FUTURITY PHILOSOPHY

DOI: https://doi.org/10.57125/FP.2022.12.30.02

How to cite: Ataeva, N. (2022). Teaching natural sciences through the prism of philosophy: an attempt to define the relationship. *Futurity Philosophy*, 1(4), *15-28.* https://doi.org/10.57125/FP.2022.12.30.02

Teaching natural sciences through the prism of philosophy: an attempt to define the relationship

Nilufar Ataeva

Doctor of Philosophy (Ph.D.) in Philological Science, Tashkent Institute of Finance, ORCID: 0000-0002-7471-5207

Received: September 25, 2022 | **Accepted:** November 19, 2022 | **Published:** December 30, 2022

Abstract: Aims: The purpose of the article is to harmonize the philosophical, educational, and philosophical-scientific aspects of teaching natural science at different educational levels. The educational and pedagogical system functions as a complex of interconnected elements of methodological, organizational, and ideological nature. Each of these segments (especially teaching and methodological activities) needs to be correlated to achieve the integrity of the educational paradigm, in which natural science knowledge forms its own principles and interacts with humanitarian or applied knowledge. The task of the research is to highlight the peculiarities of the formation of thinking activity in students of educational levels. Methodology: The methodological arsenal used in the study combines general scientific, scientific and educational, and philosophical clusters. The methodological approaches used to examine the peculiarities of teaching natural sciences through the prism of philosophy have a dialectical and synergistic basis. The complex of multidisciplinarity and pluralistic-oriented methodology is identified as a promising area of research, which makes it possible to consider natural science not as a separate (or even isolated) component of science and education, but to combine it with information technology and humanitarian and worldview elements of the world picture. Results: The results of the study indicate the formation of new benchmarks for the quality of science education in modern pedagogy and science. The key achievement of modern education is the reorientation from the fragmentation of knowledge to its synergistic integrity. The practical and pedagogical value of this process is to form the foundations of subject-action and visual-figurative thinking. Scientific Novelty: The scientific novelty of the study is focused on building educational strategies in which natural science knowledge forms synergistic links with applied and humanitarian knowledge, ensuring the integrity of

fundamental and flexible skills and the universality of thinking activity. Conclusion: Natural science remains a fundamental component of the educational system, forming an adequate understanding of the existential dimensions of human existence. At the same time, modern education offers a new approach to the organization of knowledge and skills of students at different levels, which involves the study of the laws of the universe, nature, society, human, technology exclusively in an interdisciplinary complex dimension.

Keywords: philosophy of education, philosophy of science, natural science discourse, thinking activity, methodological principles of natural science, philosophy of nature, synergistic worldview, educational strategies.

Introduction

The modern scientific and philosophical discourse demonstrates new formats of the level of knowledge perception and the corresponding formation of competencies by students of natural, social, and pedagogical competencies (Koyuncuoglu, 2021). As it turned out, content is dominant in achieving educational goals, completely leveling the specifics of knowledge. The philosophical interpretation of such results indicates the priority of content over form, which indicates the stabilization of the educational space in the civilizational dimension. A cultural and historical feature of scientific and educational development was the actualization of knowledge clusters in periods of instability of the worldview paradigm. When the scientific and worldview picture of the world stabilizes and acquires the features of stability and sustainability, the format of educational and pedagogical activity implies the dominance of targeted aspects of education, regardless of its focus on the object of research or study.

The history of natural science has many examples of attempts to introduce a model of nature interpretation alternative to natural philosophy. Ancient natural philosophical constructions (Lemos, 2020), medieval ideological and mystical elements (Page & Rider, 2019), Renaissance humanistic manifestations, pseudoscientific concepts of postmodernism - all of this was eventually leveled by the fundamental nature of classical natural science foundations. Education has always been a platform for confirming the inviolability of natural science disciplines. However, for science and philosophy, the phenomenon of the “basic element” always remains a unifying constant (Janev, 2020). The ontological essences of nature have fundamental principles that determine their educational and epistemological orientation. The philosophy of nature as a separate way of actualizing educational innovations in natural science acts as a kind of bridge between metaphysics and natural science (Feser, 2019). The philosophy of science offers an “ontologically, epistemologically, and axiologically” oriented approach to the formation of an arsenal of teaching tools (Asmara et al., 2022). If we add the fact that philosophy actualizes the issue of research ethics, we get a holistic philosophical and educational paradigm of natural science (Romero, 2019). While preserving the fundamental nature of the laws of nature, the disciplinarity of this segment of the sciences goes beyond its traditional framework (which eventually transformed into epistemological limitations). In this context, the philosophical interpretation of the conceptuality of natural science is becoming more relevant. In a situation where natural science education has formed an excessive linearity and conservatism, the philosophy of education will allow us to consider natural science from the outside, from the point of view of a humanitarian, technologist, psychologist, or simply an interested person.

The modern socio-cultural development of society dictates its own trends in the development of education and science. The principle of presenting finished products to the consumer is in some way extrapolated to the educational sphere. Without going into the discussion of the axiological compliance of this approach with the principles of education, we note that for the natural sciences, such disciplinary positioning is relevant for participants (primarily students) in the educational process. The lack of

innovation in the structure of any knowledge automatically reduces its popularity and significance in society. Based on these realities, natural science has moved away from the principles of fundamentality and is increasingly incorporating innovative elements into its foundations (Kusumayuni & Agung, 2021). New educational trends involve not only specialized training but also the comprehensive development of skills and competencies. The acquisition of basic knowledge is no longer the leitmotif for the student, as in today's dynamic world it is important to find ways to apply the acquired knowledge. Therefore, the natural science cluster is closely related to the study of social sciences, technologies, and foreign languages (Kizi, 2021). The humanization of the natural sciences is intended to actualize the educational mission. For a long time, the natural sciences have retained the status of specialized disciplines that require a special approach to learning. The use of innovative digital, humanitarian, and conceptual elements will ensure the rapid integration of natural science into the segment of understandable and interesting disciplines.

Research Problem

The research problem of the study is to integrate natural science into the modern scientific picture of the world not as a dominant or autonomous component, but as one of the elements of the integrity of human existence and the development of civilization. The vocation of philosophy has always reoriented the ontological essences of the universe or nature to the human dimension, giving them purpose and value. The epistemological arsenal of natural science was impressive in its potential while being unable to fully define the ultimate goal or purpose of its activity. Philosophy of science and philosophy of education emerged as clusters that combined practical and scientific achievements and priority goals of human activity in the development of nature.

Research Focus

The focus of the study is on the manifestation of knowledge synergy in the educational system. The natural science segment of knowledge has long maintained an autonomous status in the world picture, limiting its interaction with other elements of the educational space. However, with the growing role of information and technological progress, this positioning has lost its relevance. The educational system is faced with the need to form a new paradigm of knowledge in which man, nature, the universe, nature, society, and technology will be represented by scientific and educational methodologies in a single dimension, not separately. Interdisciplinarity, though with difficulties (organizational and ideological), is gaining a dominant methodological status in modern education.

Research Aim and Research Questions

The purpose of the study is to highlight the peculiarities of teaching natural sciences in the educational system, which is transforming from the principles of fundamentality to the ideas of interdisciplinarity. The coordination of scientific, philosophical, and educational principles for understanding, interpreting, and translating natural science ideas in the educational process ensures the formation of a holistic synergistic-oriented picture of the world. The task is focused on highlighting the peculiarities of the formation of thinking activity in the study of natural sciences. An attempt is made to add other types of thinking to the classical object-visual type of thinking (which corresponds to the traditional natural science methodology): evolutionary-symbolic, visual-figurative, and verbal-logical (in accordance with the innovative epistemological segment). At the same time, it is important to provide a philosophical justification for the effectiveness of the synergistic methodology for natural science, which combines different philosophical and scientific clusters of natural sciences.

Literature Review/Theoretical Overview

Over the past decade, there have been attempts to organize and present the concept of the nature of science (NOS) as a scientific and educational paradigm. An important aspect of this conceptual interpretation of natural science is the return of the philosophical element to the natural science cluster (Mohan & Kelly). The period of unilateral positivist dominance in natural science has come to an end, recognizing the inability of science to cope with the large-scale and rapid effect of globalization, which is reflected in the need for integrated knowledge. Therefore, the natural sciences in their classical positivist dimension were supplemented by socio-humanitarian axiological aspects and practical technological manifestations. Moreover, the integration of knowledge in natural science has a diverse nature and origin - from individual wisdom to large-scale designs of the natural environment (Wilujeng et al., 2018). Independent learning, which in the classical understanding of natural science disciplines had no prospects for development, with the help of ICT and human elements is becoming an actual educational process (Budiastra et al., 2020).

Naturalistic concepts have always been the basis of natural science, starting with the classical natural science of the New European era. However, modern principles of civilizational development require certain adjustments to the understanding of nature, humans, and their interaction. It is clear that such innovations do not affect the laws of nature, but they often lead to a revival of interpretability in scientific discourse. In modern natural science, the issue of the relationship between humans and nature is being actualized and attempts are being made to reorient it towards interaction or synergy in the context of the ecological and evolutionary approach (Rybalko et al., 2020). “The ecosystem services approach has become very influential in global science and policy” (Kirchhoff, 2019).

The peculiarity of knowledge integration in the modern scientific paradigm is to go beyond the boundaries of a field of knowledge (Nkanyani & Mudau, 2019). Previously, this was a specificity of humanitarian knowledge, but today it defines natural science as a science that is capable of activity beyond the knowledge of nature. Innovative technologies contribute significantly to this integration process. Improving existing ideas about nature with elements of virtual or augmented reality, a new understanding of human potential through the use of artificial intelligence, or the concept of transhumanism - all of these are already used in natural science, expanding its boundaries in scientific terms (Arici et al., 2019). The modern philosophy of science operates on the principles of Big Data, gaining an opportunity to understand the nature of science and improve the specifics of scientific knowledge (Haig, 2020). At the same time, the educational interpretation of the natural sciences is also undergoing transformations. The need for a new positioning of natural science in the educational and scientific paradigm is due to the transformation of the understanding of objectivity in science (Gunton et al., 2022). If earlier the principle: objectivity is a projection satisfied the scientific community, now, with the active use of technology, the understanding of projection is expanding, and with it the need for new natural science dimensions.

On the other hand, Wójtowicz (2019) is skeptical about the possibility of innovative methods in explaining nature. In particular, according to the scientist, category theory (as well as other multidisciplinary concepts) is not able to explain physical phenomena. Traditional mathematical tools (as well as other rationalistic methods) are much more effective than our everyday intuition in explaining nature (Kuś et al., 2019). Król (2019) emphasizes the need to maintain a balance in the study of ontological entities. The scientific and educational discourse faces a dilemma: the popularization of natural science or the conservatism of this segment of science. If we focus on strict adherence to the canons of natural science, the educational community will eventually face an elementary shortage of personnel in this cluster of science. When introducing innovative principles, there are threats of increasing criticism and doubts about the fundamental principles of natural science. Analyzing these

perspectives, it is noted that the popularization of natural sciences is an irreversible process of a global socio-cultural nature. At the same time, the criteria for such an innovative impact should be clearly correlated with the fundamental theoretical and methodological scientific and educational strategies.

Chan & Hume (2019) define the role of participants in the educational process in the study of natural sciences. It is noted that transformations in natural science are taking place for all stakeholders: teachers, students, and organizers of the educational process. Currently, there is a process of updating both the content and format of natural science at all educational levels, which requires a response and adaptation of the educational community.

Research Methodology

General Background

Akgun & Kaya (2020), guided by cognitive, epistemic, and socio-institutional methodological guidelines, investigated students' perceptions of the nature of science. The results of the study confirm the tendency to reorient from the fundamental nature of science to its flexibility and dynamism. If earlier the natural science cluster was considered the core of scientific life, and the humanities were assigned a secondary role, now research indicates a deeper understanding of the nature and integrity of science among humanities students. This leads to the activation of the processes of involving the methodological potential of the socio-humanities and technological sciences in the natural science cluster.

Service learning has become a new methodological approach in the educational system (Salam et al., 2019). In this context, the format of network science is methodologically close (Castro & Siew, 2020). Situated learning is also one of the promising areas for studying natural sciences in the educational system (Reyes & Dueñas, 2021). Through modeling and structuring, the paradigm of cognitive science is formed. Particularly important in the study of natural sciences is the reorientation from the fundamental and subject matter to the institutional and practical dimension. This actually destroys the traditional element of natural science that made it impossible to integrate it into the general scientific picture of the world along with humanities or technological knowledge, since natural science associated the world picture exclusively with its epistemological and methodological guidelines, leaving no room for other components. However, the pragmatically oriented (essentially philosophical) educational system destroys these beliefs, opening the way to an interdisciplinary approach.

New methodologies for environmental assessment and science education are based on innovative dimensions. In particular, Ichsan (2019) proposes a methodological model of higher-order thinking (HOTS). This approach does not seem to differ from the classical scientific paradigm and involves identifying a problem, ways to solve it (with defined issues and limitations), analyzing and interpreting the results. The difference lies in the emphasis of this methodology, which is reoriented from knowledge to thinking (from fundamental to dynamic).

Engaging students' creative thinking in the study of natural sciences requires the transformation of existing methodological guidelines. It is clear that the traditional quantitative and descriptive method for natural science cannot cope with the creative type of thinking in the process of an educational activity (Syafrial et al., 2022). Therefore, the modern scientific and philosophical discourse proposes interdisciplinarity as a mechanism that will ensure the functioning of creativity and serve to form the flexibility of practical application of natural science competencies (under the undeniable condition of observing the principle of fundamental laws of nature).

Research Results

The results of the study focus on the diverse use of thinking activities (types of thinking) in natural science discourse (see Table 1).

Table 1

Features of the formation of thinking activity in students in the natural science segment

Type of thinking	Interaction with knowledge	Acquired skills or competencies
Subject-action	Fundamental knowledge of the laws of the universe, nature, and humanity	Hard-skills
Verbal and logical	Flexible knowledge of civilization and humanitarian nature	Soft-skills
Evolutionary and symbolic	Innovation-oriented knowledge of progress and technology	Digital-skills
Visual and figurative	The creative component of knowledge that develops abilities and personality	Creative-skills

Source: author‘s own development

The basis of studying natural science disciplines is the actualization of specific operational development, which requires the formation of a critical thinking paradigm (Leasa et al., 2020). Variability in learning is both a guarantee and a result of critical thinking (Hayati & Berlianti, 2020). For a long time in natural science, critical thinking has been associated with the process of epistemological activity. However, modern scientific discourse puts critical thinking along with analytical thinking in the segment of axiological results. Therefore, thinking activity is gaining new guidelines in modern natural science. Doyan et al. (2020) emphasize the increasing role of scientific creativity (and creative thinking) in the natural sciences, revealing new synergistic guidelines for scientific progress.

Braund & Reiss (2019) emphasize the growing trend of interconnection between art and science. This approach indicates an increase in interdisciplinarity in hitherto unconnected formats. In the classical sense, natural science is a highly specialized study of the natural order. At the same time, the issues of nature in the philosophical dimension are existential and require a comprehensive study for all participants in the educational process. To a large extent, the integration of scientific knowledge is ensured by the strengthening of the role of experimental science (Robinson et al., 2019). Since the days of Hawking's philosophy of science, experimentalism has gained priority in natural science (Simons & Vagelli, 2021). In the modern educational paradigm, the role of empiricism is only increasing.

The study offers a comparative characterization of the theoretical and methodological and epistemologically oriented dimensions of natural science (see Figure 1).

Figure 1

The dominance of philosophically oriented formats of the natural science education system

Methodological format	Gnosiological format
1. Priority of rationalistic knowledge	1. Prioritization of empirical knowledge
2. Dominance of theoretical and methodological justification	2. Dominance of research results
3. Integration of innovative elements into the system of natural science knowledge	3. Use of innovative tools in the process of studying natural science

Source: author‘s own development

Modern education is facing the problem of covering the natural sciences in a global sense, not as specialized disciplines. Under such conditions, integration processes have begun in the scientific and educational space, when natural, social sciences, humanities, arts, and technology are combined by joint problematic research or by identifying common methodological guidelines. Although, Usmeldi et al. (2022) emphasize the low level of knowledge integration in the modern practical and educational sphere.

One of the main elements of the synergistic paradigm of knowledge offered to students of educational levels is the technological and creative component (Alimjonova, 2021). In this case, the natural science segment ensures the acquisition of these competencies through the study of general patterns. However, while the scientific approach limits epistemological activity to understanding natural processes, the philosophical orientation involves the transfer of fundamentality to technology or creativity, which ensures their structuredness and integrity.

The philosophical and axiological principles of natural science are implemented in the educational process in different interpretations of the interdisciplinary plan. In particular, interrelationships are formed in the sectoral dimension of individual sciences or trends in local and regional nature understanding based on worldview beliefs (Zidny & Eilks, 2020). The task of the educational process is to develop a unified global understanding of the patterns and flow of nature and the positioning of humans in this environment.

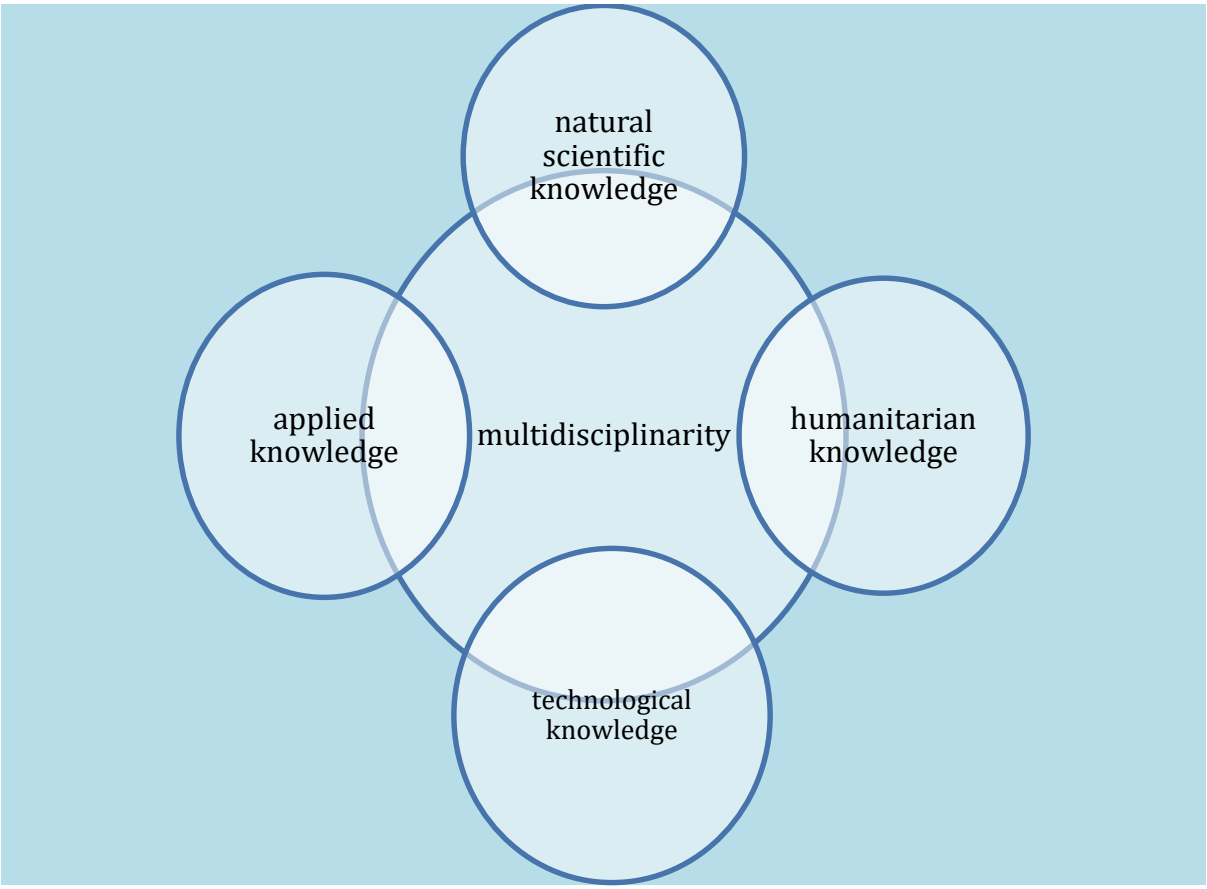
An important philosophical and ideological aspect that is acquired in the study of natural sciences is an understanding of the concept of norm and variability (Zytkowski et al., 2021). This awareness contributes to the formation of a person's system of axiological guidelines and the ability to operate with value elements. Since natural laws are mostly stable, this forms a belief in the existence of fundamental laws (the value dimension of acquired hard-skills). A different approach to the axiological component is characteristic of the social sciences and humanities, where the factor of variability and dynamism dominates (value orientation of soft skills).

STEM education has become a vivid example of reforming educational approaches (Widya et al., 2019). The format in which education focused on the epistemological dimension proved to be imperfect. The modern educational system involves updating not only theoretical and methodological knowledge but also practically oriented skills. STEM education, with its active use of technology, has been the fastest to reorient itself to new realities. At the same time, natural sciences have only just begun transformational processes in their practical and methodological dimension.

The solution that can address this imbalance (or at least reduce the tension between fundamentality and innovation) is centered on the integrative dimensions of modern natural science and its entry into interdisciplinary discourse (see Figure 2).

Figure 2

Synergistic philosophical and educational approach in building a holistic scientific picture of the world



Source: author (s) own development

The main problematic issue of the current scientific and educational space is the assessment of human destruction of biophysical boundaries, which are treated as inviolable in classical natural science (Wolff et al., 2020). Education is in a state of uncertainty:

• on the one hand, the educational system focuses on strict adherence to the norms of natural laws and emphasizes the need for harmonious coexistence with the outside world;

• on the other hand, the processes associated with the rapid development of technology destroy the balance in the coexistence of man and nature, and education acts as a translator of these innovative technological transformations.

Discussion

Informatization of education is actually an ideal tool for achieving an interdisciplinary effect in educational activities (Fedorenko et al., 2019). At the same time, such activity causes many methodological contradictions. When considering the natural sciences or humanities separately, the usual methodological paradigm is relevant. However, when these scientific clusters are combined, the

traditional model of research or study does not apply. It is noted that changes are foreseen not only in the epistemological philosophical dimension but also in the organization of natural science research (Hassard & Cox, 2019). The information component is certainly important in the process of studying or mastering the natural sciences. This element might be sufficient for methodological support of natural science as rationalistic knowledge. However, we should not ignore the presence of a large share of empirical elements in natural science knowledge. This increases the weight and deepens the status of the epistemological component in natural science. The available information and rationalistic methods of its assimilation and implementation as knowledge are not enough, since empirically oriented epistemological research activity is becoming more and more relevant in natural science knowledge.

The natural science cluster lags hopelessly behind the technological sciences in terms of innovation, and the palm in existential dimensions is being taken back by the human dimension with its various humanitarian-oriented practices. The paradoxical situation of the natural sciences is also that they are unable to go beyond their own disciplinary boundaries.

Under such conditions, the dynamism of information and digital technologies, which are not stable and linear means in the educational sphere, comes in handy. The process of comprehending natural science knowledge through information and digital technologies also faces challenges. Digital potential management (management of learning objects or modeling) has its own specifics, which requires not only technological competencies but also methodological developments for this process (Poultsakis et al., 2021). At the same time, Ketelhut et al. (2020) note that we are at the initial stage of understanding the use of ICT in the development of various disciplines.

This means that the scientific and educational community does not have a complete picture of the potential of ICT in the natural science cluster. Hence, contradictions arise, because on the one hand, the scale of technology use exceeds all norms and expectations, and on the other hand, there is no understanding of the systematic nature of this process. That is, practical expediency prevails over the intended purpose. Philosophical reflection has always tried to deny this approach, believing that a balance should be maintained between the process and values.

However, an excessive focus on ICT or interdisciplinary methodology in the study of science is not a panacea in terms of organizational and methodological issues. In the modern educational space, direct teaching is being replaced by contextual learning (Pleasants & Olson, 2019). Such realities pose certain threats to the natural sciences. Contextual learning is focused on strengthening epistemological and axiological elements while leveling certain methodological guidelines that structure knowledge. While this does not pose a threat to the humanities, and technological sciences can compensate for this with information and communication tools, the natural sciences risk losing their integrity.

Integrated learning will help to avoid the risks of imbalance between key philosophical and scientific principles (Asrizal et al., 2019). This type of organization of the educational process involves preserving the fundamentality of knowledge (which is a prerequisite for the natural science cluster, since natural laws cannot have different interpretations) and the formation of flexible skills (which is inherent in the modern socio-cultural space, which requires knowledge to be applied not only in narrowly specialized formats but also in the generally accepted sense).

Conclusions and Implications

Thus, the teaching of natural sciences in the modern educational system requires transformations and new approaches initiated by combining the efforts of the philosophy of education, philosophy of science, and philosophy of nature:

- The philosophy of science considers natural science as a continuation of natural science discourse in the educational sphere and provides for the observance of all fundamental principles of studying the laws of nature to form a common worldview understanding of life and the world order for all participants in the educational process and high-quality highly specialized knowledge and skills in the study of individual natural sciences.
- the philosophy of education considers the educational process as an actual environment for the transmission of natural knowledge and establishes methodological principles that will allow the teaching of natural science at all levels of education to meet the criteria of the general scientific rationalistic and empirical paradigm.
- philosophy of nature involves the development of evolutionary and naturalistic concepts in the scientific dimension with their subsequent introduction into the educational system for further consideration as teaching guidelines.
- the natural sciences need to be correlated with other components - the humanities, social sciences, and technology. If earlier natural science retained a certain autonomy in the structure of the sciences, this positioning has changed, since in today's globalized dynamic world it is almost impossible to do without taking into account humanistic principles or innovative technological practices. If for philosophical ontology the preservation of detachment and distancing of the natural sciences is still acceptable, then the philosophical and epistemological and philosophical and axiological aspects of natural science in education depend on integrative processes.
- the formation (general) and actualization (subject-situational) of thinking activity is formed through the study and awareness of various knowledge, including the laws of nature.
- traditionally, education has had the prerequisites for natural science knowledge to focus on object-action thinking. At the same time, integration processes in the scientific paradigm have contributed to the influence of natural science on other types of thinking activity: verbal and logical, symbolic and abstract, and visual and figurative. The actualization of various thinking potential in the development and use of innovative rationalistic and empirical methodological approaches is also noted.
- the key methodological and epistemological mechanism for teaching natural sciences in the modern educational paradigm is interdisciplinarity. The use of various methodologies of cognitive activity will not change the laws of natural existence, but it has every opportunity to transform the perception of natural knowledge both in the general scientific sense (in the formation of general ideas about nature) and in the highly specialized sense (in the formation of natural science competencies).
- the integration of knowledge is in fact the leitmotif of modern education, science, and philosophy. Natural sciences are gaining new synergistic interactions with socio-humanitarian or technological knowledge.

References

Akgun, S., & Kaya, E. (2020). How Do University Students Perceive the Nature of Science? Science & Education, 29, 299–330. https://doi.org/10.1007/s11191-020-00105-x

Alimjonova, G. (2021). Modern competencies in the techno-culture of future technical specialists. Current research journal of pedagogics, 2(06), 78–84. https://doi.org/10.37547/pedagogy-crjp-02-06-16

Arici, F., Yildirim, P., Caliklar, S., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. Computers & Education, 142, 103647. https://doi.org/10.1016/j.compedu.2019.103647

Asmara, J., Masitoh, S., & Nursalim, M. (2022). Development Of Learning Media For The Formation Of Characteristics Based On The Philosophy Of Science. Cendikia: Media Jurnal Ilmiah Pendidikan, 13(1), 182–187. Retrieved from http://iocscience.org/ejournal/index.php/Cendikia/article/view/2990

Asrizal, A., Amran, A., Ananda, A., & Festiyed, F. (2019). Effects of instructional material of natural science with literacy skills of our respiratory and excretory health theme on academic achievement of students. Journal of Physics: Conference Series, 1317, 012174. https://doi.org/10.1088/1742-6596/1317/1/012174

Budiastra, A. A. K., Wicaksono, I., & Sanjaya, I. G. (2020). The New Generation Self-Directed Teaching Materials of Natural Science in Elementary Schools Validity Tests. International Journal of Instruction, 13(4), 763–780. https://doi.org/10.29333/iji.2020.13447a

Braund, M., & Reiss, M. J. (2019). The Great Divide: How the Arts Contribute to Science and Science Education. Canadian Journal of Science, Mathematics and Technology Education, 19, 219–236. https://doi.org/10.1007

Castro, N., & Siew, C. (2020). Contributions of modern network science to the cognitive sciences: revisiting research spirals of representation and process. Proceedings of the Royal Society, 476, 20190825. http://doi.org/10.1098/rspa.2019.0825

Chan, K. K. H., & Hume, A. (2019). Towards a Consensus Model: Literature Review of How Science Teachers' Pedagogical Content Knowledge Is Investigated in Empirical Studies. In Hume, A., Cooper, R., Borowski, A. (Eds.), Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science (pp. 3–76). Springer, Singapore. https://doi.org/10.1007/978-981-13-5898-2_1

Doyan, A., Susilawati, S., & Hardiyansyah, H. (2020). Development of Natural Science Learning Tools with Guided Inquiry Model Assisted by Real Media to Improve Students' Scientific Creativity and Science Process Skills. Jurnal Penelitian Pendidikan IPA, 7(1), 15–20. https://doi.org/10.29303/jppipa.v7i1.485

Fedorenko, E., Velychko, V., Stopkin, A., Chorna, A., & Soloviev, V. (2019). Informatization of education as a pledge of the existence and development of a modern higher education. Higher and secondary school pedagogy, 52, 5–21. https://doi.org/10.31812/pedag.v52i0.3773

Feser, E. (2019). Aristotle's Revenge: The Metaphysical Foundations of Physical and Biological Science. Editiones Scholasticae, 515. Retrieved from: https://isidore.co/CalibreLibrary/Feser,%20Edward/Aristotle's%20Revenge_%20The%20Metaphysical%20Foundations%20of%20Physical%20and%20Biological%20Science%20(6971)/Aristotle's%20Revenge_%20The%20Metaphysical%20Foun%20-%20Feser,%20Edward.pdf

Gunton, R. M., Stafleu, M. D., & Reiss, M. J. (2022). A General Theory of Objectivity: Contributions from the Reformational Philosophy Tradition. Foundations of Science, 27, 941–955. https://doi.org/10.1007/s10699-021-09809-x

Haig, B. D. (2020). Big data science: A philosophy of science perspective. In Woo, S. E., Tay, L., Proctor, R. (Eds.), Big data in psychological research (pp. 15–33). American Psychological Association. https://doi.org/10.1037/0000193-002

Hassard, J., & Cox, J. W. (2019). Philosophy of Science, Social Theory, and Organizational Analysis: Paradigmatic Transformations since the Postmodern Turn. In Boje, D. M., Sanchez, M. (Eds.), The Emerald Handbook of Management and Organization Inquiry (pp. 207–227). Emerald Publishing Limited, Bingley. https://doi.org/10.1108/978-1-78714-551-120191013

Hayati, N., & Berlianti, N. A. (2020). Critical thinking skills of natural science undergraduate students on biology subject: Gender perspective. JPBI (Jurnal Pendidikan Biologi Indonesia), 6(1), 83–90. https://doi.org/https://doi.org/10.22219/jpbi.v6i1.11150

Ichsan, I. Z. (2019). ILMIZI: Innovation Learning Model for Natural Science and Environmental Learning based on HOTS. International Journal for Educational and Vocational Studies, 1(6), 578–584. https://doi.org/10.29103/ijevs.v1i6.1640

Janev, I. (2020). General Philosophy of Relationism and Its Application to the Political Theory of State and Society and Implications on Natural Sciences. Philosophy Study, 10(8), 455–471. https://doi.org/10.17265/2159-5313/2020.08.001

Ketelhut, D. J., Mills, K., Hestness, E., Cabrera, L., Plane, J., & McGinnis, J. R. (2020). Teacher Change Following a Professional Development Experience in Integrating Computational Thinking into Elementary Science. Journal of Science Education and Technology, 29, 174–188. https://doi.org/10.1007/s10956-019-09798-4

Kirchhoff, T. (2019). Abandoning the Concept of Cultural Ecosystem Services, or Against Natural–Scientific Imperialism. BioScience, 69(3), 220–227. https://doi.org/10.1093/biosci/biz007

Kizi, T. M. A. (2021). Teaching natural sciences and English language on the basis of integrative approach in higher education. Asian Journal of Multidimensional Research (AJMR), 10(1), 126–129. http://doi.org/10.5958/2278-4853.2021.00005.7

Koyuncuoglu, Ö. (2021). An Investigation of Graduate Students' Technological Pedagogical and Content Knowledge (TPACK). International Journal of Education in Mathematics, Science and Technology, 9(2), 299–313. https://doi.org/10.46328/ijemst.1446

Król, Z. (2019). Category Theory and Philosophy. In Kuś, M., Skowron, B. (Eds.), Category Theory in Physics, Mathematics, and Philosophy (pp. 21–32). Springer, Cham. https://doi.org/10.1007/978-3-030-30896-4_2

Kuś, M., Skowron, B., & Wójtowicz, K. (2019). Why Categories? In Kuś, M., Skowron, B. (Eds.), Category Theory in Physics, Mathematics, and Philosophy (pp. 1–19). Springer, Cham. https://doi.org/10.1007/978-3-030-30896-4_1

Kusumayuni, P. N., & Agung, A. A. G. (2021). E-Book with a Scientific Approach on Natural Science Lesson for Fifth Grade Students of Elementary School. Jurnal Ilmiah Sekolah Dasar, 5(1), 177–185. https://doi.org/10.23887/jisd.v5i1.32048

Leasa, M., Corebima, A. D., & Batlolona, J. R. (2020). The effect of learning styles on the critical thinking skills in natural science learning of elementary school students. Ilkogretim Online – Elementary Education Online, 19(4), 2086–2097. https://doi.org/10.17051/ilkonline.2020.763449

Lemos, N. (2020). Common Sense, Philosophy and Science. In Peels, R., de Ridder, J., van Woudenberg, R. (Eds.), Scientific Challenges to Common Sense Philosophy. https: //doi.org/10.4324/9781351064224

Mohan, A., & Kelly, G. J. (2020). Nature of Science and Nature of Scientists. Science & Education, 29, 1097–1116. https://doi.org/10.1007/s11191-020-00158-y

Nkanyani, T. E., & Mudau, A. V. (2019). Natural Sciences Teachers‟ Experiences on Teaching Planet Earth and Beyond Knowledge Strand. Journal of Turkish Science Education, 16 (4), 478–488. https://doi.org/10.36681/tused.2020.2

Page, S., & Rider, C. (2019). The Routledge History of Medieval Magic (1st ed.). Routledge. https://doi.org/10.4324/9781315613192

Pleasants, J., & Olson, J. K. (2019). What is engineering? Elaborating the nature of engineering for K-12 education. Science Education, 103, 145–166. https://doi.org/10.1002/sce.21483

Poultsakis, S., Papadakis, S., Kalogiannakis, M., & Psycharis, S. (2021). The management of Digital Learning Objects of Natural Sciences and Digital Experiment Simulation Tools by teachers. Advances in Mobile Learning Educational Research, 1(2), 58–71. https://doi.org/10.25082/AMLER.2021.02.002

Reyes, A.-E., & Dueñas, J.-M. (2021). Medicinal gardens as an educational strategy in the teaching of the natural sciences: A pedagogical proposal. Research in Social Sciences and Technology, 6(1), 25–39. https://doi.org/10.46303/ressat.2021.2

Robinson, B., Gonnerman, C., & O'Rourke, M. (2019). Experimental Philosophy of Science and Philosophical Differences across the Sciences. Philosophy of Science, 86(3), 551–576. https://doi.org/10.1086/703553

Romero, F. (2019). Philosophy of science and the replicability crisis. Philosophy Compass, 14, e12633. https://doi.org/10.1111/phc3.12633

Rybalko, L., Topuzov, O., & Velychko, L. (2020). Natural science education concept for sustainable development. E3S Web of Conferences, 166, 10030. https://doi.org/10.1051/e3sconf/202016610030

Salam, M., Awang Iskandar, D. N., Ibrahim, D. H. A., & Farooq, M. S. (2019). Service learning in higher education: a systematic literature review. Asia Pacific Education Review, 20, 573–593. https://doi.org/10.1007/s12564-019-09580-6

Simons, M., & Vagelli, M. (2021). Were experiments ever neglected? Ian Hacking and the history of the philosophy of experiments. Philosophical Inquiries, 9(1). https://doi.org/10.4454/philinq.v9i1.339

Syafrial, Ashadi, Saputro, S., & Sarwanto, S. (2022). Trend creative thinking perception of students in learning natural science: Gender and domicile perspective. International Journal of Instruction, 15(1), 701–716. https://doi.org/10.29333/iji.2022.15140a

Usmeldi, U., & Amini, R. (2022). The effect of integrated learning model to the students competency on the natural science. Journal of Physics: Conference Series, 1157(2), https://doi.org/10.1088/1742-6596/1157/2/022022

Widya, Rifandi, R., & Rahmi, Y. L. (2019). STEM education to fulfil the 21st century demand: a literature review. Journal of Physics: Conference Series, 1317, 012208. https://doi.org/10.1088/1742-6596/1317/1/012208

Wilujeng, I., Zuhdan, K. P., & Suryadarma, I. (2018). Integrating Local Wisdom in Natural Science Learning. Advances in Social Science, Education and Humanities Research, 178, 182–186. https://doi.org/10.2991/icoie-18.2019.42

Wolff, L.-A., Skarstein, T. H., & Skarstein, F. (2020). The Mission of Early Childhood Education in the Anthropocene. Education Sciences, 10(2), 27. https://doi.org/10.3390/educsci10020027

Wójtowicz, K. (2019). Are There Category-Theoretical Explanations of Physical Phenomena? In Kuś, M., Skowron, B. (Eds.), Category Theory in Physics, Mathematics, and Philosophy (pp. 33–43). Springer, Cham. https://doi.org/10.1007/978-3-030-30896-4_3

Zidny, R., & Eilks, I. (2020). Integrating perspectives from indigenous knowledge and Western science in secondary and higher chemistry learning to contribute to sustainability education. Sustainable Chemistry and Pharmacy, 16, 100229. https://doi.org/10.1016/j.scp.2020.100229

Zytkowski, A., Shane Tubbs, R., Iwanaga, J., Clarke, E., Polguj, M., & Wysiadecki, G. (2021). Anatomical normality and variability: Historical perspective and methodological considerations. Translational Research in Anatomy, 23, 100105. https://doi.org/10.1016/j.tria.2020.100105