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PHILOSOPHICAL UNDERPINNINGS OF TEACHING SCIENCE THROUGH INQUIRY-BASED APPROACH

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The drive to resolve perplexing states of affairs is a natural trait of the human cognitive makeup. As a result, most of the philosophical systems and schools of thought see their task both in formulating remarkably complex issues and in coming up with solutions (answers) to such pressing conundrums as the nature of reality, existing ways to its perceiving and the way our activities interact within this reality. Accordingly, the authors of this article consider the aim of the cyrrent study in elaborating some of the interconnected (philosophical and other) notions of a problem-based teaching methodology which presents a fresh alternative to more perennial, didactic modes of obtaining information and forming knowledge. The latter, in our opinion, proves to be counterproductive to the genuinely Socratic method at the heart of the educational process. In particular, in contrast to predominantly mechanical fact-based accumulation and transmission prevalent in conservative teaching methodology, inquiry-based education provides the necessary means to achieve a beneficial functional dialectic allowing students to combine guided instruction with self-actualization. Thus, when properly executed problem-based learning directs instructor's activities towards a curriculum presenting a number of issue-based assisted learning schemes, cultivating an active knowledge acquisition attitude whereby students are required to analyze the problem at hand and come up with effective ways to solve it independently and interacting together in a group. The authors are deeply convinced that the implementation and targeted use of equivalent and other similar strategies in the educational process has a number of significant advantages over more conservative teaching methods. In particular, within the critical research paradigm, students are able to acquire not just thematic (subject-relevant) knowledge but (an most importantly) habituated educational skills and constantly evolving learning competencies.

Key words: *science education, constructivism, inquiry-based learning, interactive pedagogics, critical thinking*

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ФІЛОСОФСЬКІ ЗАСАДИ НАУКОВОГО НАВЧАННЯ ЗА ДОПОМОГОЮ ДОСЛІДНОГО ПІДХОДУ

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Потяг до розв'язання проблемного положення речей - це природна риса людської пізнавальної складової. Як наслідок, більшість філософських систем і шкіл, бачать власне завдання як у формулюванні особливо складних питань, так і в тому, щоб надати розв'язання (відповіді) таких наріжних загадок як характер реальності, які способи її сприйняття існують і, як наша діяльність взаємопов'язана в рамках цієї реальності. Відповідно, автори даної статті розглядають мету поточного досліду в роз'ясненні ряду взаємозалежних (філософських та інших) аспектів методології викладання заснованої на проблемному підході, що слугує альтернативою більш традиційним, дидактичним способам отримання інформації та формування знань. Останні, на нашу думку, часто виявляються контрпродуктивними щодо дійсно Сократичного методу, що лежить в основі як конвенційних, так і прогресивних освітніх підходів. Зокрема, на відміну від переважно механічного накопичення та поширення, що переважають у методології консервативної освіти, навчання, засноване на дослідженні, забезпечує необхідні засоби для досягнення плідної функціональної педагогічної діалектики, що дозволяє учням об'єднати кваліфікований інструктаж викладача з поглибленою самореалізацією. Таким чином, при правильному підході метод навчання шляхом відкриття допомагає педагогу домогтися вироблення навчального плану, який містить комплекс завдань, що базуються на реальних проблемних ситуаціях, культивує підхід до активного нарощування знань, коли від студентів вимагається проаналізувавши актуальну проблему розробити ефективні шляхи її вирішення, як самостійно, так і взаємодіючи спільно в групі. Автори глибоко переконані, що впровадження і цільове використання подібних і інших схожих стратегій в рамках освітнього процесу, має ряд виражених переваг в порівнянні з більш консервативними методиками навчання. Зокрема, в рамках критично-дослідної парадигми учні здатні збагатити не тільки тематичні (предметні) знання, але, (що і є відмінною рисоюз прагматичної точки зору) укоренити пізнавальні навички та прагнення до нарощування постійно удосконалюючихся навчальних компетенцій.

Ключові слова:*філософія наукової освіти, конструктивізм, навчання шляхом відкриття,інтерактивна педагогіка, критичне мислення.*

Introduction. The ever-widening gap between the so-called fundamental, cutting-edge science and the way it is being taught calls for close attention from science educators at all levels of academia: from elementary school to post-graduate programs. Indeed, if we are to effectively combat and successfully remedy the chasm between the way practicing scientists operate in their respective fields and the overwhelming majority of caricatures and misrepresentations of the scientific method prevalent in the curriculums of Ukrainian schools and universities, our teaching mentality and methodology will have to drastically transform. Diagnosed as far back as 1970 as a pronounced degradation of science education the urgency to reform outmoded, overly romanticized Enlightenment Age stereotypes of the scientific worldview is even more of a pressing task almost 52 years later. In light of this, it is important to note that the particular curriculum alterations do not solely have to do with supplanting the previously predominantly objectivistic subject-neutral way of doing and teaching science giving due credit to the humanistic and anthropological aspects of science education.

At the same time, such anthropocentric educational perspective (shaping and determining the student's inner development) cannot be solely associated with the emphasis on a relativistic, humanities-oriented

perspective, but ought to be formed combining the idea of nature and culture [10]. Therefore, we strongly believe that a genuinely universal educational perspective should be based on establishing a dialogue between the scientific and more humanitarian forms of social knowledge facilitation, shaping in this way a new eclectic pedagogical paradigm whose task is to produce professionally and vocationally well-equipped, intellectually all-rounded individuals.

Level of scientific development. As a pedagogical philosophy inquiry-based learning originated in the 1960s as part of the discovery learning movement. From the very beginning, its proponents positioned it as an alternative to the more traditional forms of teaching (i.e. direct instruction and rote training) which relied primarily on memorization and reproduction of knowledge from established sources of legitimized expertise and wisdom [1]. Much inspired by the critical reevaluation of the scientific endeavor and method by Imre Lakatos, Thomas Kuhn and Karl Popper, the constructivist philosophical basis traces its origin to the works of such renowned figures as John Dewey, Jean Piaget, Paolo Freire, and Lev Vigotsky among others [4].

Following the development of the constructivist ideology Joseph Schwab, encouraged learners to form and indulge in their personal academic preferences, criticized undergraduate education as a compendium of ready-made approaches, argued against outmoded, stagnant rhetoric of conclusions urging students to extend their academic interests beyond their assigned field of competence believing liberal arts to be a particularly helpful resource at that.

Schwab's demarcation of inquiry-based pursuits into three distinct levels was formalized by Marshall Herron in 1971, who developed the Herron Scale in order to assess the amount and level of inquiry-based and problem-solving engagement within a particular laboratory setting and/or exercise [4]. Subsequently, following this renewed interest in the benefits of constructivist educational philosophy, the field of alternative pedagogics has witnessed a proliferation of assisted exploratory knowledge acquisition methodologies.

Research objective. The scope of our present research explicated in this article hardly allows us to give full credit to the multifaced nature of the inquiry-based philosophy of education. We, therefore, would like to limit ourselves to briefly sketching some of the major threads surrounding the less controversial aspects of this notion. Specifically, the authors wish to elucidate the fact that when thoroughly scrutinized constructivism as an underlying philosophical foundation for problem-based teaching does not appear as a unified system of ideas, but, in fact, has many representatives (Dewey, Vigotsky, Piaget, Freire) whose ideas (though possessing a dominant common theme), nonetheless, differ in many respects, often deal with divergent subject matter and might appear wholly incompatible when applied to different aspects of the problem-based approach.

Discussion and results. When addressing particular philosophical foundations buttressing the scientific enterprise, several theoretical frameworks frequently get mentioned. In particular, one of the principal approaches (which oddly enough does not get its full credit) fueling the investigative strand of science education is constructivism. As a knowledge acquisition theory, it views learners as active participants taking an utmost active role in the creation and (re)design of knowledge, acquiring, deciphering and filtering the information they receive. Hence, constructivist educational philosophy perceives learning as an interactive process whereby learners independently or through a joint collaborative experience deliberate on

and attempt to design and reconstruct a shared pool of knowledge and meaning.

Accordingly, the primary objective that this method seeks to inculcate in students is to broaden their outlook on the multitude (didactic and alternative) of ways one can gather and interpret information, arrive (teacher-assisted and autonomous) at conclusions regarding a particular research status quo in question regardless of whether it reflects the actual state of affairs or not. In other words, the thing that separates constructivist methodology from a host of more conventional approaches is a special emphasis put on the task of personal (self)discovery (echoing the Socratic "know thyself" maxim) as well as the practical, process-oriented model of utilizing information which stands in sharp opposition to outdated fact-based schooling and instruction presupposing passive compiling and regurgitation [7: 8].

A rather generalized estimate presents us with four roughly outlined levels (or stages) of inquiry-based teaching. The first stage is congruent with what is known as the standard (closed) model of imparting material which is still considered the bedrock of classical education. In particular, it is characterized by viewing the teacher as an authority figure who imparts information to students pertaining to a specific topic which is then reinforced through a series of exercises designed to imprint the main theme and general content of the material being presented [10: 25, 58]. As a result, at this level students are taught to follow learning objectives, re(collect) data, and perform semi-mechanical knowledge generation procedures. Unlike, its previous form the second tier of problem learning requires students to perform their own assessment of the findings and results they arrive at with the teacher beginning to play the role of an active facilitator as opposed to the passive instructor. In contrast to the preceding two levels, stage three presupposes a specific guided instruction toolset on the part of the teacher who is now responsible for briefly outlining research agendas which are subsequently proposed to students who are fully responsible for arriving at their problem scenario resolutions following a methodology of their choosing and design. The last tier (usually considered as a genuinely open mode of self-education) is characterized by an almost completely unassisted inquiry whereby learners fashion their personal research topic(s), come up with bespoke evaluation techniques and procedures, and communicate jointly or separately achieved research findings [10].

Note, that one usually comes across these types of problem-based learning either as part of the real-life scientific experiments and investigations or encounter it as a result of the exemplary level of science education that occurs among gifted high school and university students who engage in carefully crafted simulations of the scientific method which are often indistinguishable from genuine professional lab practice [2: 504]. It is interesting to point out how some of the later stages of the inquiry-based approach presented in the previous paragraph (especially when one considers the kind of education future scientists receive) echo related ideas of the American philosopher and educator John Dewey, who criticized the fact that science education was not taught in a manner that assisted the proper training of young scientists, critically-minded intellectuals and citizens.

By underscoring the active component whereby the scientific method is perceived not as a solidified body of established unquestionable truths, Dewey, instead put forward a radical idea of teaching science as an ongoing activity and way of pragmatically relating to external reality and circumstances rather than approaching it as immutable baggage of facts that must be revered and uncritically committed to

memory. Although Dewey's insistence on overhauling the principal tenets undergirding scientific inquiry and education was one of the first attempts in the early 1910s and 1920s which served as an important precursor to the constructivist movement of the second half of the twentieth century, much of the more tangible amendments (especially within U.S. educational system) came as a result of the legacy of Joseph Schwab's reformist efforts.

As an educator inspired by the Dewian anti-traditionalist sentiment, Schwab maintained that the method of science and its teaching need not necessarily rest on mapping out a fact-based topology of the external world, but should be approached as a flexible multi-directional inquiry providing motivation and inspiration for further exploration and self-betterment (much akin to the difference between a static photograph and a dynamic movie). Consequently, he thought that classroom science education ought to follow the principles and be modeled on the method employed by practicing scientists, thereby experiencing alterations and revisions in light of new data and findings. To better reinforce his theory Schwab came up with three consecutive degrees of problem-solving closely mirroring the investigative strategies used by specialists in various scientific fields of inquiry [13: 99].

Again, if properly interpreted, we are presented with a progressively scaffolding system of incrementally increasing learning competencies. Thus, initially, all that is asked of the class is that they (collectively or individually) come up with a pattern of connection between various research variables by utilizing particular study techniques, methods, and materials provided by the instructor (fully-assisted learning). The next stage (semi-assisted learning), again, presupposes students being assigned their respective research agendas, however, this time all of the investigative tools and means have to be arrived at through personal (or group) autodidactic inquiry and exploration. Finally, when engaging in problem-solving at the highest level of fully-autonomous learning, students are presented with a minimal amount of data regarding a potential research agenda and are encouraged to fashion their own tools and ways to discover the specifics of the state of affairs in question [4]. This specifically constructivist bent is reinforced by the fact that knowledge acquisition and interpretation is considered one of the principal activities of the learning individual whose educational activity is always inadvertently immersed in and is shaped by the shared communal and/or social experience.

Another relevant insight comes from Lev Vygotsky who was convinced that students' everyday activities and concepts must serve as a necessary, natural gateway to acquiring a proper scientific worldview allowing them to perceive and deliberate on the surrounding phenomena with ease and clarity. By engaging learners in inquisitive tasks that take advantage of their familiarity with mundane conceptual basis, Vygotsky sought to help crystalize scientific modes of inquiry, believing that dissecting the world in terms of concepts must come before analyzing the conceptual apparatus which permits us to do so. Accordingly, he made a tri-fold distinction between a. "concepts-in-themselves" representing an initial sign-object relation and b. "concepts-for-others" as socially-mediated interconnected conceptual entities c."concepts-for-myself" viewed as an individual, intrapsychological means of interpreting reality [12].

Vygotsky considered that both the learner's (child's) and the adult's (teacher's) meaning of a given word often intersect and come together in the same concrete object reflecting his belief that

raw objects and phenomena provide reference points from which further conceptual systems may be constructed. Hence, it becomes obvious that the scientific worldview which is gradually formed by individuals is in direct correspondence to their subjective contextual experiences and interactions (both with each other and the world around them). Consequently, this entails that if one is engaged with the scientific process taking part in the (singular or joint) construction of an elaborate interconnected conceptual topology and knowledge structures, they would be required to necessarily draw on subjective personal experiences crafting, as Vygotsky saw, a rich scientific conceptual apparatus through manipulating objects in various contextual settings.

From a purely educational perspective, aquiring and reinforcing the use of scientific conceptuals is not the end goal of schooling but presupposes that having internalized them the individual then furthers their functional adroitness by incorporating a problem-solving toolset into particular daily routines. More importantly, according to Vygotsky, our understanding of scientific and natural processes and phenomena is never an isolated purely cerebral activity, but always exists and is mediated within a socio-cultural milieu of constant interaction whereby the linguistic component acts as a crucial eidetic buffer between the personal and the public which transforms learning into knowing. Scientific concepts, therefore, do not exist in nature as a given uncritical a priori but are dialogically constructed in social and individual psychological activity. Consequently, in Vygotsky's view, both scientific concepts and activity are characterized by a linked two-dimensionality taking place both within the inter- and intrapsychological realm of the individual's intellectual maturation.

When dealing with the philosophical aspects of forming a holistic scientific worldview, it is important to try and account for as wide a field of phenomena and their interpretation as possible. It would, thus, be improper to omit an important contribution from the psychological perspective made by Jean Piaget to the study of how the basic principles of knowledge acquisition relate to science education.. Similar to Vygotsky, Piaget thought that learning (active intelligence) is a continuing process of "adaptation" and "organization" whereby a pupil interacts with their physical and social environment. Furthermore, he believed that our intelligence and cognitive apparatus are based on intricate "chemas" Hence, whenever we wish to ascribe meaning and purpose to the particular things we come in contact with and interact with, there is a need to engage these intellectual structures and programming that can be recalled by the child as separate inquiry "units" in order to explore and give meaning to the physical and mental particulars their respective surroundings [5: 285].

Probing further in our attempt to reconstruct and explain the concrete specifics of Piagetian knowledge acquisition mechanics we encounter a complicated system of interconnected conceptual relations whereby the aforementioned schemas provide a learner with a system of adaptive assimilation and/or accommodation. Accordingly, if one encounters an unfamiliar object what is required for the (self)educational process to take place is that an individual recall the previously cultivated functional schemas and fit this new data into an established pattern of behavior, successfully completing the operation of conceptual assimilation. Conversely, once we are faced with an unfamiliar set of schematics (causing a disequilibrium to take place), what happens, according to Piaget, is that either obsolete schemas are modified or

(in case they are completely dysfunctional) novel ones are developed following our interaction with an object in question, leading to the process of accommodation taking place in the child's cognitive system [8: 235]. Genuine intellectual development, thus, presupposes the fashioning within a learner's eidetic system of (semi) logical structures as one actively interacts, absorbs, and reconstructs the general patterns and intricacies of their intellectual and material spheres.

One of the less-discussed constituents of inquiry-based learning is the concept of open learning. As evidenced by research from all levels of the academic sphere, teachers encouraging the use of minimal, lower-tier investigative techniques fail to achieve the realization of the students' learning potential which prevents them from forming the necessary scientifically-informed outlook and an active, inquisitive approach to their field of specialization. Lacking critical thinking skills these future professionals frequently fall short of reaching their full academic potential [7: 8]. Another important feature that often gets misunderstood receiving severe criticism from more conservative voices in the global academic community is the belief that educators incorporating the concept of open learning into their methodology do not pursue any fixed objectives, sending their students on a free-roaming, unassisted exploration with questionable outcomes.

What seems to be left out of the picture is the importance that such exploratory models of learning put on a teacher's ability to reorient their effort and classroom activity towards serving as capable guides who are able to direct their students' academic experience in a way that nurtures manipulating information and shaping meaning derived from a set of continuously fluctuating data and contexts [9]. As a result, when compared to more familiar rigorously structured study environments (dominant in our national education system) which operate on a confirmationist premise whereby one is given a set of fixed prescriptions of what their academic outcome and learning objectives are supposed to amount to, educators who (in part or fully) subscribe to utilizing efficient inquisitive learning practices display an increased level of interest and academic commitment corresponding to higher grades and subject satisfaction among various secondary and higher education establishments.

Conclusion and research prospects. Bringing our brief foray into the underlying, broader features of inquiry-based education, the authors wish to reiterate that when properly employed the potential of constructivism can lead to remarkable gains in the teaching and learning process both domestically and worldwide. By bringing class activity in line with the demands of the modern interactive education, teachers who follow the previously outlined postulates on imparting knowledge through discovery, in our mind, are bound to achieve a significant increase in the development of critical and creative thinking coupled with other autonomous-inquiry skills among their student body.

We firmly believe that implementing such a philosophy of facilitating a shared (group) learning environment can be genuinely conducive to a guaranteed acquisition of a flexible learning toolset, enabling students to take advantage of the latest approaches to acquiring relevant knowledge through an updated, student-friendly methodology and technological innovation. When perceived as a socially grounded approach, constructivism, therefore, appears to provide potentially productive application not just as a purely academic "ivory tower" fib but bears close cultural ties since our knowledge is always socially mediated. As such it affords the possibility for educators to enrich their

curriculum with positive, socially-relevant themes, empowering students to engage and take action by tackling such scientifically-laden issues as global warming, economic instability, improved healthcare, and standards of living.

Viewed as facilitators of a stimulating learning environment rather than guardians of a fixed set of "sacred" infallible prescriptions, modern-day educators employing constructivist, inquiry-based methodology are able to positively impact the teaching practice by instilling a sense of responsibility and ownership in their students. Such changes are becoming especially relevant in our globalized society and education system, where teachers (if they wish to continue to be effective) are becoming increasingly challenged with the need to transform autocratic instruction stereotypes, fruitfully mixing the essential with the progressive. Naturally, if the aforementioned enterprise is to be in any way relevant to the aims of such progressive philosophy of education it should be supported by a well-defined, structured base which is currently almost completely absent in our national educational philosophy.

At the same time, the authors feel that current trends of trying to adapt and adopt the best alternative educational approaches practiced in the West create a somewhat biased attitude towards domestic methodologies (mostly of the Vygotskian type) that are close in spirit to the aims of inquiry-based approach, yet are deemed inappropriate and ineffective being stigmatized as Soviet-era failed experiments. Lastly, what seems even more worthy of a separate intricate analysis is the precise way inquiry-based paradigm ties into the need to produce a new type of an educator expected to democratize the learning process, balancing the needs of an open investigative mode of knowledge acquisition with the demands of a more conventional academic assessment (standardized testing and a score-based system of grading) requirements still holding sway over the majority of the Ukrainian academic mindset and practices.

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