate of resource consumption while maintaining development in the face of negative external and internal influences.
- The introduction of the "power" measure into the project management of sustainable development makes it possible to establish a physically measurable relationship between needs and opportunities and formalize a system of natural-scientific parameters of sustainable innovative development.
- The only way to increase the amount and density of solar energy retained on the Earth is human mental creative labor, which, with the help of more advanced machines and technologies, makes physical labor more productive.
- The elementary scheme of the production cycle is determined by the equality: the total power at the input of the system is equal to the useful power plus the power of losses at the output.
- A necessary and sufficient condition for the continuous development of society is people who are able to put forward and implement ideas that ensure the growth of society's capabilities, the satisfaction of its needs, both non-vanishing and new.
- A society that is able to use the creative innovative ideas of an individual to grow the opportunities of society as a whole and a society that uses its growth

of opportunities to form such a creative individual will have the fastest growth rate of opportunities.

– If, as a result of the implementation of creative ideas, society ensures a non-decreasing rate of growth in the efficiency of using the full consumed power not only for the present, but also in the future, then it will retain its development not only at the present time, but also in the future.

Within the framework of the complex system theory, in accordance with the above provisions and with the aim to formalize the tasks of sustainable development, a methodology for managing sustainability has been developed using the approach of analyzing energy flows (power) changes in open and dynamic socio-economic systems (Jermolajeva & Trusina, 2021).

Sustainable development is a continuous process of increasing the opportunities to meet the current needs of the existing socio-economic system in power measurements without compromising the ability to meet needs for future generations, while increasing the efficiency of using the full power of the system, reducing power losses and not increasing consumption in the face of negative external and internal influences (Bolshakov et al., 2019).

Based on the above formulated concepts, in the frame of complex dynamic system and the power change analysis, an approach to the analysis of life open systems (Trusina & Jermolajeva, 2021) is formulated below:

- a complex socio-economic system, open to energy flows, meets all certain parameters and can be represented as a system of nested systems – the economic system is 'invested' in society and further surrounded by the natural system;
- the laws of economic growth and development of the ecological system determine the development of the economic system;
- input energy flows are directed from the external circuit;
- the value of total power, useful power, lost power and technological efficiency of the socio-economic system as a basis for constructing an invariant coordinate system;
- quality of life per inhabitant in terms of power as a function of the useful power of the socio-economic system (created as a result of activities), life expectancy and environmental quality. The quality of life characterizes the current present state and the potential for development in the future;
- the system of power change as a dynamic state and direction of development of the entire socio-economic system as a whole.

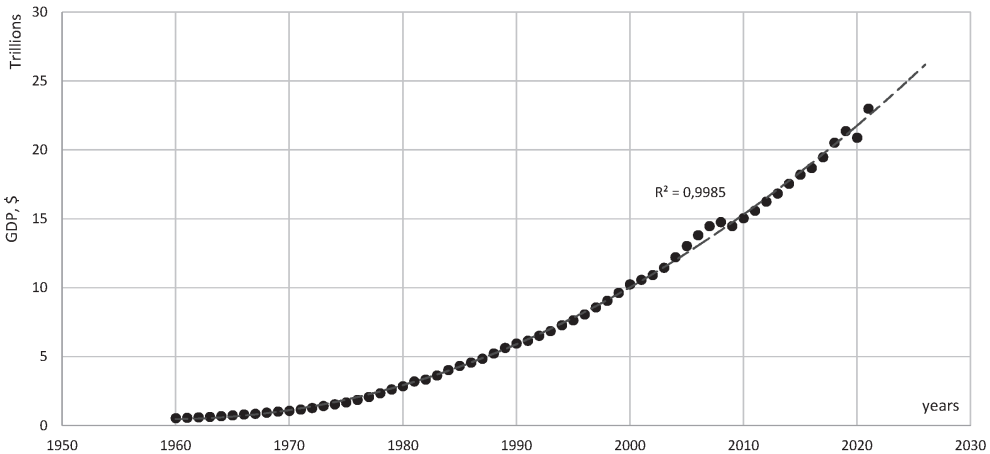
Analysis of Statistics and Results Based on the USA Data

The analysis of life open systems is made based on the above formulated concepts and changes of the power. The calculation of sustainable development parameters was carried out using the data of the World Bank (The World Bank, 2022), database of the United Nations (UNDATA), UN ICT (2021).

Figure 1 presents statistics on changes in the United States of America (USA) GDP from 1960 to 2021. During the study period, the graph line corresponds to a fairly smooth function ($R^2 = 0.9985$). Over the entire period, there has been a continuous positive increase in GDP.

Figure 1

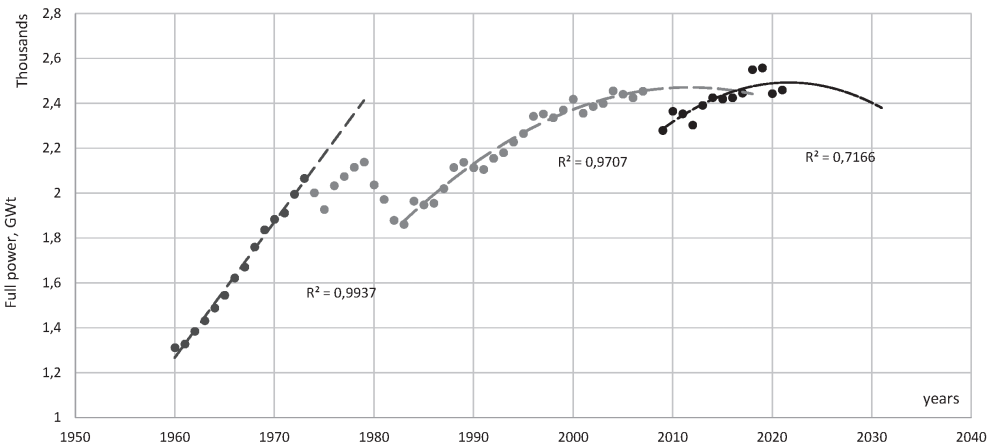
Changes of Gross Domestic Product (GDP) in the United States of America (USA), Period 1960–2021, USA Dollars



Source: Made by the authors.

Figure 2

Changes of Full Power of Energy Resource Consumption With Trend +10 Years in the United States of America, Period 1960–2021, GWt



Source: Made by the authors.

In accordance with the model for analyzing the power changes of the socio-economic system, the calculation of the total power energy resource consumption of the USA for the period of 1960– 2021 was carried out. By definition, the total power consumption is equal to the sum of all types of energy resources that are necessary for the support of the system activities. Figure 2 shows three periods of continuous sustainable consumption with different characteristics of changes:

The period of 1960–1973 is a stable steady linear growth in the power change of energy resource consumption ($R^2 = 0.9937$). The end of the period is characterized by great changes in almost all areas – a change in the technological paradigm, a change in the economic paradigm as a transition to a liberal economy and a change in the monetary system as a final rejection of the gold standard.

The period of 1983–2008 is a stable non-linear decrease in the power changes of energy resource consumption ($R^2 = 0.9707$) with reaching of a constant level of changes since 2002. The end of the period is characterized by the beginning of the 2009 crisis.

The period 2009–2021 reaches the level of change in consumption until 2008. Function stability has lower parameters ($R^2 = 0.7166$).

This example is an analysis of the development of the USA socio-economic system in a new invariant coordinate system in units of power instead of money (USA dollars). These results and the different approach show ambiguous sustainable development and raise the question – What is real sustainable development?

The Need for a Change in Thinking and Attitude Based on Education

According to the authors of the article, there is a clear need for changes in the consciousness and actions of each individual, as well as in the society as a whole, in relation to the concept of sustainability, both theoretically and practically.

In Europe, three revolutions are simultaneously under way which are bound to alter the strategic challenges that Europe will have to address: (1) an economic and technological revolution: the convergence of digital, biological and industrial technologies and the digital tools; (2) a social and democratic revolution: more empowered and better connected individuals will be more creative, more dynamic, less wedded to life-time jobs, but also more demanding and critical; (3) a geopolitical revolution: Asia's rise will continue and the roughly two centuries of global dominance by the European continent and the United States are drawing to a close (ESPAS, 2015).

Several authors write about the new competences and skills in the 21st century, which include the digital, social, basic and contextual skills, including scientific literacy. Scientific literacy as an element of employability skills is growing nowadays, as science has become part of people's everyday life and it is expected that the importance of scientific literacy will only increase in the future (Bikse et al., 2022).

The environmental problems are becoming part of a wider problem of people's attitudes towards the environment. They are socially conditioned and their causes are found in the approaches that are based on external factors rather than internal, i.e., they are found in environmental factors such as demography and geography, economy, politics, education, and culture (Andić & Vorkapić, 2017).

Director-General of UNESCO A. Azoul in the "Report of the International Commission on the Future of Education" emphasizes that we must act urgently to change the current course, because the future of people depends on the future of the planet, and both are at risk. A new social contract for education is being proposed, which aims to renew our relationship with each other, with the planet and with technology. This new social contract is our opportunity to take the responsibility for the injustices of the past and transform the future. Above all, it is based on the right to quality education throughout life, embracing teaching and learning as a shared societal endeavor and thus a common good (UNESCO, 2021).

The authors of the article also agree that one of the most important basic things for such changes to happen is educating people in various forms – formal education from kindergarten to university, informal education opportunities – courses, seminars, discussions, etc. There are various developments and proposals in the world, which should be implemented, while creating an interdisciplinary approach and explaining sustainability as a set of economic, social and ecological factors.

It was concluded that the attraction of citizens and the successful use of their potential in specific territories are also important factors in ensuring sustainable development (Aleksejeva et al., 2018). And in this case too, it is necessary to educate people in the acquisition of knowledge and skills, as well as in the formation of civic self-awareness.

However, in order to achieve changes in formal education, it is obviously necessary to improve the training of teachers themselves. There are several good examples of education systems in world practice, such as in Finland. Education is the main key to changing people's unsustainable lifestyles and through education we need to teach a way of systems thinking that every member of society can understand (Hofman-Bergholm, 2018).

Final Considerations

The changes taking place in the 21st century in various areas of life affect each person individually and society as a whole, as a result of which the understanding and attitude towards sustainability issues should also change. Therefore, it is necessary to develop and analyze different approaches, models and their interpretations in order to determine the most reasonable and effective means for real sustainability, and not only for determining sustainable development of country, for example, based on GDP in monetary terms, as it has been accepted in economic analysis for several decades. Development is sustainable in a certain cycle of the existence of a living system. In the transition between cycles, the chronointegrity of development is destroyed, dimensional gaps arise – crises that require breakthrough management technologies and sustainable development becomes a strategic goal of managing the way out of the crisis.

Scientists and practitioners should deeply and comprehensively review and consider sustainable development in the nature-society-human system as development that conforms to the laws of global evolution of living nature and the laws of historical development of humankind.

In accordance with the model for analyzing the power changes of the socio-economic system, the calculations of the total power energy resource consumption and GDP of the USA for the period of 1960–2021 were carried out. This example is an analysis of the development of the US socio-economic system in a new constant coordinate system in power units, and it can be concluded that the development is not as smooth as it appears when analyzing in monetary units.

The authors of the article believe that the necessary changes in people's thinking and attitude can be changed mainly based on the education system throughout the life of a person and by introducing an increasingly broad and research-based interdisciplinary perspective on issues of sustainability and sustainable development.

References

Aleksejeva, L., Šipilova, V., Jermolajeva, E., Ostrovska, I., & Oļehnovičs, D. (2018). Regional risks and challenges in smart growth in Latgale Region (Latvia). *Journal of Security and Sustainability Issues*, *7*(4), 727–739. doi.org/10.9770/jssi.2018.7.4(10)

Andić, D., & Vorkapić, S. T. (2017). Teacher education for sustainability: The awareness and responsibility for sustainability problems. *Journal of Teacher Education for Sustainability*, *19*(2), 121–137. https://doi.org/10.1515/jtes-2017-0018

Bauer, E. S. (2002). *Theoretical Biology*. Rostok.

Bell, D. V. J. (2016). Twenty-first century education: Transformative education for sustainability and responsible citizenship. *Journal of Teacher Education for Sustainability*, *18*(1), 48–56. https://doi.org/10.1515/jtes-2016-0004

Bikse, V., Grinevica, L., Rivza, B., & Rivza, P. (2022). Consequences and challenges of the fourth industrial revolution and the impact on the development of employability skills. *Sustainability*, *14*, 6970. https://doi.org/10.3390/su14126970

Bolshakov, B. Y., Karibaev, A., & Shamaeva, E. F. (2019). Introduction to the theory of management of novation's with the use of spatiotemporal measures. *AIP Conference Proceedings*, 2116, 200009. https://doi.org/ 10. 1063/ 1. 5114190

Brundtland, G. H. (1987). Our common future – call for action. *Environmental Conservation*, *14*(4), 291–294.

Capra, F., & Jakobsen, O. D. (2017). A conceptual framework for ecological economics based on systemic principles of life. *International Journal of Social Economics*, *44*(6), 831–844.

Costanza, R. (2004). Value theory and energy. In C. J. Cleveland (Ed.), *Encyclopedia of Energy*, vol. 6 (pp. 337–346). Elsevier. https://doi.org/10.1016/B0-12-176480-X/00118-2

Daly, H. (2015, June). "Economics for a Full World". *Great Transition Initiative*. http://www. greattransition.org/ publication/economics-for-a-full-world

Daly, E. D. (1993). Steady state economics: A new paradigm. *New Literary History*, *24*(4), 811–816. https://doi.org/10.2307/469394

Dart, B. C. (2022). Nicholas of Cusa's mathematical theosophy: On the symbolic method, learned ignorance, and conjectural knowledge of God. Memorial University of Newfoundland. doi: 10.13140/RG.2.2.15695.56487

Dias, G. B., Onevetch, R. T. S., Santos, J. A. R., & Lopes, G. C. (2022). Competences for sustainable development goals: The challenge in business administration education. *Journal of Teacher Education for Sustainability*, *24*(1), 73–86. https://doi.org/10.2478/jtes-2022-0006

ESPAS. (2015). *Global trends to 2030: Can the EU meet the challenges ahead?* European Strategy and Policy Analysis System. https://espas.eu/files/espas_files/about/espas-report-2015.pdf

Fang, D., & Chen, B. (2019). Inequality of air pollution and carbon emission embodied in inter-regional transport. *Energy Procedia*, *158*, 3833–3839. https://doi.org/10.1016/j.egypro.2019.01.864

Georgescu-Roegen, N. (1986). The entropy law and the economic progress in retrospect. *Eastern Economic Journal*, *XII*(1), 3–15. https://www.jstor.org/stable/40357380

Hofman-Bergholm, M. (2018). Changes in thoughts and actions as requirements for a sustainable future: A review of recent research on the Finnish educational system and sustainable development. *Journal of Teacher Education for Sustainability*, *20*(2), 19–30. https://doi.org/10.2478/jtes-2018-0012

Jermolajeva, E., & Trusina, I. (2021). A new approach to the application of the principles of sustainable development. Economic Science for Rural Development. *Proceedings Paper, 22nd International Scientific Conference on Economic Science for Rural Development (ESRD)* (55), 231–240.

Jeroen C. J. M. van den Bergh. (2009). The GDP paradox. *Journal of Economic Psychology*, *30*(2), 117–135. https://doi.org/10.1016/j.joep.2008.12.001

Karibaev, A., Bolshakov, B. Ye., & Shamaeva, E. F. (2019). Introduction to the theory of management of novations with the use of spatiotemporal measures. *AIP Conference Proceedings*, 2116, 200009.

Kuznetsov, P. (2015). *Life development science*. PAEH.

Kolganov, A., & Buzgalin, A. (2010). Economic crisis: Scenarios of post-crisis development. *Science and Society*, *74*(4), 538–546.

Lindeman, R. (1942). The trophic-dynamic aspect of ecology. *Ecology*, *23*(4), 399–417.

Miedema, S., & Bertram-Troost, G. (2015). The challenges of global citizenship for worldview education. The perspective of social sustainability. *Journal of Teacher Education for Sustainability*, *17*(2), 44–52. https://doi.org/10.1515/jtes-2015-0010

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth*. Universe Books.

Odum, E. (1968). Energy flow in ecosystems: A historical review. *American Zoologist*, *8*(1), 11–18. https://www.jstor.org/stable/3881528

Pestel, E. (1989). *Beyond the limits to growth: A report to the Club of Rome*. Universe Publishing Company.

Podolinsky, S. (2004). Socialism and the unity of physical forces. *Organization & Environment*, *17*(1), 61–75. https://doi.org/10.1177/1086026603262092

Salīte, I., Drelinga, E., Iliško, D., Oļehnoviča, E., & Zariņa, S. (2016). Sustainability from the transdisciplinary perspective: An action research strategy for continuing education program development. *Journal of Teacher Education for Sustainability*, *18*(2), 135–152. https://doi.org/10.1515/jtes-2016-0020

SDR. (2019). *Sustainable Development Report, 2019*. https://www.sdgindex.org/reports/sustainable-development-report-2019/

Shamaeva, E. F. (2019). Novation management methodology in design of regional sustainable development systems with the use of universal measurable values. *Journal of Advanced Research in Dynamical and Control Systems*, *11*(8 Special Issue), 329–338.

Šipilova, V., Ostrovska, I., Jermolajeva, E., Aleksejeva, L., & Oļehnovičs, D. (2017). Evaluation of sustainable development in rural territories in Latgale region (Latvia) by using the conception of smart specialization. *Journal of Teacher Education for Sustainability*, *19*(1), 82–105. https://doi.org/10.1515/jtes-2017-0006

Trusina, I., & Jermolajeva, E. (2021). The scientific discourse on the concept of sustainable development. *Eastern Journal of European Studies*, *12*(2), 298–322. https://doi.org/10.47743/ejes-2021-0215

Ulanowicz, R. E., & Huang, J. (2014). Ecological network analysis for economic systems: Growth and development and implications for sustainable development. *PLoS ONE*, *9*(6), e100923.

UN. (1972). *Report of the UN conference on the human environment*. https://www.un.org/en/conferences/environment/stockholm1972

UN. (1987). *UN General Assembly Resolutions*. https://research.un.org/en/docs/ga/quick/regular/42

UN. (1992). *The United Nations Conference on Environment and* Development (UNCED). https://www.un.org/en/conferences/environment/rio1992

UNDATA. (n.d.). United Nations Statistics Division. http://data.un.org/. Access: 03.12.2021.

UNESCO. (2021). *Reimagining our futures together: A new social contract for education. Report from the International Commission on the Futures of Education. United Nations Educational, Scientific and Cultural Organization*. https://unesdoc.unesco.org/ark:/48223/pf0000379707.locale=en

UN ICT. (2021). *UN specialized agency for ICT ITU*. https://www.itu.int/hub/

Vernadsky, V. (2006). *Essays on geochemistry & the biosphere*. Synergetic Press.

Weizsäcker, E. U., & Wijkman, A. (2017). *Come on! Capitalism, short-termism, population and the destruction of the planet*. Springer.

World Bank. (2022). *The World Bank, digital development overview: Development news, research, data*. https://www.worldbank.org/en/topic/digitaldevelopment/overview

Correspondence concerning this paper should be addressed to Dr. Elita Jermolajeva, Leading Researcher of Latvia University of Life Sciences and Technologies, Faculty of Economics and Social Development. Email: elita.jermolajeva@gmail.com