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Philosophical Bases of Science Education Concept: History and Modern Developments

[Filozoficzne podstawy koncepcji naukowej edukacji: historia i współczesność]

Streszczenie: Autorzy analizują filozoficzne podstawy odnoszące się do opracowania koncepcji naukowej edukacji z uwzględnieniem retrospektywy historycznej i współczesnych osiągnięć badawczych. Badanie jest zatem próbą kompleksowego oglądu aspektów wielowektorowej koncepcji naukowej edukacji oraz różnorodności podejść, zmierzających do opracowania tejże koncepcji. Edukację naukową analizuje się poprzez pryzmat rozwoju wartości i środki demokracji. Ponadto podkreślono znaczącą rolę i miejsce naukowej edukacji w rozwijaniu odpowiedzialnego obywatelstwa.

Summary: This article is devoted to the analysis of philosophical bases for developing science education concept taking into account historical retrospective and modern research achievements. The inquiry is one of a comprehensive attempt to analyze the range of philosophical and pedagogical aspects of the multifaceted concept of science education, the diversity of approaches to elaborate science education concept as a case of philosophical analysis, and the axiological aspects of science education through the prism of developing values and means of democracy. The role and place of science education in developing responsible citizenship are examined.

Słowa kluczowe: naukowa edukacja; filozofia; koncepcja naukowej edukacji; demokracja; odpowiedzialne obywatelstwo.

Keywords: education; philosophy; science education concept; democracy; responsible citizenship.

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Introduction

Today the global society is experiencing complex processes of transformation of social architecture, which raise the issue of developing new generations of responsible citizens who understand the importance of science and technology in modernity and the future. These challenges and changes have reflected in the educational system (Marcelo C., 2002), which is becoming ever more contradictive, complex, and heterogeneous, as are the students themselves and the social system in which the educational system is a part (Schulz R., 2014). At the forefront of the global agenda are issues of knowledge, technology, and innovation, and the success of certain economies in their production will depend on their place and role in creating Economy 4.0. The global situation with transit towards the new economic system has been exacerbated since 2020 by the challenges of the COVID-19 pandemic. Along with the economic recession, the pandemic challenges have raised the issue of responsible citizenship for the future of humanity, and science education occupies a special place in this process. A strong science education system is a prerequisite for a knowledge-based and innovation-based economy that promotes greater citizen participation in knowledge-based innovation and meets the highest ethical standards, helping ensure sustainable development in the future.

The relevance of the paradigm of science education provokes new debates about its philosophical foundations, exploring the peculiarities of progress in the field since antiquity and proposing new projects to develop the concept of science education, given the challenges and requirements of today. The process is complicated by multifaceted and multilevel phenomenon of scientific education, which is the interaction of inquiries on science content, science process, and teaching pedagogy. However, this complexity gives a broad space for the philosophical elaboration of the issue, an attempt to conduct which was made by the authors of this article.

The multifaceted concept of science education: philosophical and pedagogical aspects

Science education has multiple goals. It should aim to develop an understanding of a set of big ideas in science which include ideas of science and ideas about science and its role in society; scientific capabilities concerned with gathering and using evidence; scientific attitudes (Harlen W., 2010, 2015).

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Science education aims systematically to develop and sustain learners' curiosity about the world, enjoyment of a scientific activity, and understanding of how natural phenomena can be explained. The main purpose of science education should be to enable every individual to take an informed part in decisions, and to take appropriate actions, that affect their own well-being and the well-being of society and the environment (Harlen W., 2010, 2015). This multiplicity of goals leads to the certain specific functions and roles, which science education represents in society. Thus, science education is vital (Science education for responsible citizenship, 2015):

– to promote a culture of scientific thinking and inspire citizens to use evidence-based reasoning for decision-making;

– to ensure citizens have the confidence, knowledge, and skills to participate actively in an increasingly complex scientific and technological world;

– to develop the competencies for problem-solving and innovation, as well as analytical and critical thinking that are necessary to empower citizens to lead personally fulfilling, socially responsible, and professionally-engaged lives;

– to inspire children and students of all ages and talents to aspire to careers in science and other occupations and professions that underpin our knowledge and innovation-intensive societies and economies, in which they can be creative and accomplished;

– to empower responsible participation in public science conversations, debates, and decision-making as active engagement of citizens in the big challenges facing humanity today.

However, science education can also be defined as special politics of knowledge, which is caused by changes in the regime of knowledge existing in modern societies. J.-F. Lyotard (1984) draws attention to this in his famous report published under the title The Postmodern Condition (Lyotard J.-F.,1984). The situation of the end of metanarratives, which is diagnosed in it, gives rise to the phenomenon of technological production of knowledge, which itself acquires technological significance (Matusevych T., Shevchuk D., 2022). Today we are experiencing a moment of cultural development that encourages a specific overproduction of knowledge. As a result, we get the separation of intangible values as fundamental values in the culture. Acquiring a global character, this new dimension of the community aims to fulfill the function of the humanization of globalization, which shows its ideological aspect. Based on the latter, a policy is developed that is focused on ensuring "human development", "empowerment", and "ensuring the effective fight against poverty". Since education is

directly related to knowledge institutions that can form and maintain knowledge regimes, it must find a place in this policy aimed at developing a "knowledge society". However, educational policy should avoid excessive ideologizing and technologicalization and, conversely, provide a reflective and critical dimension of knowledge policy (Matusevych T., Shevchuk D., 2022).

Simultaneously, science education is a special education policy that creates a unique system of social meaning. In the world of "post-" (postmodern, post-ideology, post-science, post-politics, etc.), the dominance of nihilism is observed, which leads to the end of meaning. Therefore, an essential principle of educational policy, which focuses on developing science education, should be the search for the translation of meaning means (Matusevych T., Shevchuk D., 2022). Actually, education is a huge translator of meaning: through education in society, the transfer and dissemination of social meaning are occurred (which can be perceived in a broader sense as the social significance of ideas, values, and things), which provides for the stability and continuity of the socio-cultural system. This definition actualizes the reflection on the changes required by modern education, which lead to a different essence of education, instead of translating the meaning; the focus should be on the sense (Matusevych T., Shevchuk D., 2022). As the meaning, essence and senses live in the philosophical realm, thus, the analysis of philosophical bases of science education concept become relevant nowadays.

In this case, the development of a "philosophy of science education," that is, an "in-house philosophy" for the field, could be significant for reforming science education (Schulz R., 2014). Israel Scheffler summarized the value of the "philosophies of" for science educators and outlined four main efforts through which they might contribute to education (Scheffler I., 1970, p. 392):

– the analytical description of forms of thought represented by teaching subjects;

– the evaluation and criticism of such forms of thought;

– the analysis of specific materials so as to systematize and exhibit them as exemplifications of forms of thought;

– the interpretation of particular exemplifications in terms accessible to the novice.

He understood these "philosophies of" would provide invaluable components to a science teacher's identity and preparation, in addition to the common three: subject matter competence, practice in teaching, and educational methodology (Schulz R., 2014).

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Science education concept as a case of philosophical analysis: the diversity of approaches

Researching the paradigm of science education, we should note its holistic nature, understanding science education as a cross-cutting approach that covers all levels of education – from preschool, extracurricular, secondary, and higher education to lifelong learning. Simultaneously, there are many approaches to interpreting the philosophical bases of the science education concept.

The first approach to define the concept of science education is based on appealing to philosophical directions and their understanding of the scientific meaning and rationality, their interrelations and contradictions. Such approach normally elaborates the concept of science education through the prism of such philosophies as follows:

– John Dewey's pragmatism, which is considered the origin of the science education paradigm and is based on understanding science as a complex system and a universal tool for ensuring a better future for humankind, having experience as a core term of philosophy (Aleksandrova Y., 2021);

– the rationalist school, which stresses the importance of reason and the concepts created by the mind in the process of forming the foundations of scientific knowledge (Mellado V., 2006);

– classical empiricism, emphasized the justification of knowledge on the basis of data obtained directly from sensory experience, and deals with establishing an inductive scientific method supported on the data of that experience. (Mellado V., 2006);

– constructivism in its manifestations from radicalism to social conditioning as the dominant paradigm or research program of science education, elaborating world and ways of its cognition in their fundamental complexity, rejection of the universality of truth in favor of a pragmatic measure of its effectiveness, and emphasizing causation in a multicomponent world (Aleksandrova Y., 2021);

– postmodernism is a relativistic strategy of cognition, which brings rhizomatic configurations to modern scientific developments, understanding the world around us not as a substantial but as a harmful variable complex of hybrid connections and relations (Aleksandrova Y., 2021).

The second approach is based on revealing the interrelations between philosophical fields and science inquiry (Schulz R., 2014). The main fields that are investigated are ontology and epistemology.

Questions regarding scientific ontology are concerned with ascertaining the status (or validity) of the products of human creativity or

discovery; included are scientific models and theoretical entities (e.g., gene, field, black hole, tectonic plates), evaluated as to their truth (realism) or merely useful (fictive) construct to solve problems and "fit" experimental data (empirical adequacy) (Schulz R., 2014). Scientific epistemology is concerned with describing and ascertaining the nature of both the body of known scientific facts and theories (degree of certainty) and the production of new knowledge (i.e., scientific inquiry) (Schulz R., 2014). Personal epistemologies are commonly taken to include individual beliefs, views, and attitudes about a particular subject; hence, they can be considered a "personal knowledge framework". It has also been historically associated with particular schools of thought (e.g., idealism, rationalism, empiricism, existentialism); hence, particular philosophies which themselves are often associated with individual philosophers (Schulz R., 2014).

Quite another approach to defining the science education concept is based on revealing the interrelation of the philosophy of science and science education. There have been numerous lines of research relating the philosophy of science to science teaching. Aduriz-Bravo (2001) groups these relationships into seven classes. Two of them refer to the objects of study shared by the two disciplines – the epistemological foundation of erudite science, and the epistemological foundation of school-level science. The other five refer to the relative positions taken by educational and philosophical metadiscourse (Mellado V. et al., 2006).

Also, the attempts of elaborating the special philosophy of science education were made. Shulz notes that the "philosophy of science education" (PSE) can be understood as the intersection or synthesis of (at least) three academic fields. With this project, he draws attention to two useful aspects pertaining to philosophy in general which can come to aid and contribute to improving science education and developing such a philosophical perspective: the ability of philosophy to provide a synthesis of ideas taken from associated disciplines with their major educational implications and providing what can be called "philosophies of" (Schulz R., 2014)

The axiological aspects of science education: developing values and means of democracy

Examining the diverse nature of the phenomenon of science education, it is important to consider its axiological characteristics, namely the relationship with democracy. The study of this question has long roots, finding a systematic reflection in the work of Dewey: "Dewey recognized these as problems, and Democracy and Education make it clear that

democracy is the key to progress; it is impossible to create a science of education – or grow as people and as a society – without democracy. Just as Dewey warns that the "exceptional teacher" paradigm stands in the way of progress, so too do top-down, non-collaborative approaches to improving teaching. Teaching will not improve without the presence of a strong democracy." (Frank J., 2017, p. 5)

The multifaceted and multidimensional conceptualization of the phenomenon of democracy also needs a separate understanding, as the phenomenon of democracy goes far beyond the formal political system. This is, first of all, a way to get involved in public life, communication, and experience (Carr P., 2010).

Democracy and science, according to a number of researchers, share several basic characteristics like critical thinking, public discourse, open debate, free flow of information, mutual respect, and the critical role of inquiry and evidence (Wistrøm Ø., Madsen J., 2018). Science education is principal in preparing young people to become responsible citizens and be able to contribute fully to the socio-economic development of their societies. Science education promotes responsible citizenship by developing scientific literacy and scientific style of thinking, critical thinking, and personal and public decision-making skills in the 21st century. A strong science education system is a prerequisite to having an economy based on knowledge and innovation (Gluckman, 2011). Science education equips citizens, enterprises, and industries with the skills and competencies needed to provide sustainable and competitive solutions to modern challenges. More responsive science education can promote broader participation in knowledge-based innovation that meets the highest ethical standards and helps ensure sustainable societies in the future (Science education for responsible citizenship, 2015).

The paramount importance of developing a solid system of science education for responsible citizenship in pandemic times leads researchers to consider the potential of *civic science education* (CSE), which includes experiences that have been intentionally designed to foster or enhance individuals' interactions with and/or engagement in science-related public matters and include three sub-categories: foundational, exploratory, and purposefully active. Researchers argue that enacting CSE could help to support students' science learning and civic engagement and also strengthen civil society and that CSE could motivate students both to learn science and become engaged in civic issues (Levy B. et al., 2021).

In present times, there are several dominant directions/objectives in developing science education for responsible citizenship (Science education for responsible citizenship, 2015):

1. An expanded understanding of science education that goes far beyond STEM education or education that prepares for scientific activity, considering science education as an educational paradigm that should develop a scientific style of reasoning.

2. Science education should be an essential component of a learning continuum for all, from preschool to actively engaged citizenship.

3. Science education should focus on competencies with an emphasis on learning through science and shifting from STEM to STEAM by linking science with other subjects and disciplines.

4. The quality of teaching, teacher induction, pre-service preparation, and in-service professional development should be enhanced to improve the depth and quality of learning outcomes.

5. Collaboration between formal, non-formal, and informal educational providers, enterprise, industry, and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase uptake of science studies and science-based careers and employability and competitiveness.

6. Greater attention should be given to promoting Responsible Research and Innovation and enhancing public understanding of scientific findings and the capabilities to discuss their benefits and consequences.

7. Emphasis should be placed on connecting innovation and science education strategies at local, regional, national, European, and international levels, considering societal needs and global developments.

8. Shifting from content learning to inquiry-based, problem-oriented, and project-based

Science education research, innovation and practices must become more responsive to the needs and ambitions of society and reflect its values.

Conclusions

Summarizing the above, it should be noted that the development of science education as a research concept and educational paradigm is a multilevel and multifaceted phenomenon, the formation of which contributes to the overall progress of society, and ensures citizen participation in socio-political life, democratic policies, and institutions. Currently, the development of the concept of science education is taking place in a complex process of transformation of social architecture, which raises the issue of developing new generations of responsible citizens who understand the importance of science and technology in modernity and the future.

This multiplicity of science education goals leads to the specific functions and roles that science education represents in society. At the same time, science education implements its holistic nature through a cross-cutting approach that covers all levels of education – from preschool, extracurricular, secondary, and higher education to lifelong learning.

Certain methodological ambiguity provokes the development of a significant number of approaches to interpreting the philosophical grounds of the science education concept, starting from appealing to philosophical directions and their consideration of the scientific meaning and rationality, their interrelations and contradictions to the elaboration of in-house philosophy of science education. However, this complexity gives a broad space for the philosophical elaboration of the issue and provokes future philosophical inquiries and educational research.

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