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When the Beauty of Research Becomes more Important than its Findings: An Aesthetic Framework of Scientific Inquiry as an Extension of Dirac's Beauty Principle

Abstract

The contemporary wave of commodification of scientific knowledge and the ongoing trend of rendering the working culture in natural sciences ever more entrepreneurial have taken an immense toll on the popularity of disciplines that explore natural sciences through the prism of arts and humanities. One of such disciplines has been the history of exact sciences, the study of which bears an extraordinary importance for ensuring the harmonious future developments in this sphere of knowledge.

In this article I hark back to the history of a principle proposed by the English physicist, Paul Adrien Maurice Dirac, in 1963, and turn it into a heuristic for directing the growth of scientific knowledge in a previously unexplored and, to most, unforeseen direction. In a *Scientific American* article from 1963, Dirac, who had been rewarded for his contribution to the atomic theory and success in reconciling general relativity with quantum mechanics with the Nobel Prize in physics thirty years earlier, asserted that "it is more important to have beauty in one's equations than to have them fit experiment".

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This statement of his came to be known colloquially as Dirac's beauty principle. To Dirac, however, who had nil inclinations toward art and who openly disparaged parallel studies of poetry and physics, the term "beauty" meant something more prosaic than what it would mean to a person with an aesthetic sensibility, in which sense it can be argued to have represented an ill choice of the word, causing confusion in later attempts to interpret this controversial statement.

A more radical aspect of this principle is that it puts more weight on the "beauty" of human models of reality than on their concordance with the empirical findings and facts, which most positivists would find to be absurd.

Despite the empirical quixotism of Dirac's principle, here I propose, after following a line of thought rooted in personal reflection, the thesis that extending this principle to scientific concepts in general, ranging from hypotheses and methods to forms of expression, could lead to a radically new scientific worldview: one in which the beauty of research concepts is perceived as more important than the solidity of their experimental backing.

Proliferation of this worldview, where creative ideas and forms are valued more than their proofs, may halt the ongoing progression of the natural sciences culture toward ever more entrepreneurial, industrial and impersonal grounds and restore its romanticist roots that extend deep into the fields of philosophy, sociology, arts and humanities.

Keywords: *Dirac's beauty principle, aesthetic framework of scientific inquiry, education, narrative, philosophy, science and art, sociology, aesthetic judgment, context of discovery, context of justification, philosophy of science in practice, biography*

Kiedy piękno badań naukowych staje się ważniejsze niż ich wyniki: Ramy estetyczne badań naukowych jako rozszerzenie diracowskiej zasady piękna

Abstrakt

Współczesna fala komodyfikacji wiedzy naukowej i trwający trend nadawania kulturze pracy w naukach przyrodniczych coraz bardziej przedsiębiorczego charakteru mocno negatywnie wpłynęły na popularność dyscyplin badających nauki przyrodnicze przez pryzmat sztuki i nauk humanistycznych. Jedną z takich dyscyplin jest historia nauk ścisłych, której badanie ma niezwykle znaczenie dla zapewnienia harmonijnego rozwoju w tej dziedzinie wiedzy w przyszłości.

W niniejszym artykule nawiązuję do historii zasady zaproponowanej przez angielskiego fizyka Paula Adriana Maurice'a Diraca w 1963 roku i przekształcam ją w heurystykę do kierowania rozwojem wiedzy naukowej w dotychczas niezbadanym i, dla większości, nieprzewidzianym kierunku. W artykule w *Scientific American* z 1963 roku Dirac, nagrodzony trzydzieści lat wcześniej Nagrodą Nobla w dziedzinie fizyki za wkład w teorię atomu i sukces w pogodzeniu ogólnej teorii względności z mechaniką kwantową, stwierdził, że „ważniejsze jest piękno w równaniach niż ich zgodność z eksperymentem”.

Teza ta stała się potocznie znana jako zasada piękna Diraca. Dla Diraca jednak, który nie miał żadnych skłonności do sztuki i otwarcie pogardzał równoległymi badaniami nad poezją i fizyką, termin „piękno” oznaczał coś bardziej prozaicznego niż to, co oznaczałoby dla osoby o wrażliwości estetycznej. W tym sensie można argumentować, że wybór słowa był niefortunny, powodujący zamieszanie w późniejszych próbach interpretacji tego kontrowersyjnego stwierdzenia.

Bardziej radykalnym aspektem tej zasady jest to, że kładzie ona większy nacisk na „piękno” ludzkich modeli rzeczywistości niż na ich zgodność z wynikami badań empirycznych i faktami, co większość pozytywistów uznałaby za absurdalne.

Pomimo empirycznego donkiszotyizmu tej zasady, proponuję tutaj, wychodząc od pewnej osobistej refleksji, przyjąć tezę, że jej rozszerzenie na koncepcje naukowe w ogólności – od hipotez, przez metody, po formy wyrazu – może doprowadzić do zupełnie nowego światopoglądu w nauce, a mianowicie takiego, w którym piękno koncepcji badawczych będzie postrzegane jako ważniejsze niż to, jak solidnie są one poparte eksperymentami.

Rozpowszechnienie się tego światopoglądu, w którym kreatywne idee i formy są cenione bardziej niż ich dowody, może zatrzymać trwający postęp kultury nauk przyrodniczych w kierunku coraz bardziej przedsiębiorczych, przemysłowych i bezosobowych podstaw oraz przywrócić jej romantyczne korzenie, sięgające głęboko w dziedziny filozofii, socjologii, sztuki i nauk humanistycznych.

Słowa kluczowe: *Diracowska zasada piękna, estetyczne ramy badań naukowych, edukacja, narracja, filozofia, nauka i sztuka, socjologia, osąd estetyczny, kontekst odkrycia, kontekst uzasadnienia, filozofia nauki w praktyce, biografia*

“If a man could pass through Paradise in a dream, and have a flower presented to him as a pledge that his soul had really been there, and if he found that flower in his hand when he awoke - Aye! and what then?”

Samuel Taylor Coleridge (circa 1818)¹

1. The role of aesthetic judgment in scientific breakthroughs

There is little doubt that the epidemic of commodification of scientific knowledge and the expansion of entrepreneurial foci in natural sciences are responsible for marginalizing methods of scientific inquiry that integrate artistic aesthetics and humanistic outlooks. In this extensively autobiographical article, I take a stand on the ground where the historical evolution of the relationship between aesthetics and scientific thought has converged – a ground, unfortunately, as of today, as derelict as the Zone of Alienation from Tarkovsky’s *Stalker* and as abandoned as the Pannonian village from Béla Tarr’s *Sátántangó*. In the center of this spot I am taking a stand on rests an idea, as historically neglected as consistently misconstrued. It was articulated by the English physicist, Paul Dirac sixty some years ago; according to it, beauty in theoretical physics should be granted a greater importance than whether this beauty can be experimentally verified or not.

While Dirac’s beauty principle may seem controversial at first, it reflects a long-standing tradition in scientific inquiry. From antiquity throughout the modern period to the digital age, the aesthetic dimension has guided, albeit subtly and subliminally, the formulation and proliferation of scientific models. Archimedes’ geometric discoveries pursued through mechanical imaginations,² Copernicus’ and Kepler’s search for harmony in planetary orbits,³ Galileo’s modeling of the natural world after the Platonist and Aristotelean aesthetics,⁴ Newton’s pursuit of Pythagorean mathematical simplicity in search of fundamental laws of mechanics⁵ and Einstein’s reliance on the aesthetic of universalism⁶ exemplify how aesthetic standards have been intimately twined with scientific reasoning throughout the history. The success of Maxwell’s equations, the

¹ Coleridge 1895/[2012](#), p. 282.

² Chen 2024, p. 23.

³ Kokowski 1996, p. 7; Rodrigáñez 2010, p. 27.

⁴ Panofsky 1956, p. 11.

⁵ Guicciardini 2021, p. 129.

⁶ Ryckman 2021, p. 195; Pais 1979, p. 908.

formulation of quantum mechanics, and the role of symmetry in the physics of elementary particles further illustrate this principle.⁷ Yet, what was and what should be implied by the notion of beauty has usually been shunned as a subject not worthy philosophizing about by the scientists lest its subjectivity spoil the supposed pureness of the objective scientific thought. Despite this aversion to the idea of letting aesthetics, along with arts and humanities that would tag along, be merged with physical sciences, the eye for beauty continued to be open and active among some of the most inventive natural scientists in the modern era, with the 20th century physicists such as Einstein, Heisenberg, Bose, Penrose and Feynman exemplifying this by their advocating for symmetry and mathematical elegance as guiding principles in scientific discovery.

Over and over again, ideas behind groundbreaking discoveries have emerged from the aesthetic intuition rather than from the passive extension of empirical principals. Einstein's general relativity was accepted largely due to its mathematical elegance, long before its empirical confirmation.⁸ Similarly, the decisive appeal of Mendeleev's version of the Periodic Table lay in its ability to anticipate the existence of elements that were yet to be discovered at the time.⁹ The prediction of antimatter based on Dirac's relativistic wave equation presents another example of how aesthetically driven theoretical insights can lead to experimental discoveries.¹⁰ Heisenberg's uncertainty principle, likewise, according to some historians,¹¹ emerged from the aspiration to create knowledge that, albeit embracing the discrete character of quantum mechanics, would fit within a "unified world picture"¹² and counteract the fractionation of the world that was going on at the time on geopolitical planes. Despite this indisputable influence of aesthetic criteria on the evolution of scientific models of the physical reality, in this article I am situating Dirac's perspective within a personal quest for beauty in science and report how far this quest has guided me to this day. Throughout the discourse, it will become obvious that the worldview I have drawn and delved into is more radical than the simple appreciation of mathematical elegance in theoretical works of science or finding inspiration and source of enjoyment for the senses in art outside the scope of scientific research that historians and popular writers most commonly classify as the conjunction of science and aesthetics. My goal, therefore, is not to explore how aesthetic considerations have influenced major scientific breakthroughs, from the development of classical mechanics to quantum theory to undocumented contemporary cases. Rather, it is to develop the thesis that the beauty of scientific research – including its hypotheses, methodologies, and modes of expression – can hold a greater value than its immediate or postponed empirical validation. The aesthetic considerations, in other words, should not be confined to theoretical models only, but should also govern the experimental design and scientific communication alike.

By pursuing this thesis, I also argue for revitalization of creativity and philosophical depth in scientific inquiry. Reaching, maintaining and professing the balance between creativity and rigor, intuition and empirical evidence, is a fundamental challenge in today's natural sciences, yet by recognizing the importance of aesthetics, as I hold, the scientific community could engage in the fosterage of a research culture that would value conceptual depth as much as it values analytical rigor. Strengthening this perspective could counterbalance the increasing industrialization of research and restore a more holistic approach that would bridge science with philosophy, sociology

⁷ Zee 1986, p. 96.

⁸ Turyshev 2008, p. 207.

⁹ Scerri 2008, p. 54.

¹⁰ Pashby 2012, p. 440.

¹¹ Schaa 2021, p. 59.

¹² Carson 2010, p. 76.

and the arts. The increasing specialization and commercialization of scientific research have led to a decline in the interest in philosophical and artistic considerations, yet by highlighting the enduring relevance of aesthetics in scientific inquiry, science could undergo a true renaissance. Emphasizing the beauty of scientific concepts – whether in theoretical elegance, experimental design, or imaginative expressions – can inspire a more holistic and harmonious approach to research. Restoring the balance between creative intuition and empirical validation may counteract the increasing industrialization of science and encourage a renewed focus on the philosophical and humanistic dimensions of scientific thought. Beauty, to that end, as I will come to this point again at, symbolically, the very end of this article, has the opportunity to save science as we have known it.

2. Aboard a trip down the memory lane: toward the junction where science and philosophy have not fallen out of joint yet

History of natural sciences is a discipline essential for understanding the big picture in which the given sciences evolve. It can be argued that without the proper understanding of this history, neither can the present nor the future of natural sciences be properly navigated. At the same time, relative to the developments in natural sciences on theoretical and especially practical levels, studies of the history of these sciences have been relatively neglected. The practice of exact sciences, in other words, has become linearized and narrowed in the methodological sense, and any detours toward territories where these sciences cross-fertilize with humanities have been customarily perceived as second-rate in terms of their significance. This point of view, however, is dangerously erroneous, simply because history, as the colloquial wisdom has it, repeats itself. To prevent tragedies from reoccurring, the history must be subjected to rigorous scrutiny by scholars in natural sciences, and lessons from it must be drawn lest, as Marx would have noted,¹³ these tragedies convert to farces, desensitizing the populace to their tragic character and hampering the progress of humanity.

History of science that is instructive to study, as it is often neglected by historians, themselves, need not be impersonal and need not revolve around events that have no living witnesses remaining. This history can be personal and can pertain to events and eras one has directly experienced in the past. With that being said, one curiosity about the curriculum of the School of Physical Chemistry at the University of Belgrade, which I attended as an undergraduate from 1995 to 2001, was that it contained an odd number of semesters. Another, greater one was that its final, ninth semester had only one subject to complement the final research project: philosophy of science. Yet another curiosity was that the neighboring School of Chemistry began, not ended, its curriculum with this subject and ended it with sociology of science, which the School of Physical Chemistry offered in the first semester. The reasons for this diametrical opposition may be sought in the antagonism the chemists occasionally nurtured with respect to physical chemists, whom they would often see as but deserters from the province of chemistry. The aspiration of physical chemists to bridge that gap between physics and chemistry as arguably two most fundamental basic sciences was also often perceived as annoying and lofty. Additionally, the theoretical and empirical grounds claimed by physical chemists continuously shifted over time, which was often interpreted by the chemists as a sign that this was but a fictitious scientific discipline. For example, the degree I would eventually earn in physical chemistry translates to an equivalent degree in chemical physics in the United States, without there being any clear-cut

¹³ Marx 1852, p. 1.

definitions of these two disciplines, let alone an unambiguous distinction between them. Regardless of these artificial divisions, to this day I feel grateful for this sandwiching of a myriad of natural science subjects between sociology and philosophy, the curricular quirk that I have yet to see in any western European or American university. The implicit message that this conveyed to me was that science, fundamentally, is rooted in sociological and philosophical phenomena, the understanding of which is mandatory lest we turn into sheer automata for calculating numbers and predicting physical effects, without ever reaching the insights into the big picture, the How and Why of it all.

As my career progressed, I became increasingly deeply immersed in the effort to untangle the sociological and philosophical effects on the evolution of this career and of science as a whole from their concrete contents. What once had started as an endeavor stemming from classical, objectivistic premises that most scientists routinely assume transformed over time into an awareness that social effects have a crucial say as to which theories or which scientists would be accepted and granted a ticket to success and which would be halted in their ambition and progress. The crooked paths of destiny led me to become one such scientist whose style differed exceedingly from the mainstream and the mainstream dispelled him as an outlier, a heretic, a radical. It was the same fate that struck and that still awaits many worldviews that fall far beyond the limits of the reigning paradigms and trends. The only hope that the bearers and nurturers of these unconventional worldviews can cling onto is that time will tell their innovativeness and that they will be rescued someday from the steady descents into oblivion in today's rat race for success, prestige and material wealth all across the scientific arena.

The way I interpreted the conclusion of my *alma mater* curriculum with the course on philosophy of science – the attending of which paralleled the work of a research thesis, which was mandatory to finish before one could graduate – was that philosophy, really, is neither more nor less than the crown of science. Today, however, having taught a vast array of scientific subjects across a number of different public and private American universities, I am free to say that there is an ongoing epidemic of illiteracy in philosophy among not only students in sciences, but their professors and mentors as well. We have reached a stage where science has become entrepreneurial, serving as an attractor for those who are in it for money, prestige and power, all of which are detractors from the engagement in a fundamentally prolific and truly inspirational work as a researcher and an educator. Naturally, when the material becomes the measure of success, everything moral and humanistic will be the first to fly out the window. But this need not be so and classes could be conceived, from those at research-intensive, so-called R1 universities to those at community colleges, in such a way so that the discussions on any given scientific subjects are deepened down to their roots, which, I assure the reader, always extend beyond the domains of human inquiry about the physical world and into ruminations on nonphysical phenomena. Whether these are sociological, philosophical, political or metaphysical ideas, into their embrace we inescapably fall when we look deep enough into the nature of scientific thought.

To the dismay and occasional horror of my pragmatic peers and supervisors, such resorts into these nonscientific territories have been a common trait of the courses I offered as an instructor. As for students, this was a drag to all those who have come to attend them with the goal of picking the know-how quickly and monetizing the skill in a big wide world. But it was also a source of wide-eyed wonder to those whose minds did manage to be intrigued by this extraordinary broadening of views. And when the goal is really to expand the curiosity and open up the minds, then any teaching strategies intending to lock the thought dogmatically down to

specific paths along which things “must be done” is perceived as backward and a disservice to both the students and the teaching profession *per se*.

Yet another curiosity of the curriculum of the School of Physical Chemistry was that, innumerable colloquia conditioning the entrance to the final exams aside, all the final exams save organic chemistry were conducted orally. Students would be given typically three topics to elaborate on and they would sit for about an hour, writing down the concepts for each and deriving any equations related to them from the basic principles, after which they would come up to the blackboard and be grilled mercilessly by the professor. To fail an exam was far more probable than to pass it and the average duration of studies at the time I was a student was twice the number of semesters for which the instruction was offered; in other words, about a decade, and this statistic did not account for the fact that over 50% of the students dropped out before the end of the first year. This is nothing to be proud of, but it illustrates an educational system fostering intellectual elitism and a profound disregard of the benevolent “no student left behind” policy. Not every student could maintain the high standards of learning, yet instead of adjusting to these individual paces, the system weeded out those left behind and they were forced to find alternative professions. Two of my best friends from college dropped out during the sophomore year, having bumped into the wall called atomic physics, and are now a children’s toy maker and a renowned visual artist, and I can only imagine how much benefit their views of the world would have brought to science, which appears to be in need of such spirits today more than ever before. Neither was the fact that my home country, Yugoslavia, was being torn apart by economic sanctions, internal corruption and civil wars any help to those who could not keep the pace with the elitists any helpful; all those things had to be deemed secondary to the timeless appeal that the scientific multiverse has graced us with.

3. Dirac’s beauty principle: the first time coming face to face with it

If the reader perceives this as an interlude to my confessing that, like many exams before and after it, I failed the philosophy of science in the first attempt after I decided to improvise the answers with impromptu composed children’s stories¹⁴ in lieu of exact textbook lines and references, then let it be. The rebel against the system I was then as I am now and renegade I vow to remain until the day I die, notwithstanding the cost. However, the second time I entered the exam, a few months later, brought before me a topic from the philosophy of science that has been with me ever since. It was formulated, somewhat sloppily, as Dirac’s theory of beauty in science. Very soon it became clear to me that this was not a theory, not even a testable hypothesis, in the real sense of the word, but more of a personal guideline, a recipe on how to approach the creation of theoretical models, if not creative thinking in general in sciences. Before I understood these limitations, however, my mind engaged in the act of some serious mental acrobatics on the topic of aesthetics in sciences, the subject very rarely addressed by top scientists, if at all. For, we had been trained through exhausting coursework to leave any subjective drives that invoke beauty behind since they, presumably, can only pollute, but never enrich, the scientific thought; they, we were told, mislead us and lure us to inaccurate judgments. Before I knew it, before me was a vision, ultimately rebellious, that beauty, the paragon of virtue in the realm of arts, can guide the evolution of natural sciences, the idea that to this day electrifies my whole being. The exam was not over yet, yet I spun all this in my head and the thoughts on this subject have never since left me. My response at the exam was, expectedly, convoluted, but also confident enough so that some transcendent ambition

¹⁴ V. Uskoković 2023c, p. 245.

proliferated through it and I was granted a pass. It was an entry into the kingdom of scientists as philosophers, which I have remained loyal to up to this very day.

This question of the place for beauty in science instigated by Dirac added to my intense appreciation of Hesse's idea of the glass bead game,¹⁵ an elusive fusion of science and art, and these two, which already formed a binary star system in my microcosm of thought since my first reading of Hesse's classic in 1993,¹⁶ now received a new member in their orbit: Dirac's beauty principle. Since then, the spaceships of my thoughts would repeatedly circle around this stellar couple in search of the answer to the question that preoccupied me through my entire scientific career: how do we make science more artistic? My preoccupation with this question stemmed from the conviction that not only are there strong benefits for scientific creativity that infusing scientific thought with the streams of poetry and lyricism could bring about, but also that our survival as a species critically depends on this humanization of natural sciences,¹⁷ which, as these lines are laid here, become colder and colder, more and more callous, at all levels, from the epistemic to the cultural. There is hardly anyone who would religiously argue that science, as a profession, is good for the soul these days; in fact, the great majority of people I know would argue in favor of the opposite. Art, however, can serve as a grand ennobler of this coldness and, with some effort and imagination, turn it into a heartwarming flame. Yet, putting art and science side by side does not mean that they would react and produce a fabulous compound simply because they are in each other's proximity. The truth is that for the reaction between the two reactants to occur, they both must agree to change, yet the rigidity of sciences would prevent this from happening and the chance is that art and science, regardless of how closely they are being pushed, simply would not react.

Science and art, of course, like any given chemical elements, can be combined in a variety of manners. Some proponents of this marriage bring catchy scientific and technological processes to museums to create installation artworks, an approach which can be classified as "science in art". Others try to reduce the artistic experiences and sensations down to the level of neurological flickers or cellular pathways via scientific tools, and this can be called "science of art". Yet others focus on creating content for rather diluted popular books and blogs that break down the complex scientific terminology to simpler wordings that laymen could understand, in a way that can be considered an "art of science". But the idea that the rigidity of scientific thinking toward novel, if not groundbreaking, ideas could be rejuvenated by, say, teaching the scientists the merits of the artistic sensibility and cross-fertilizing their oh so often insipid and unimaginative thoughts with the taste for music, poetry and visual arts has been completely ignored. Artists, simply, do not feel like the augmentation of the creative thought process amongst scientists is up to them to contribute to, in part because there is already enough animosity between starving artists and better-off scientists and in part because the language barriers have ensured that the artists lack confidence when it comes to entering and exploring the media for scientific communication and expressing themselves therein. As for scientists, we should know by now that their resistance to accepting the influence from the realm of arts is symptomatic and difficult to overcome, as the result of which the question of "art in science" has remained unexplored. No one to this day, for example, save my recent work, has treated scientific paper as a medium for combined expression of scientific novelties and artistic expression. In other words, how do we create papers that are as enlightening to read as Dučić's poetry, Tezuka's comics or Dostoyevsky's novels, but without compromising

¹⁵ Hesse 1943.

¹⁶ V. Uskoković 2023b, p. 747.

¹⁷ V. Uskoković 2024c, p. 57.

their analytical accuracy, empirical rigor and scientific value? This and other “art in science” questions, in fact, have been some of those that I have zealously tried to answer over the course of my scientific career. There were periods when external circumstances demanded focus on more pragmatic research and did not leave enough space for the pursuance of this goal, and then there were times when spare time research did allow for these fanciful grounds to be explored. Then came the period of unemployment, of being sidelined by the scientific community because of all these radical goals pertaining to the unification of science and art, when productivity in this compound field exploded, leading to the creation of personal *pièces de résistance*.

4. Dirac’s beauty principle: its origins and diverse interpretations

Let us now look at the premises of Dirac’s postulate a bit. Even though he sporadically used the term “beauty” in his descriptions of theoretical research in private and public conversations, his most notable exposition of the idea that beauty is to be a guidance in the quest for the scientific discovery came relatively late in his career, in a *Scientific American* article from 1963, where he asserted this:

It is more important to have beauty in one’s equations than to have them fit experiment (Dirac 1963, p. 47).

This statement of his would come to be known as Dirac’s beauty principle, and was followed by the following string of thoughts in the given article:

It seems that if one is working from the point of view of getting beauty in one’s equations, and if one has really a sound insight, one is on a sure line of progress. If there is not complete agreement between the results of one’s work and experiment, one should not allow oneself to be too discouraged, because the discrepancy may well be due to minor features that are not properly taken into account and that will get cleared up with further developments of the theory (Dirac 1963, p. 47).

The first and the foremost observation to be made here is that Dirac appeared never to have been a type much moved by art. This aversion to anything artistic can be illustrated by his own opinion on whether there is room for lyricism in physics, the answer to which was a clear no based on his reprimanding the older of the two Oppenheimer brothers, Robert, for his interest in poetry:

How can you do physics and poetry at the same time? The aim of science is to make difficult things understandable in a simpler way; the aim of poetry is to state simple things in an incomprehensible way. The two are incompatible (Mehra 1972, p. 17).

Or so was at least the viewpoint held by the theorist’s theoretician, Paul Dirac, known to have “maintained practically no interests outside physics and never feigned engagement with art, literature, music, or politics”, which found reflection, among many other things, in his exceptional prosaicness, papers criticized for “lacking words”, and never ever resorting to the use of diagrams, even in his books and textbooks.¹⁸ Neither did he nurture any interest in philosophy of physics, despite the fact that never before nor after did this subject preoccupy the attention of academicians and popular audiences alike to the same extent; rather, he unreservedly cast aside any philosophical inquiries starting from the grounds of fundamental physics as trivial.¹⁹ Despite that, Dirac can be indisputably credited for his inclination to probe uncharted scientific grounds and look where no

¹⁸ Gallison 2000, pp. 145, 147.

¹⁹ Ryckman 2018, p. 237.

one had looked before, which, we know, is the commonality of both good science and great art. However, what he meant by beauty was primarily the mathematical “beauty” in terms of a delicate fit of individual parameters tied by equations to the foundations of preexisting scientific models. In that sense, what Dirac, who was never much of an aesthete, meant by beauty was more similar to that of an elegant combination in chess than to riotous, avant-garde dancing of ballerinas to Stravinsky’s *Rite of Spring*, trembles of Mallarme’s *fin de siècle* poetry or bedazzling series of moving images in Linklater’s *Waking Life*, if I were to recount examples that have fallen off the top of my head. In fact, the closest we could historically come to Dirac’s rather square, scientist’s view of beauty is in Socrates’ remark on the subject from Plato’s *Philebus*:

I do not mean by beauty of form such beauty as that of animals or pictures, which the many would suppose to be my meaning; but, says the argument, understand me to mean straight lines and circles, and the plane or solid figures which are formed out of them by turning-lathes and rulers and measurers of angles; for these I affirm to be not only relatively beautiful, like other things, but they are eternally and absolutely beautiful, and they have peculiar pleasures, quite unlike the pleasures of scratching (Plato 1871, n.p.).

It suffices to say that beauty has meant different things to different professionals and just like soccer pundits would call a goal scored by a volley from the edge of the penalty box beautiful and fashionistas consider catwalk models beautiful, so do mathematicians find formulaic fits that bring scattered complexities into peaceful agreements beautiful. Still, if we accept that aesthetics is an artistic category and that artists have the final say as to what constitutes beautiful expression and what does not, then we come to the general consensus among art critics and scholars that all that “scratching” disparaged by Socrates and the creation of irregular forms, like those found in Nature or in paintings by, say, Van Gogh or Kandinsky, are more beautiful than the niceties of geometry or arithmetic. As a result, Dirac’s resorting to the use of the notion of “beauty” can be righteously called the case of inappropriate wording, when mathematical elegance, clarity or even straightforwardness would have been choices truer to the intended meaning. Fortunately or not for us and for the originator of this postulate, the rather ill phrasing of it can create and it has created the expansions of this principle into semantic territories that are far more focused on the traditional understanding of aesthetics than what taciturn and matter-of-factly Dirac meant to convey. For example, even a brief search through the literature from the past 12 years where Dirac’s *Scientific American* article appeared as a reference reveals cases where the principle:

- has been used as a hint at “an aesthetic intuition as an arational (as opposed to irrational) component in creative problem solving”;²⁰
- has been used to support the importance of metaphors in scientific reasoning, “in that they permit to explore uncharted lands and offer new perspectives for expanding scientific knowledge”;²¹
- has been used as a proof that mathematics is the prime instigator of scientific revolutions;²²
- has been used as a “provocative” call to understand that scientific models describing the parts of the reality that are imperceptible to the human senses are the products of human

²⁰ Sadler-Smith 2015, p. 350.

²¹ Matassi, Martinez 2023, p. 15.

²² Brush 2015, p. 505.

imagination, and since these “visualizations that arise from combining aesthetics and science reveal the hidden beauty that is encoded into the mechanics of the natural world”,²³ much more attention ought to be paid to ensuring that scientists approach the probing of the secrets of this natural world with developed aesthetic senses than it is the case today;

- has been accused of doing disservice to good science in the peer-review process by favoring clean but inaccurate data over the messy but realistic one;²⁴
- has been used to exemplify how the perception of beauty is consensual, but also subjective, in such a way that the physical system or a human work are judged to have or not have it based on views that are “composed not only of what lies before our eyes but what lies within our heads”.²⁵

Therefore, like many notions Gregory Bateson would have classified as “explanatory principles”²⁶ all throughout the history, Dirac’s beauty argument has encountered a similar fate, having been grasped in numerous, occasionally mutually contradictory manners. In fact, Bateson’s own concept of “pattern that connects” was one of such multifaceted, if not plainly misunderstood concepts. For ones it represented the aesthetic similarities of living systems,²⁷ for others the tie between nature and culture,²⁸ for yet others the human being at its core²⁹ or the “computational thoughts of relation” including “the phenomenological-emotional dimension”³⁰ or the bridge over the gap between the independent homunculi in a subjective idealist world³¹ or the links that connect everything to everything else³² or a spiritual force serving as an interconnection between human beings and the world,³³ the metaphor for the divine³⁴, and so on. Hesse’s glass bead game, likewise, offers a great deal of mystery surrounding it, with the game of chess being the closest critics have come to deciphering its mystical character. One such obscurity in expression can be ascribed to the filmography of Jean-Luc Godard and to the belletristic but also hardly penetrable writings of Gregory Bateson, himself, thanks to which I returned to them over and over again, thus allowing them to lead me to invaluable philosophical insights and ideas.

Dirac’s key argument presented in the *Scientific American* article, which is that “it is more important to have beauty in one’s equations than to have them fit experiment”, and which may sound outrageous to many a positivist both then and now, was derived from the observation of more than one instance where the derivation of what Dirac christened “beautiful” equations preceded and almost prophetically predicted their later confirmation in experiments. Dirac referred to a couple of such cases to illustrate this principle of his. One of them was the story about how Erwin Schrödinger published his seminal work on his famous equation describing electron in an

²³ Mitchell et al. 2016, p. 140.

²⁴ Giner-Sorolla 2012, p. 568.

²⁵ Williams 2019, pp. 17–41.

²⁶ G. Bateson 1972, p. 48.

²⁷ M.C. Bateson 2008, p. 19.

²⁸ Hoffmeyer 2008, p. 42.

²⁹ Cashman 2008, p. 46.

³⁰ Brier 2008, p. 234.

³¹ Deacon, Sherman 2008, p. 61.

³² Favareau 2008, p. 170.

³³ V. Uskoković 2009.

³⁴ Brier 2008, p. 256.

atom as a wave.³⁵ To his great disappointment, when he took into account the relativistic effects, he received poor correlation with the experimental energy values; when he did not take them into account, the correlation was significantly better. This was not good news to the theoretician, yet he went on to publish his model in this crippled form and only later was it discovered that when the spin of the electron, which had not been known at the time of Schrödinger's work on the wave equation, was taken into consideration – the feat achieved by none other by Dirac, himself – the equation applied in its expanded and complete, relativistic form would give an excellent correlation with the experiments. This is what Dirac used to conclude that when one is driven by an inner intuition and the “beauty” principle, one need not be discouraged by the poor concordance with the reality and one should just go ahead and share one's findings with the world, in the hope that “the discrepancy may well be due to minor features that are not properly taken into account and that will get cleared up with further developments of the theory”.

Dirac's argument can also be supported by the case of Einstein's theory of relativity, which was extraordinarily beautiful when it was first formulated in its general form,³⁶ even though only one out of the three experimental proofs for it, as proposed by Einstein in 1915, namely the anomalous precession of the perihelion of Mercury, was satisfied at the time. The other two, that is, the bending of light in gravitational fields³⁷ and the gravitational redshift,³⁸ were confirmed only in 1919 and 1954, respectively. Here, again, the trust in the theory because of its “beauty” would be sufficient not to discard it on the basis of limited or missing experimental evidence. In fact, considering that the one and only time Dirac's wife, Manci, saw his husband cry³⁹ was when Albert Einstein passed away in 1955, a year after the final evidence of the general theory of relativity was obtained, it is reasonable to assume that Einstein's theory of relativity, because of its remarkable elegance, if not beauty in the artistic sense of the word, provided a major source of inspiration for Dirac to derive his “beauty” principle.

Another example, which Dirac must have been even more intimately bonded to, came from the work that paralleled his candidacy and reception of the Nobel Prize. Namely, after he succeeded in the second half of the 1920s to combine quantum mechanics and the special theory of relativity in his equation for the electron by accounting for its spin,⁴⁰ Dirac went on to elaborate his theory of so-called holes.⁴¹ This theory came to being via Dirac's realizing that his equation for the electron allows for the existence of electrons with negative energies,⁴² in such a way that the encounter and collision of electrons with different energy signs would lead to their mutual annihilation. This concept of antimatter seemed unrealistic at the time, but Dirac believed his equations more than the reality and the proof of the validity of this belief came in 1933, when Carl Anderson discovered antielectron in cosmic rays.⁴³ Prior to this discovery, protons and electrons were the only known elementary particles and Dirac was unsure whether his equations predicted the scenario where such exotic particles as antielectrons and antiprotons really existed or the scenario where protons were effectively “holes” created by electrons jumping out of them, in which case electrons would be the only elementary particles. The experimental evidence of

³⁵ Schrödinger 1926.

³⁶ Einstein 1915.

³⁷ Dyson et al. 1920.

³⁸ Pound, Rebka 1959.

³⁹ Kattupalli 2022, n.p.

⁴⁰ Dirac 1928, p. 610.

⁴¹ Dirac 1930, p. 360; Hovis, Kragh 1993, p. 104.

⁴² Dirac 1928, p. 610.

⁴³ Anderson 1932, p. 238.

antimatter solved this dilemma and fortified Dirac's belief that equations are to be trusted more than reality; they can guide what is yet to be experimentally discovered. This belief forms the crux of Dirac's beauty principle in science. Or, as Dirac put it in his own words toward the end of his *Scientific American* article,

It may well be that the next advance in physics will come about along these lines: people first discovering the equations and then needing a few years of development in order to find the physical ideas behind the equations. My own belief is that this is a more likely line of progress than trying to guess at physical pictures (Dirac 1963, p. 53).

Dirac's subsequent theoretical work failed to hit the same kind of jackpot, yet it clearly did not shake Dirac's belief in the capacity of theory to open up our eyes to empirical phenomena that we had been blind to. One example of these failed theories can be Dirac's theory of a varying gravitational constant, which was based on the elegant interconnection of the fundamental constants of nature, but the proof for which was never found. Another example can be magnetic monopoles, which Dirac predicted in 1931,⁴⁴ but which are likely never to be observed either. Dirac's large numbers hypothesis also belongs to this list, even though it is not derivable from the laws of physics nor could it be tested except for some of its consequences. Despite all this series of failures, Dirac never ceased to believe that disagreement with the experiments should not be the reason to discard a beautiful theory, as deeper probing of its secrets may lead in the future to extraordinary insights, for both theoreticians and empiricists. As pointed out by Helge Kragh, "in Dirac's view, aesthetic criteria could and in some cases should preserve a theory from refutation in the face of falsifying experiments; the same criteria could also prompt the abandonment, or at least mistrust, of a theory that is as yet empirically satisfactory".⁴⁵ Ironically, to this day, this code of aesthetics in science proposed by Dirac, himself an eschewer of all things artistic, represents one and only invitation to view physics or any natural science whatsoever through the prism of artistic senses.

This call to listen to an inner aesthetic sense and disregard the correlation with the experiments would have surely been shunned as heresy had it come from a lesser known authority than Dirac, at the time not only a Nobel Laureate, but also the Lucasian Chair of Mathematics at Cambridge for over 30 years, longer than Isaac Newton.⁴⁶ The dangers of this proposition can be best grasped by recalling how hearing or seeing things that no one can is a sure sign of any of the numerous delusional mental disturbances, ranging from delirium to severe mental shock to schizophrenia. Yet, this edge of the cliff is where extraordinary artists and scientists have always gravitated to and must walk on if that gorgeous seascape, the privilege of only intellectually the bravest and the most courageous, is to be held in view.

Although the presumed obligation of every theoretical physicist is to make sure that his or her models fit the reality, many physicists in the past sank so deep into their theoretical worlds that these worlds gained independent dimensions of their own. On one hand, the models, then, were obliged to agree with the theoretical models on which they were based, but on the other hand, they had to agree with the empirical observations. This dual pull, however, rarely leaves one standing in the middle; depending on one's inclinations, one may tend to cater more either to the former or to the latter. It is not a secret that Dirac, like many of his equally lauded contemporaries working

⁴⁴ Dirac 1931.

⁴⁵ Kragh 2016, Chapter 9, n.p.

⁴⁶ Knox, Noakes 2003, p. xix.

in the fields of quantum mechanics and relativistic physics, were more interested to ensure that their models fit the preexisting theory than that they fit the preexisting experiment. The paramount beauty of Dirac's argument, albeit rarely discussed, is that he professed the departure of our models from the experiments. It is as if he was saying that our dreams of reality need not comply with the real world because sometimes, somewhere, if these dreams are beautiful enough, they may become real. Of course, despite the fact that Dirac was so reticent that his peers proposed Dirac to be the unit of speech equivalent to one word per hour,⁴⁷ the man was not a lunatic and he did not deem that beautiful equations can change the reality as if by some act of magic. What he intuited instead was that deriving and boldly reporting theoretical models that disagree with the empirical observations could prompt the scientific community to look in the direction of testing these models, which, if the theoretician was lucky or oracular, could lead to their experimental validation more than refutation. This is where Dirac implicitly touched upon that aforementioned sociological aspect of science, having understood that the evolution of science, even at the most fundamental level, is not simply about proving the truthfulness and disproving the falsities; rather, it is the result of a complex web of social relationships, which, sadly, may not always favor the excellent and the accurate over the mediocre and the imprecise.

In the final passage of his *Scientific American* paper, Dirac, in fact, admitted to this favoring the theoretical side of things in physics over the experimental one when he noted the increasing chances for their pending divorce. He did make a complain that experimentalists increasingly work independently of the theoreticians and that was certainly a valid observations to make in the early 1960s. However, Dirac did not live to witness an ever growing gap between the two that has been continuously accrued since then. Some fields of physics, such as physical chemistry, have deteriorated into predominantly computational chemistry, with conformations from the experiments not being necessarily sought all of the time. The prevalence of applications of these computational tools that trace to first principles has proceeded in inverse proportion with the literacy in their theoretical backdrops and there is a lesser and lesser number of users who understand how the algorithms exactly spit out the values at them. Meanwhile, the experimentalists work towards practical solutions that can be translated to the market via spinoffs and startups that universities increasingly harbor, turning the universities from the sites of free-spirited, revolutionary thought into venues for commercialization of science, the goal that cannot proceed without its parallel utilitarian vulgarization. Dirac, however, did share his hope that as physics, and perhaps other sciences too, continue to collect "a vast storehouse of information", a new Heisenberg will pop up, who would be able to use all the abundance of information to create a profoundly new theory. Dirac, of course, was a 20th century man and to any of the prominent scientists and artists of that century, being fundamentally different from the pack counted amongst the most glorious achievement to be strived after.

Dirac's inclination toward the beauty of the theory, even at the disregard of the experiment, was pronounced too late to yield a considerable number of followers. The world had already started to set and solidify into a more practically oriented shape than ever before and this thirst for aesthetics was destined never to find resonance with the scientific community again. However, to renaissance people, such as you and I, it is never too late to return to it and discover an instructive analogy. Essentially, if Dirac was a man who valued the beauty of the theory more than its match with the experience, we could, in analogy, imagine a man who would care about the artistic

⁴⁷ Farmelo 2009, p. 89.

features of scientific research, theoretical or experimental, more than about how truthfully it relates to the reality. That man was me.

5. Toward a conceptual scientist: from a beautiful theory to a beautiful science

I have made nothing short of a mountainous effort over the years to extend Dirac's principle from the theoretical to the empirical domain by asserting that the beauty of research, including the study subjects, the methodologies, the experiments and the forms of expression, is more important than its ability to pave way to a practically meaningful discovery, a claim as outrageously heretic as Dirac's. Along the way, I have trumped the academic ladder and drifted from coast to coast, descending deeper and deeper on the scale of professional admiration, risking the wellbeing of myself and my family, and losing each day a thread that tied me to the scientific community. Alas, to a martyr to whom sowing the seeds of beauty across meadows desperately needing them is as natural as the air to breathe, no alternative to this daring way of being has been conceivable.

The type of science I have advocated along the way was that I christened "conceptual", meaning the science of revolutionary new concepts and, occasionally, their proofs, but not much beyond that necessarily. Promoting this science of new concepts, as I have come to hold, is nothing short of vital in today's scientific climate, where major industries have thrown most of their basic science projects to academic labs, which have, in turn, ignored the need to become the incubators of fundamental novel concepts and have turned instead into spaces for merely optimizing preexisting concepts toward their promptest commercialization via various spinoffs or industry-academia partnerships. Importantly, whereas industrial science is rooted in the slick & snazzy, error-fearing philosophy, the conceptual science is its exact opposite – it is messy, disheveled and unruly, yet from chaos, everywhere and at all times, do the starriest ideas spring to life.⁴⁸ This "conceptual" science stems from the awareness that the closer we find ourselves to that seminal stage at which creative ideas are being born, the greater the probability of faults and errors. As a result, many of the new concepts put forth will be destined to demise, yet, as Dirac would have advised us, the beauty of these ideas counts more than their sooner or later refutation by the crude empirical facts.

In 1818, at the dawn of romanticism, Caspar David Friedrich painted a painting known as *The Wanderer above the Sea of Fog*, showing an artist with his back turned to the viewer, standing at a rock formation and gazing at the misty landscapes before him. The rocks he stands on are known as Kaiserkrone and the view is that of the Elbe Sandstone Mountains, albeit, surprisingly, unreal. Namely, the painter did not paint the landscape exactly as it looks from these rocks. Instead, he took the different elements of it and rearranged them in his studio. Then, seventy years later, in the painting known as *The Starry Night*, Vincent van Gogh accurately depicted the view from the window of his bedroom at the lunatic asylum in a village near Avignon in southern France except for one detail: a completely imaginary, nonexistent village occupying the right bottom portion of the painting. Why Caspar and van Gogh did this remains unclear, but in the context of this discussion, this raises questions as to how important it is that our experimental findings fit the reality, if at all. Perhaps, what is more important if we aspire to create science that will resonate with the people as strongly as these two memorable paintings did – used to this day as frequent covers for books and illustrations for encyclopedia entries on the Romanticist and Expressionist movements in art, respectively – is for the work to come out of the heart, paying no heed all the while as to whether it will be a truthful portrayal of the real state of things or not. For, if Dirac

⁴⁸ Nietzsche 1883, Prologue, n.p.

alleged that beautiful theories need not necessarily match the experiments, then it is conceivable that research conducted with the prime goal of eliciting its beauty likewise need not conform to reality at all costs. This, of course, is by no means an excuse to falsify the research findings or approach experimental work in a nonchalant manner; rather, it is to emphasize that research can be impactful and drive the progress of science toward more prolific and creative territories when it is focused on simply being beautiful, even at the cost of neglecting its compliance with reality, than when it is rigorous and accurate but in disregard of this aesthetic element. Be that as it may, it is the fact directly derivable from Dirac's principle that even experimental results deliberately rearranged but obtained by following an utterly inspiring original method and stemming from a strikingly inventive and beautiful idea may hold a greater significance for science as a whole than findings that are accurate and pragmatic but derived from the bedrock of insipid old paradigms.

But how exactly can one such science primarily focused on its aesthetics be meaningful for the progress of science *per se*? For one, science that is intrinsically beautiful has the potential to inspire and thus act as a powerful motivational tool, recruiting a plethora of creative stars in the making. Tired stars, too, can have their creative juices shaken when they come face to face with works that strike the aesthetic chords inside them and reshuffle their inner structure. Second, beauty in art, as well as in science, resonates strongest when it also satisfies the criterion of originality, meaning that science that has the aesthetics of art to it should have the ability to awaken today's scientific culture from its deep sleep in a state of dull, prosaic and lackluster obedience to the paradigms and pursuance of the inert stream of trends. Science that is beautiful also teaches implicitly how science could be approached with the heart and not just the brain, which could lead to more complete mindsets to be preoccupied with science, as opposed to purely analytical, single-hemisphere frames of mind with which science is being practiced today. Whether scientists are motivated to do science because of its pragmatic goals or because of the fondness of the mysteries of basic science, there are humanistic elements underlying this motivation and they are being nourished through recognizing and fostering this artistic side of science. Note that these are only the effects that come to mind off the top of this slovenly head, and there is always more to the picture than meets the eye.

Here, a connection could be made with the discovery vs. justification dichotomy proposed by the UCLA philosopher, Hans Reichenbach in the 1930s.⁴⁹ According to this distinction, whereas science in the context of discovery benefits from the stochastic probing of myriads of possible theories guided by the aesthetic principle, science in the context of justification is required to adopt a more rigorous and normative perspective in order to adequately parse through the probabilistic outcomes of the discovery process and single out the most viable theories. Whereas the latter component of the evolution of scientific thought is highly rationalizable and grounded in exhaustive experimentation and standardized decision-making, the former belongs more to the realm of creativity that stems from intuition and aesthetic senses. Because of this intangibility of the scientific thought governing the process of discovery, Reichenbach went as far as to propose that justification of developed theories is the only component of the scientific practice that is susceptible to logical reconstruction by the philosophers.⁵⁰ For him as well as for the logical empiricists at large, it is the only segment of science that complies with Hume's matters of fact so that empirical skepticism can be applied to it coherently.⁵¹

⁴⁹ Reichenbach 1938, p. 21.

⁵⁰ Reichenbach 1951, p. 231; Schickore, Steinle 2006, p. vii.

⁵¹ Howard 2006, p. 4.

Naturally, the conceptual science, as envisaged here, given its role in proposing inventive new concepts while ignoring to engage in rigorous testing of the scopes of their validity, is such that it resonates intensely with the discovery pole of this so-called context distinction and very little with the justification pole. If the distinction between thinkers and workers lurks underneath the context dichotomy, the conceptual science credos tend to naturally gravitate toward the former. On the other hand, by eschewing the logical in favor of the empirical, the principle of conceptual science implies that creative practice is what expands the scope of inventive insights. Flexing the norms surrounding the scientific practice by conceiving of and experimenting with new methods and ideas, accordingly, constitutes the path toward the enrichment of the intellect. Hereupon, the gap between the idealists and epistemologists on one side and pragmatists, naturalists, operationalists, experimental realists and late Wittgensteinians, all of whom have sought to anchor the philosophical meaning of science in its practice,⁵² becomes bridged in a blink. Here is how the loop between the doers and the philosophers becomes closed so that whichever the side the wheel becomes spun, we could be certain that it will move not only itself, but also its complement.

In all, Paul Dirac touched upon the complementarity between reason and aesthetics when he proposed that scientists in their derivation of formulae that describe the physical reality ought to satisfy the aesthetic thirsts within them rather than try under all circumstances to have them match the experience. What is particularly interesting here is that it was never Dirac's intention to create any sort of room for the inflow of art into the province of science; rather, this came through the partial misreading and misinterpreting his ideas. Moreover, Dirac's idea, like Hesse's glass bead game, classical thermodynamics or the propositions of quantum mechanics, was rather convoluted and not perfectly concise. Yet, exactly because it was vague, it invited me to ruminate over it over and over again, for many days and decades. These ruminations led to daydreams and daydreams led to accomplishments of something original and new. So let me briefly exemplify what I mean by beautiful scientific research with a couple of examples from my personal oeuvre as a researcher.

First of all, the earlier mention of Gregory Bateson and his idea of "the pattern that connects"⁵³ was not just a passing reference. Rather, it signifies the commonality of relationships observable in different systems and at different scales and stands at the gateway to what is nowadays known as systems science, that is, science of relationships applicable in a vast array of systems, ranging in complexity from eukaryotic cells to human bodies to biospheres to swirling galaxies and stars. The reason is that analogies, which Bateson's concept encompasses, are the keys to recognizing the beauty of many research projects and ideas, which I will illustrate now with a couple of examples. For one, there is earthicle, the world's first microscopic particle modeled after the structure of a celestial body, in its case the planet Earth. The idea for it came to me as I sat in the colorful second-floor guestroom of the Lincoln Hotel in frosted Chicago on one of the first nights of 2014. After a couple of years of mostly unsuccessful attempts to synthesize the earthicle and then a year or two of more successful ones, these particles were reported in a publication⁵⁴, which attracted mostly dismay and disparagement from the scientific community, primarily because of the unorthodox analogy intrinsic to its design. Yet, it is this analogy that presents the basis for recognizing the aesthetics of this idea,⁵⁵ which can be so immense as to eclipse the importance of whether 100%, 50% or 1% yield of earthicles in synthesis batches were obtained or of whether the ratio of the thicknesses of cores, mesolayers and shells is equivalent to

⁵² Chao, Reiss 2017, p. 4; Anon. 2025, n.p.

⁵³ G. Bateson 1979, p. 8.

⁵⁴ V. Uskoković et al. 2017, p. 1305.

⁵⁵ V. Uskoković 2020b, p. 1843.

those comprising the Earth. Moreover, the testament to the greater weight of the concept than that of its proof oftentimes comes from the impact this concept can have on its parent field of science. Thanks to the idea of the earthicle, for example, astromimetics, a field of science complementing biomimetics, psychosomimetics, andromimetics, radiomimetics and other mimetics, was born around this time.⁵⁶

Other research where an aesthetic analogy lurked may include that where I demonstrated for the first time that reverse micelles as reactors for running chemical precipitation reactions are not passive walls that confine these reactions into small spaces, as it was widely believed at the time,⁵⁷ but rather fine structures that have an active influence on the pathways that these reactions will follow and the products that will be obtained.⁵⁸ Another example may be research where I showed that amelogenin, the main protein of the developing enamel matrix does not act as a hindrance to the crystal growth, blocking the growth of faces on which it adsorbs, as the authorities in the field back then held,⁵⁹ but that it instead channels the growth units to the right sites on the crystal surface.⁶⁰ Notwithstanding that there is quite some beauty in research that topples the dominant paradigms, no matter the means, there is also something beautiful when we learn, through an analogy, that what used to be thought of as a wall is, in fact, a bridge, a channel, a connection between things. Despite the limited, albeit finite, evidence in favor of this alternative mechanism of growth, the beauty of it is, again, as in Dirac's opinion, of greater importance than whether the concept is supported by tons or tads of evidence.

In analogy with Dirac's expectation that a beautiful theory should invite enthusiastic peers to probe its secrets and thereby discover extraordinary empirical phenomena, research based on a beautiful idea, content or form should have the power to inspire the fellow scientists to explore it deeper and refine it. Such was the hope, for example, behind the new concept for cancer therapies I proposed in 2023,⁶¹ after 7 years of vain hope that the opportunity to test this concept more thoroughly would arrive. Namely, the idea was based on the inversion of the classical approach to treating cancer by trying to eradicate the malign tissue while leaving its healthy counterparts intact. Accordingly, it was hypothesized that incorporating anti-apoptotic properties in healthy cells and promoting tumorigenesis in cancerous cells would present a more viable approach to slowing down the growth of cancer and eventually integrating, if not dissolving, it with its healthy niche. This proposed mechanism at the molecular biology level was derived from a broader idea, which is that cancer, alongside all other existential disturbances, should be best curable by being loved and nurtured; hence the method of empowering it via enhanced tumorigenesis and via having the healthy tissues copy it and becoming more anti-apoptotic, as all subjects in love do – they mimic the objects of their affection⁶² and give them what they crave. Yet, without the financial and logistical support for this study, it remained at the level of a few rudimentary experiments and an idea as bold and grand as an idea could be.

Sometimes context is required to recognize the beauty of a scientific work and one example may be that of the research on flowers I undertook with my children in the spring of 2018, in the wake of the most shocking moment of my scientific career: my excommunication from academia

⁵⁶ V. Uskoković, Wu 2018, p. 1.

⁵⁷ Tanori, Pileni 1997, p. 639; O'Connor et al. 1999, p. 65; Pileni 2003, p. 145.

⁵⁸ V. Uskoković, Drofenik 2005, p. 168.

⁵⁹ Iijima et al. 2002, p. 69; Margolis et al. 2006, p. 775; Palmer et al. 2008, p. 4754.

⁶⁰ V. Uskoković et al. 2011, p. 106; V. Uskoković 2010, p. 45.

⁶¹ V. Uskoković 2023a.

⁶² Duffy, Chartrand 2015, p. 112; Kämpf et al. 2018, p. 131.

on the grounds of being a left-wing radical who challenged the oppressive and exploitative, neoliberalist business model of academic labs in his role of the senator and the most scholastically productive faculty member of the school. Society, however, irrespective of its sphere, has little tolerance for the dissident⁶³ who dares to speak the truth when not many would want to hear it, who champions justice in the midst of an epidemic of unfairness, and who would, like myself, give away a comfortable life in the shade of the palm trees to defend the notions that are as old as the veins of philosophy running through the heart of the human race: justice and truth. Suddenly found “on the street”, though, my decision was firm: teaching is not to be confined to academic institutions; rather, what better way to show one’s dedication to this professional call than by continuing to engage in educational activities and inspire the learners when it seemed least possible, even under the open skies, in parks and playgrounds. Furthermore, biological models involving tissue culture, insects and small mammals that I worked with on the daily basis up to that point could not be practiced anymore in such natural ambiances; instead, objects that are alive and that would respond to a treatment in reasonable spans of time and in ways that would be measurable using modest characterization means at hand had to be found as substitutes. These criteria excluded a number of biological structures that proliferated in the environment, but two living things did prove satisfactory: birds and flowers. And so, in the summer of 2018, I engaged children in the study that tested wildflowers plucked from the neighborhood as cost-effective *in vivo* models for assessing biocompatibility and antibacterial activity of fine particles. To the best of my knowledge, by the end of the summer this became the world’s first model of this kind that utilized the flower petal morphology as the biocompatibility metric, and when it was published, two years later, it gave the opportunity to my then four year-old daughter to become the world’s youngest coauthor of a scientific paper⁶⁴. She was engaged in measuring the dimensions of the petals with a ruler, organizing the flowers in the test tubes and plotting the little tables with data, which were filled by her older brother, another coauthor of the study. The recognition of the educational potential of this study came a couple of years later, in 2023, with the release of a description of this model in the journal dedicated to inspiring young and aspiring scientists, who act as its only “peer” reviewers.⁶⁵

But this, really, was only the beginning and what happened in terms of the scientific output of relevance for inspiring young, starry-eyed scientists in the years to come went beyond my wildest dreams. A number of studies carried out and produced through the adversity of permanent and permanently failing search for academic and nonacademic employment spoke about the resilience of the human spirit and of how the desire to create new knowledge could overcome even the sturdiest of obstacles. Space here is too limited to describe each of these studies in detail and so I will limit myself to the so-called theatrical trilogy only. The prelude for it took the form of an imagined dialogue of two jobless scientists on the brink of existence, evoking Beckett’s *Waiting for Godot*⁶⁶ and referring to its lines all throughout the review article⁶⁷, which was written for the occasion of the 250th anniversary since the discovery of calcium phosphate, the material that had stood in the center of my research attention for many years until then. As for the trilogy, however, its protagonists were a family of four and it veritably described the research I conducted with my children between 2018 and 2023 in our backyard, bedroom and neighboring parks. It started with

⁶³ Cukić 2024.

⁶⁴ T. Uskoković et al. 2020.

⁶⁵ V. Uskoković, Wu 2023.

⁶⁶ Beckett 1953.

⁶⁷ Wu, V. Uskoković 2019.

the Mpemba paper in 2020,⁶⁸ moved on to the Brazil nut paper in late 2022,⁶⁹ and ended with the writer's block, birds-in-cages paper in late 2023.⁷⁰ The beauty of each of these research projects is elaborated in detail in their respective papers, including (i) that tied to the philosophy of poverty emerging from the attempt to figure out what causes the peculiar Mpemba effect observed in the poorest, yet also the richest of all liquids, namely water, which freezes faster when it is hot than when it is cold; (ii) that tied to the ethics of falling stemming from seminal research on the Brazil nut effect in colloidal systems, which predicts that the lightest particles in a mixture would sink to the bottom while the heaviest would emerge to the top; (iii) that tied to referencing birds as saviors for our souls, in sciences and beyond, in parallel with the search for the exit from the state of writer's block and from the sense of confinement in the same old boundary conditions outlining the features of our experience, alongside probing countless other fine aesthetical points. What made me fall in love with the idea of structuring scientific research papers in the form of theatrical plays was not only the subversive revolt against the reigning conservatism of scholarly expressions that spoke from them and not only the decades of nostalgia over the leisured philosophizing in Socratic days, but also the realization of how more naturally and accurately the collisions of different points of view represented by the different characters in the play reflect the creative thought process going on in the head of a researcher pursuing the scientific method as compared to virtual monologues comprising the stereotypical scientific papers of the day. In other words, papers written as plays do not only allow for literal playfulness to enter the traditionally conservative, stiff and deadpan serious content and structure of scientific papers, but they also allow for the dialogues to act as a means of producing fecund juxtapositions of contrasting points of view. Hence, when traditional papers are written to strengthen a single or a few arguments at hand, in a play a character may challenge the arguments proposed or defended by another character, thus creating conditions for dialectical syntheses at one time and deductive syllogisms at another, which more veritably reflect a creative thought process than the comparatively dogmatic and defensive reiteration and reinforcement of a single perspective does.

What is essential to note here is the power of the studies comprising the theatrical trilogy, like that of many other ones conducted at around the same time, to inspire and motivate young people for a career in sciences – not just any career, but career rooted in humanitarian values and aspiring for critical thought and creativity, something that is desperately needed in today's materialistic and callous corporate climate in sciences and technologies. My motivation to devote life to this humanization of natural sciences through works like this has sprung from a lifetime of observing and sensing how young spirits enter this domain as beautifully sensible and exit it as bitterly tyrannical, the transition that, in my eyes, has had largely to do with how dry and prosaic the scientific paper, the major form of expressing and communicating scientific ideas among scientists, has been by convention. Yet, to provide aesthetic inspiration that is to ennoble and uplift the careers of newcomers to the world of science has been possible, as it turns out, only insofar as one's own career acts as a counterweight, dragging one deep underwater. Namely, although the dire existential conditions under which these studies were conducted and completed, during which no paid academic posts were held and endless rejections were experienced, did provide the right context for elevating their aesthetic power, this was by no means a boost to a career in sciences; rather, to create all this without a steady academic position was perceived as the sign of fanaticism,

⁶⁸ E. Uskoković et al. 2020.

⁶⁹ E. Uskoković et al. 2023c.

⁷⁰ E. Uskoković et al. 2024.

which is a big turndown in any profession where the will to conform and belong is prioritized over the will to create and inspire.

One major structural feature that is common to this trilogy is that all three pieces of it have created new forms of expression for the medium that the scientific paper is, and this is where the commonality of these studies with conceptual arts becomes important to discuss. Namely, in conceptual arts, the concept exceeds in importance the content and very often very plain creations earn the highest accolades only because of the innovativeness of their conceptual message.⁷¹ To describe scientific research in a novel form, therefore, can be endowed with and praised for a very vital aesthetic. These novel forms of expression have included the aforementioned research papers written as theatrical plays; the world's first research paper written in a stream of consciousness, containing also a short poem for the conclusion;⁷² a series of papers written as reality papers, documenting the search for a research idea in a diary format and in real time;⁷³ a paper composed of figures only;⁷⁴ a paper intercepted by the children's play triptych;⁷⁵ the first fully Dadaistic, absurdist paper;⁷⁶ the first research paper written in free verse;⁷⁷ and so on. Common to all these cases, as we see, has been the use of art as a guidance in conducting scientific work; hence the term "art in science" as an appropriate description of the type of merger between science and art that has been at work here. This prioritization of the beauty of research over its practical potentials, it should be mentioned, is particularly suited to those who, like myself, view science through the eyes of an artist. This may be a curse or may be a blessing, but one such artist lost in the world of science I am and this will not change for anything in the world. This unorthodox worldview, after all, has led to all this extraordinary work on innovating the scientific paper as the major form of expression amongst natural scientists; it was also a work that, in my opinion, has the power to the inspire the young and enthusiastic scientists and also touch them, deeply, the way only profound works of art and extraordinarily innovative scientific thought can do. This connection with arts and humanities has been essential all throughout my career as an academician and a researcher.

The absence of research funds, interestingly, proved crucial in enabling this type of work, in such a way that the missing access to sophisticated experimentation and workforce has been compensated with detours into aesthetic territories. Research studies backed with typically two years of benchwork and massive amounts of data were no longer possible and had to be swapped for studies where inventive ideas and/or methods of presenting them stand out over lavish experimentation. This lack of resources also naturally led to the shifts of attention to fields that would not have been otherwise considered as possible or appropriate to do research in. For example, when daily goings to wet chemistry and biotech labs were substituted with standing in the backyard and listening to birds, it became natural that birds be considered as possible subjects of research, especially when the major goal shifted from that of satisfying the practical goals of conventionally funded research to that of making research conceptually beautiful. An exemplary project that resulted from this shift of attention was that performed to assess whether feeding birds by pairs of feeders, who are alive and who stand near each other, would have a different outcome on the closeness of the avian aggregates than when they are being fed by solitary feeders.⁷⁸ The

⁷¹ Honnef 2004, p. 74; Mink 2016, p. 18; Weschler 2009, p. 32.

⁷² V. Uskoković 2022a.

⁷³ E. Uskoković et al. 2022b; 2023a; 2025.

⁷⁴ E. Uskoković et al. 2023b.

⁷⁵ E. Uskoković et al. 2022c.

⁷⁶ V. Uskoković 2025.

⁷⁷ T. Uskoković et al. 2024.

⁷⁸ E.W. Uskoković et al. 2022a.

study turned the children's habit of feeding coots and ducks by a lake into an original experimental plan and was performed for the most part in early 2020, in months preceding, almost prophetically, the COVID-19 pandemic. And so, when people started distancing from one another in March 2020, I held in my hands the findings of the study that showed how bringing two individuals, in this case bird feeders, together could alter the birds' psyches at some subconscious levels and promote their own coming closer together. This was, implicitly, the call for people to get closer to one another, the call that is nothing short of beautiful to those who believe in harmony, friendship and love. From this beauty stems the hope that through one such simple act of two souls' getting nearer to one another, many of the disparities reigning in the world today could be spontaneously healed. Because in a digital world where the pandemics such as COVID-19 come and go, while the epidemics of indifference and of inimical disconnect tear the social fabric at a deeper level, the healing may start from the humans', wordlessly, making as little as a step toward one another. Studies have repeatedly shown that the use of smart phones and the immersion in virtual reality experience, which are nearly universal today in one form or another, increase distances between people, both emotional⁷⁹ and physical,⁸⁰ yet by knowing that it takes only two people to come nearer one another to create a social chain reaction of recovering the intimacy between people, the positive change could be brought about with simplest and least conspicuous of means. As far as the science of proxemics⁸¹ is concerned, which studies for the most part the spaces people set between themselves and others and which has recently been busy answering the questions such as how to automatize the estimation of interpersonal distances in images to detect violations of social distancing measures,⁸² how these distances affect psychological perceptions in business-customer relationships,⁸³ how to best manipulate with the feelings of a neighboring human by controlling spacing in communication,⁸⁴ how to adapt behavior of robots to social circumstances while respecting distances between people⁸⁵ or how to design alert systems to notify virtual reality users about the presence of non-immersed bystanders,⁸⁶ the beauty of the experimental setup employed and the findings derived in this bird-feeding study where children were the prime actors can open whole new avenues for research, evidently more soulful and fanciful than those pursued by the mainstream researchers in the field.

Importantly, poverty as a condition under which excellence in science is being strived after teaches one naturally how to recognize a lot in a little. To celebrate this point, alongside the role of intuition, spontaneity and many other subliminal drivers of creative thought in natural sciences, a study was conducted that tested how many relevant and inventive insights could be derived from one and only image of a sample captured randomly under an atomic force microscope.⁸⁷ Other studies that stemmed from the bedrock of poverty and had this primordial element of beauty in them were those where this systematic shortage of resources inspired the search for more economical and simpler means of achieving some practical aims. One example may be that of tackling the concept of functionalization of advanced materials, which normally implies the chemical bonding of their surface to particular organic molecules that would interact specifically

⁷⁹ Allred, Atkin 2020.

⁸⁰ Kim, Sung 2024.

⁸¹ Hall 1966.

⁸² Aghaei et al. 2021.

⁸³ Song et al. 2021.

⁸⁴ Reed 2021.

⁸⁵ Daza et al. 2021.

⁸⁶ Medeiros et al. 2021, pp. 21–30.

⁸⁷ V. Uskoković 2020a.

with a target.⁸⁸ What I demonstrated in one study,⁸⁹ however, was that such functionalization could be achieved by much simpler means: for example, by aging the material in a mixture of water and alcohol at a suitable ratio thereof. In fact, a number of different physical and biological properties of the material can be controlled in a tunable manner by adjusting the degree of surface disorder via simply setting the ratio of water-to-alcohol in the medium. In such a way, costs of functionalization can be significantly reduced, creating lesser ecological footprints and toxicological concerns as well, while the process is also more readily translatable to the underdeveloped and developing communities and regions of the world.

In fact, the design of new technologies with the emphasis on their potential to be translated across the rich-poor divide has naturally become the subject of personal interest during the probing of these particular aesthetic territories in the vast kingdom of science. Aside from conceiving of models for quantifying this degree of translatability⁹⁰ or revealing the lack of translatability of medical formulations as essential as the COVID-19 vaccines,⁹¹ the paramount beauty in this research intending to bridge the gap between the rich and the poor was displayed by two studies I carried out in the first summer of the COVID-19 pandemic,⁹² where a whole new meaning was given to the term “ethnoscience”. Namely, while this term was until then mostly used to denote problem-solving skills, if not scientific methods *bona fide*, devised by the old and/or the forgotten ethnic traditions,⁹³ the research I conducted that summer showed how forgotten arts or skills practiced in the various developing societies throughout the history, which need not be strictly scientific, can be converted to contemporary scientific methods of practical significance and thus, tentatively, rescued from oblivion. In two studies from this period, the ancient storytelling method that was practiced in parts of West Africa and that involved drawing lines in the sand and the ancient seafaring methods used by canoe voyagers from different islands in Micronesia were converted to methods for predicting the fate of cancer cells subjected to a nanoparticle therapy. As in agreement with Dirac’s principle, more important than the evidence of feasibility was the implicit beauty of the approach, through which a hand was being handed to nearly extinct traditions in the attempt to save them from decline in the rapidly globalizing world, where monotony of cultural worldviews is an ever present rule and diversity, despite the lip service of scholars and politicians, an exception and a hindrance to the shortsighted goals of neoliberal swindlers who run the science show behind the scenes.

As a matter of fact, there has been a number of research studies that I carried out in the past that had a social responsibility element intrinsic to them, primarily in terms of the intention to bring together communities that stood divided because of various political reasons, the objective that, to the socially aware, represents a rarely beautiful one. One of those studies became the first collaboration between Serbian and Albanian scientists from Kosovo in 25 years since the Kosovo War in the late 1990s.⁹⁴ At that time, the only state university, the University of Priština, split into two, as its campus in the capital of Priština became populated solely by the Albanian academics while the campus in exile at different locations, primarily in Kosovska Mitrovica, became populated strictly by the Serbian scholars, and there had been not a single collaboration between

⁸⁸ Pinelli et al. 2020, p. 6; Tian, Zhou 2021, e1668; Li et al. 2021, p. 102479.

⁸⁹ V. Uskoković 2022d, p. 129676.

⁹⁰ V. Uskoković 2024a, p. 4489.

⁹¹ V. Uskoković 2021, p. 1203.

⁹² V. Uskoković 2022b, p. 27; 2022c, p. e12035.

⁹³ Lightner et al. 2021, p. e37; Abonyi et al. 2014, p. 52; Bishop 1990, p. 51.

⁹⁴ V. Uskoković et al. 2022, p. 122065.

them in the 25 years that followed the breakup. The collaborative study I organized in the early 2020s, thanks to the goodwill and braveness of two extraordinary individuals on these two sides, however, became a precedent in the history of relations between these two nations. It sprang from a quixotic hope that one such work may become a spur for bringing these divided nations together, something that we, teachers and scientists, can achieve, in my opinion, better than politicians can. Another example may be a study on a colloidal chemistry phenomenon inspired by the coffee-making process common in Bosnia and Herzegovina. The study was performed in such a way that the research was entwined around the discussion of how coffee-drinking culture has become a source of reconciliation of Bosnian Serbs and Bosnian Muslims in the wake of Yugoslav civil wars.⁹⁵

The third and the final example of this aesthetics of socially responsible research can be a study on a particular physical model invented by the Russian-Ukrainian materials scientist, G.V. Samsonov.⁹⁶ The study,⁹⁷ which was inspired by the idea to reach out with it to intellectuals in these two countries that were at war at the time and inspire them to find a common and peaceful way forward, managed to demonstrate a considerable historical closeness of the western world during the Cold War to scientific ideas coming from Eastern Europe, irrespective of whether they originated from Russia or from Ukraine or from other countries of the Soviet Union, thus crushing the commonsense belief that science is objective and knows of no flags of nations or cultures. In reality, which science emerges to the top of the social pyramid and which is relegated to the bleachers or plunged to the pits is defined not by its objective excellence, but by various human biases, ranging from personal preferences for certain subjects or methodologies to territorial instincts for survival of one and one's relevance within a profession to racial, ethnic, gender and other discriminatory prejudices to simpler matters of taste. This conclusion reiterated the findings of my earlier work, which I have christened the world's first anticolonial materials science paper⁹⁸ and in which I showed how the wealth of the countries presents a greater determinant of the extent of the spread of trends in materials science and engineering than their objective propensity for innovation and technological translation. Not coincidentally at all, the first presentation of the findings of the study pertaining to Samsonov's configurational model was given a few weeks after the onset of the invasion of Ukraine in early 2022, at a scientific conference in the country's capital, Kiev. To a child of war that I am, who lived through formative years as a scientist immersed in a decade-long civil war conflict, the potential of scientists to resolve geopolitical issues that seemingly exist outside of their spheres of influence should never be underestimated and holds a special importance in my personal pantheon of ethical and aesthetical engagements. Besides, to stop the tears and substitute them with smiles is the goal of all art and science and all their mergers, from the more abstract and the idealistic to the more positivistic and the practical.

Last but not least, almost all of the aforementioned papers present belletristic writings and the totality of their aesthetic content cannot be reduced to these succinct descriptions thereof. Rather, to experience this aesthetic, one must meet these works directly and independently of their author's synopses provided here or elsewhere, for there is a greater probability that they will act as spoilers and detractors than that they will serve as facilitators of comprehending these works in the best possible light. This makes me settle at the end of this discussion on a disclaimer in the form of that oft-cited response Isadora Duncan, in whose footsteps I tiptoed around the Warwick

⁹⁵ V. Uskoković 2024b, p. 790.

⁹⁶ Samsonov et al. 1973, p. 7; Vasilkovska et al. 2018, p. 3.

⁹⁷ V. Uskoković 2023d, p. 106.

⁹⁸ V. Uskoković 2020c, p. 11443.

Square last October, gave when she was being asked to say what her dance meant: “If I could tell you what it meant, there would no point in dancing it”.⁹⁹ After all, each of these works used to illustrate what beautiful science may amount to was intellectualized as much as it was danced out, with the improvisatory spontaneity of a performance artist or a child at play, who touch the heart gently as they go.

6. Conclusion: beauty before all

The central argument I have propped in this partially autobiographic article is that any of the various aspects of research, spanning from the hypothesis to the concept to the methods, can be treated in the same way as Paul Dirac, the theorists’ theoretician, approached the theoretical work in relation to its experimental counterpart. Their beauty, namely, should be considered as more important than whether they do or do not conform to the empirical evidence. This opens up whole new aesthetic territories before us and allows for the inflow of countless authentically artistic points of view to fertilize scientific thought and supposedly yield ideas that are otherworldly imaginative and significantly more creative than the ideas preoccupying the attention of the scientific community today.

The irony that must be noted here is that one Paul Dirac, who, we have seen, was an exceptionally reticent and prosaic individual, with no noted interest in arts, created an inspiration for this translation of his “beauty” principle into a broader concepts, which, like a rainbow, extends a newly found aesthetics across the entire kingdom of science, starting from its core, where that elusive treasure at the end of the rainbow awaits the eager seekers and the seers. This irony where the prosy has become an inspiration for the birth of something poetic, in fact, can be a reminder that beauty, indeed, lies in everything. Regardless of whether, say, scientific research satisfies some of the relatively broad aesthetic criteria elaborated in the previous section and deserves accordingly to be called “beautiful” or it does not, it will always contain infinite beauties in it for those whose eyes can recognize them. It is one such pair of eyes that the future extensions of the viewpoints shared here is to be bred. Because beauty, really, is a multifaceted notion that can mean different things to different sentient standpoints, and it also always lies in the eye of beholder, meaning that it can be perceived in anything, absolutely anything.

Yet, as of now, we are very far from the times when this accentuation of aesthetics in natural science research will be considered normal. Today, one such viewpoint appears so eccentric and radical that any practitioners or supporters of it would be classified as heretics and, like myself, ostracized, mobbed and persecuted by subtler, less centralized and more democratic means than those employed by the Inquisition or secular courts from 13th to 19th centuries. However, as my own experience has taught me, the outcome is, more or less, the same: an expulsion from the profession and the suppression of the freedom to work as an independent scientist. However, everything is a vicious circle and the fact that the ideas propped here do not resonate with people yet is simply due to the fact that there are no avid followers of this particular form of fusion of science and art, which, in my opinion, represents the purest of all versions of this merger practiced today. Both the followers and the faith of the fellow scientists in the validity and the value of the ideas presented here and of the research used to exemplify them are difficult to earn when one is forced to publish these ideas in low-impact journals, the content of which has been casually assumed to lack originality, rigor and inventiveness. As a result, in these times of pervasive plagiarisms, superficial assessments of scientific outputs and the aforementioned lack of literacy

⁹⁹ White 1998, p. 92.

in humanistic roots of natural sciences, these works are destined to become covered by the thick layer of prejudice that they are all that they are not: conceptually derivative, banal, and of low scientific quality. Years upon years of coping with such shallow assessment have been difficult to live through, although on a more positive note, I have been aware that this has created a powerful potential difference for the sustainment of all this creative work, which may have been lost if circumstances suddenly became favorable and the recognition of the community won. Conditions, after all, are never ours to choose, but it is our duty to work our best under them, however unfavorable they seem.

Before I sign off, I owe to the reader and to myself one more revisit of the beginning of this article. Namely, if I were interrupted in the work on my first research paper¹⁰⁰ and brought back to the classroom table to face the examiners and discuss Dirac's principle amongst other concepts in philosophy of science, how would I feel? The academic experience was always a wall to be surmounted and a gate to be unlocked with a key tripped upon in an unlit underground corridor, and this would not change by a slightest bit, but would the view from the top of this wall and beyond the gate look any different? Would I have taken an altered, more conventional route had I known of all the travails and humiliations I would face on the road I have chosen to follow – the road toward the horizons of unified science and art in the way that no one thought of or tried out before? The answer, however, is a clear, “No, I would do it again”. A different I in different times and under different existential circumstances would, of course, give a unique twist to things, but the destination journeyed to would be, I believe, the same, namely that of trying my best to reinstate beauty in the center of the kingdom of science and crown it its queen, to rule over this kingdom together and evenly with the king of rationality. Accordingly, all this forced descent into poverty and isolation would have been embraced wholeheartedly again, simply because the goal of all this adventuring through the mystical land of science, where lasting truths about wonders of the physical world intertwine with sociological and philosophical perspectives, has been spiritual, not careerist and not driven by the thirst for material wealth by any means. And if one is eager to search for the soul of things, in science amongst elsewhere, then one must be prepared to discard the material shell wrapped around the soul and proceed with a translucent attitude, as vulnerably as this can make one. As gentle and deliberate steps are being made, toxic arrows will fly at and around one from all sides, but the resoluteness of the spirit will increase in scope as we continue the footfall. Because if we do not walk this way, no one else in a foreseeable timeframe will, and the awareness of the uniqueness of this effort is sufficient to give us wings and ensure that our strides are never brought to a halt.

In the end, the take home message of all this is remarkably simple. It resonates with the line that served as a guiding light for a quixotic visionary conjured by the pen of Fyodor Dostoyevsky: “Beauty will save the world”.¹⁰¹ Beauty, as we can conclude now, is a multidimensional concept and it may mean different things to different people: a sleek numerical solution to a mathematician, an elaborate experimental setup to an engineer, an elating combination of color and geometry to a visual artist, a moving metaphor to the lyricist, a plush doll or a broken crayon to a child. However, that is nothing to cry about; rather, it is a thing to celebrate because the notion as precious as beauty should always live and change and adopt different forms from different perspectives and in different times. This infinite, multifaceted nature of it is perhaps the best testament to its value. And for as long as it is placed and nurtured at the center of our creative attention, there is a chance that nothing we attempt to do in the big picture will go amiss.

¹⁰⁰ V. Uskoković et al. 2003.

¹⁰¹ Dostoyevsky 1869/1913, pp. 318, 438.

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