Understanding The Aesthetic Values Based On Scientific Theories

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Abstract: This aims of research is to explore how to define the beauty of scientific theories for scientific education. Theories have the following requirements in common. First, they represent values as a kind of objectivist beauty and aim to expand and integrate new knowledge into simple forms. Second, they share objectivist beauty. Usefulness as a non-human value and the transition as subjectivist beauty can enhance psychological elements that heightens the experience of the values that constitute the beauty of scientific theories. We will discuss what values are involved in the evaluation of the aesthetic beauty of scientific theories. Then, we will investigate how such aesthetic values influence the development and motivation of scientific theories.
Keywords: the beauty of scientific theories, integrative, simplicity, transition, aesthetic values

INTRODUCTION

It is commonly understood that science and art make a heterogeneous pair. Science is a rational discipline that treats objective facts. Science is said to be subjective and treat subjective feelings. Science is about the empirical evaluation of the world, whereas aesthetics is art (Montano, 2013, p. 133). However, Steven Weinberg made an apt comment: 'Einstein's theory of general relativity and Newton's theory of gravitation are equally beautiful' (Feynman and Weinberg, 1999, p. 107). Furthermore, well-known scientists like Paul Dirac (1980, p. 10) supported the thought that the beauty of theories plays a crucial role in the advancement of science. Sometimes, scientists describe their work as beautiful. They often cite beauty as what motivates their work. Poincaré (1946, pp. 366–367) said, 'Scientists do not study nature because she studies her because they like her. We enjoy and rejoice in beauty. Such intellectual beauty brings certainty and strength into wisdom.'
These arguments suggest that creativity and aesthetic values play a crucial part in the formation of scientific theories created by scientists (Chandrasekhar, 1987; Dirac, 1963; McAllister, 1996; Poincaré, 1946; Tauber, 1997; Wechsler, 1978).
In this study, we aim to explore the beauty of scientific theories, focusing on inner theoretical values of the cognitive values of such scientific theories. First, we examine the aesthetic theory by James McAllister, a philosopher of science, to see how cognitive values have influenced the transition of scientific theories to good theories, and how they form and motivate scientific theories. Then, we will look at the work

of the aesthetic experience of transition in philosophers and educators' quest to change the world.

Subjective and Objective Properties of Good Scientific Theories

Value is not merely a term that refers to an entity, but it is an evaluative concept. The sensational entities that we call data, regardless of their ideals or conceptual components (such as logical and scientific laws), are not values. Value itself is not an entity but an evaluation given to such an entity by a subject. If such values can be classified as relative and universal, they can in turn be divided into internal and external values. Let us examine the value of scientific knowledge. This value is not external, it is relative; it is simultaneously internal and universal. Even if scientific theories were used to build a machine, the joy of understanding such theories is self-evident.

However, value is inevitably external, that is, instrumental. If knowledge can be compared to shedding light onto darkness, then its joy and value is not focused on the source of the light. Instead, it is about the help the light brings into our daily lives. Perhaps, this is extreme pragmatism.

However, the joy diminishes when we understand the difficult principles of physical phenomena or a tough mathematic problem. Such internal values are not relative but universal. In spite of the differences, they are human values. As far as knowledge is concerned, the brighter the light is, the more joy people commonly feel. Therefore, the value of science education is incredibly high.

Even though scientists modify scientific theories in order to respond to the empirical world and external values, certain internal values of successful theories do not change. Moreover, they can be projected onto future theories. McAllister introduced the concept of aesthetic induction, and scientists understand the aesthetic norm *qua* as the internal value of *veritas splendour*.

According to McAllister (1996), the historical and empirical success of a theory with specific properties is associated with a preference for such properties and their establishment as aesthetic norms. It may be said that such norms successfully advance science and form the judgmental criteria for choosing among valid and competing theories. For those theories that achieve considerable empirical success, the aesthetic norms of the community are reconstructed to such an extent that norms give greater weight to the aesthetic properties of the contemporary theory. Accordingly, future theory must overcome a bias toward the aesthetic properties of the current successful theory. In other words, by their empirical success, existing theories implant an implicit bias in favour of future theories that share similar attributes (McAllister, 1996, p. 79).

To explain ideas about scientific beauty and distinguish empirical from aesthetic criteria, McAllister recommends the following basic aesthetic theories.

The metaphysical beauty that derives from Plato can be understood as objectivist. It presupposes the idea of beauty or absolute spirit. However, beauty, which is regarded as a fact grounded in psychology, can be described as subjectivist.

Projectivism: McAllister rejects objectivism. Beauty is interpreted not as an objective attribute but as the value that an observer projects onto objects. Value is defined as good, important, or desirable.

Aesthetic Properties Evoke Aesthetic Responses: Objects that include scientific theories can have intrinsic properties that evoke aesthetic responses, which award aesthetic values to such objects.

Beauty in Science: When scientists have aesthetic criteria that award values to the attributes of their contemporary theories, they project beauty with certain theories

(McAllister 1998, pp. 30–34). The aesthetic value of theories depends on two elements: (1) the aesthetic properties of the object itself and (2) the values of the observers. Aesthetic values project and bestow beauty onto objects with certain properties (McAllister, 1996, p. 34).

Here, we can see that empirical criteria distinguish facts, which are calculated through scientific activities, from values, which engage in and are projected onto scientific activities. Normally, they are composed of data as an outcome of calculation from empirical scientific activities, theories, and laws that are obtained from inference. The former is called 'actual fact'. The latter is called 'judgmental fact'. However, the process in which data are collected through observation and engagement is projected onto scientific activities that involve inference; this is not an empirical outcome. Since it is a kind of attitude and methodology, values that are different than objectively existing facts are engaged and projected. Beauty in science is formed through aesthetic induction. Beauty not only makes an important and desirable criterion for the formation and evaluation of theories but also stimulates the formation and revision of theories that are projected onto other theories.

Aesthetic induction by McAllister may be viewed as an upgraded alteration of the mere-exposure effect. Specifically, McAllister argues that, from a psychological perspective, aesthetic induction as empirical success is an upgrade. When the number of empirically successful theories with specific non-empirical properties grows, the aesthetic appreciation of the properties increases. Similarly, if successful revisions of an increasing number of theories have certain non-empirical properties, those properties are rated increasingly high (Kuipers 2002, p. 299).

For example, Newtonian dynamics have empirically undergone continuously successful revisions, but their internal properties, determinism, and visualization remain unchanged. These properties have also been projected onto other theories and held in high regard in comparison to other aesthetic viewpoints. Additionally, such determinism has been forcefully projected onto the theory of relativity. Of course, probabilistic causation also remains valid in quantum dynamics.

In Einstein's theory of relativity, theories have been formed and revised according to theoretically empirical data. However, symmetry as the integration of theories and the non-empirical property of coherence has long been implied in the special theory of relativity. Symmetry has been maintained and those properties have engaged in and have been projected onto the general theory of relativity.

In science, the aesthetic norms change over time. For instance, in Newtonian science, its theory and the criteria of *determinism and visualization* have been received as successful aesthetic norms. Whereas, with the successful theory of relativity by Einstein, modern physics has brought the new aesthetic norms of symmetry and simplicity into the spotlight.

In general, good theories should build on models that include a small number of random elements to accurately explain numerous observations and clearly predict the outcomes of future observations (Hawking & Mlodinow, 2005, p. 27).

Thus, data or events calculated from the empirical world, explanatory systems, or theories and laws that are judged in the conceptual world can be distinguished by calculated results. In fact, they are closely interrelated. In our experience, they are not free from error. We relate expected data or events with theories that reflect our best possible judgment. However, unless expected results are produced, previously determined theories may be revised or replaced. As a result, the previously calculated data is re-interpreted or new data are collected. Here, the data that we obtain from the empirical world and the theories and laws that are judged in the conceptual world may be described as products acquired from activities in human society.

Values must engage in data obtained from human activities. In the context of science, we distinguish between two different types of values (Crespo, 2019). Cognitive values are values that are commonly used to determine the most plausible theories and laws about the world. These values, which are used to acquire scientific knowledge, must be used by scientists. Such values do not change with time and place; Therefore, such values are called non-cognitive values.

As explained in Reiss and Sprenger (2014, p. 7), values can influence science in the four following cases: i) selection of scientific research questions, ii) data collection, iii) approval of an appropriate answer to questions or scientific hypotheses based on proof, and iv) propagation and application of scientific research results.

Most philosophers of science will agree that the role of values in science remain controversial with regard to ii) evidence collection and iii) acceptance of scientific theories. It is universally accepted that the selection of research questions is often influenced by the interests of individual scientists, funding groups, and society in general. Such influences may make science even more superficial and delay its long-term development, but it has its own advantages, too. Scientists can focus on providing solutions to intellectual problems that society finds pressing and, in so doing, improve people's lives. Similarly, the propagation and application of scientific research results seem to be influenced by the personal values held by journal editors and end users. Therefore, practically nobody can raise objections. In fact, the discussion is about whether the core of scientific inference (i.e., evidence collection, evaluation, and acceptance of scientific theories) is value-neutral.

A clear but ultimately compelling criticism of the *value-free ideal* gives rise to the ‘underdetermination of a theory by evidence’. As frequently shown in the history of science, existing evidence in some areas does not justify calling those theoretical explanations unique. ‘Crucial experiments’ do not refute specific scientific arguments. Instead, they show errors within the entire hypothetical network (Duhem, 1906 [1954]). Therefore, we are often unable to select a competing theoretical explanation from existing evidence.

In this sense, philosophers of science tend to look with favour on value-ladenness. Epistemic (or cognitive) values, such as accuracy of prediction, scope, explanatory power, simplicity, and coherence to other accepted theories, represent a good scientific theory and indicate a standard argument for preferring one theory over another. Kuhn (1977) said that cognitive values are defined as the common duty of science. In other words, they evaluate criteria that award specialty to scientific approaches.

Sometimes, epistemic values are regarded as subsets of cognitive values. They are considered the same as empirical validity and internal consistency, which directly supports the truthfulness of scientific theories (Laudan, 2004). Therefore, values such as scope and explanatory power, which represent scientific demands, are aptly calculated as cognitive values lacking epistemic implications. However, we decided to choose such a wide reading of the term ‘epistemic’ that, instead of serving as the only goal of scientific inquiry, *truth* provides the causal mechanism, finds natural laws, and builds comprehension. In this sense, scope or explanatory power contribute to accomplishing our epistemic goals. It is hard to discover a clear-cut difference between the scientific values involved in strictly pursuing truth and purely cognitive scientific values.

Of course, all philosophers do not agree on the same list of epistemic values. From a pragmatic point of view, Lycan (1985) included simplicity as it would reduce the cognitive workload of scientific practitioners and promote the use of scientific theories in treating real-world problems. In contrast, McMullin (2009) did not include simplicity because he could not conclude that ambiguous and simple theories would have the chance of being facts or empirically adequate. This is also one of the reasons why 'value' is favoured more than 'rule' as a term. The evaluation of scientific theories is not so much the automatic application of rules or algorithms as the careful weighing of various standards in choosing the best theory (McMullin, 1982, p. 17).

VFI (Value-Free Ideal)

Scientists must try to minimize the effects of contextual values on scientific inference by collecting evidence and evaluation and accepting scientific theories among others. According to VFI, scientific objectivity is characterized as the absence of contextual values and an exclusive dedication to the epistemic values of scientific inference.

VNT (Value-Neutrality Thesis)

Scientists can collect evidence, evaluate, and accept theories without judging situational values. VNT is used as useful defence in discussing the chance of accomplishment. Please note that VNT is not a norm. It investigates only whether scientific judgments contain or lack contextual values. However, it is rejected by the thesis that argues that contextual values are indispensable for scientific research.

VLT (Value-Laden Thesis)

It argues that scientists are unable to collect evidence and evaluate/accept theories without judging situational values. VLT, as such, sometimes reinforces the argument that epistemic and contextual values are indispensable for scientific values. It suggests that pursuing science that lacks contextual values causes epistemic and social harm

Table 1. The Roles of Epistemic and Non-Epistemic Values in Scientific Inquiries

Scientific inquiry Reiss and Sprenger (2014, p. 7)	Types of facts	Types of values	Philosopher of science
ⅰ) Selection of scientific research questions		Non-epistemic values	Social construction (Thomas S. Kuhn, 1970)
ⅱ) Data collection	Producing actual facts	Epistemic values Non-epistemic values	Theory-ladenness of observation (Hanson, 1958)
ⅲ) Approval of appropriate answers to questions or scientific hypotheses based on proofs	Producing judgmental facts	Epistemic values	Indeterminacy of theory (Duhem, 1954).
ⅳ) Propagation and application of scientific research		Non-epistemic values	Social construction Thomas S. Kuhn (1970)

results			

We can cite induction as a scientific methodology that typically demonstrates the usefulness of theories (Ferber, 1999, p. 65). When regularity is discovered, initially it is viewed as a preliminary hypothesis for a scientific theory. Then, more data are added and such data are predicted through the hypothesis. The possibility of the hypothesis being true grows until it turns into a law or theory. Describing the external properties of the theory, this makes the most important epistemic value in judging theories. Induction draws from observed facts that include unobserved facts as well, but the process always involves a big leap of logic. Because facts may remain unobserved somewhere in the universe, there is the spatial limitation that makes it difficult to categorically state that facts are universally applicable. Because facts may remain unobserved in the past or in the future, there is the temporal limitation that make it difficult to categorically state that facts *always* apply. These two limitations inhibit defending categorical statements of applicability. Hume said that human nature includes the tendency to form habits. Kant said that causal necessity, which is not found in nature, is embedded in the human cognitive ability. However, inductive reasoning, which is logically invalid, has a general advantage. On the contrary, prohibiting induction is like ordering a suicide. When our survival is considered, assuming that phenomena run counter to experience can create irrational thoughts. When the degree of usefulness is pointed out, inductive validity is not about choosing among alternatives but about the degree. As with the degree of inductive probability, we can quantify the degree of usefulness as similar to rational choice (Ferber, 1999, pp. 64–66). Furthermore, historical values that are non-epistemic demonstrate practicalities that suit the times.

However, we can see that the internal values of theories strongly motivate the discovery of scientific theories, demonstrate the internal beauty of theories, and engage in the formation of scientific theories. Accordingly, it is important that these research questions are treated in this study.

First, we will investigate the value that philosophers of science place on good scientific theories. Then, we will consider how Hawking, a well-known contemporary scientist, emphasizes epistemic values that engage in the formation of scientific theories. In addition, we will explore the transformation of such values through the history of science.

2. Values Judged to Be Good Scientific Theories

Regarding the properties of good theories, scientist and philosopher Thomas Kuhn chose five typical answers.

- A theory must be accurate in its domain. In other words, it must be proven that the conclusion may be derived from theories that match the existing experiments and observations (**Explanatory power, Accuracy**).
- A theory must have a wide scope of application. Specifically, it must provide conclusions that transcend the individual observations, laws, or sub-theories that it is intended to explain (**Scope**).
- A theory must beget a great deal of new research results. We understand that this refers to fertility, leading to further research in follow-up studies prediction**, Fruitfulness**).

➢ This is connected to the third characteristic. A theory must be simple, in that it brings order to phenomena that would otherwise be isolated and chaotic **(Simplicity).**

➢ Theories must be independently coherent, as well as compatible with currently accepted theories (**Coherence**).

2.1 External Accuracy, Responsiveness, Scope, Fruitfulness of Scientific Theories as the External Properties of Theories That Expand Knowledge

The five properties—accuracy, coherence, scope, simplicity, and fruitfulness—are standard criteria for evaluating the cognitive values of a theory (Kuhn, 1977, pp. 321–322). Looking into the epistemic values presented by Kuhn confirms that the properties are closely connected in terms of explanatory power and correspondence. As an internal value, coherence is also required to fulfil the goals of explanatory power and correspondence (Jo In-rae, 2017, p. 293). They bespeak the importance of correspondence as an epistemic value.

For example, the special theory of relativity, which comprises Galilean invariance, is more accurate than that. Specifically, for motion that is slower than the speed of light, the special theory of relativity delivers results similar to those of Galilean relativity. For motion that is as fast as light, it provides a more accurate explanation than Galilean relativity.

2.2 The Internal Rigidity of Scientific Theories and Theoretical Beauty Demonstrated in Internal Properties: Values That Add to Aesthetic Significance, as Delivered from the Understanding of Knowledge

If a signal faster than light were discovered, it would require a fundamental revision of dynamics, thermodynamics, nuclear physics, cosmology, etc. Arguments about light are deeply and strictly grounded in the structure of the theoretical description of nature. This leads to a necessary outcome (Kosso, 2009). Necessity is a kind of **coherence**. We can understand necessity as non-empirical and induced from theoretical systems or connections. More observations acquire more knowledge but do not get more wisdom (Kosso, 2007). For example, there is one crucial difference between Bode's law and the absoluteness of the speed of light. Many things boil down to the space-time combination, increase in mass, and mass-energy equivalence in **the absoluteness of the speed of light.** Yet, practically nothing is related to Bode's law. This speaks not only to the importance of the coherence among theories of all epistemic values but also to the internal aesthetic properties of theories and their relationship to a greater understanding of theories. In general, symmetry refers to something that achieves appropriate harmony and balance. It refers to how multiple parts integrate, through overall coherence. Thus, beauty is closely related to symmetry. Therefore, we can see that of the epistemic values, it is an internal feature that demonstrates the beauty of scientific theories.

Table 2. Properties of Scientific Theories That Enable the Judgment of Values for Them

	Epistemic Values (Cognitive Values), objectivist values		Non-epistemic values, subjectivist values
	Aesthetics in science, internal features (the beauty of theories	Knowledge in science, external	Sociocultural Value: 'the practicality of

	functions as an internal feature that is demonstrated through understanding)	features (expansion of knowledge through the adequacy of theories and external data)	theories’
Kosso (2011), Coherence	Global coherence	Correspondence	Psychological virtue, Plausible, the achievement of **Understanding** as increasing global coherence (Kosso, 1992; 2007)
McAllister (1996), Aesthetic influence for justification	Simplicity, symmetry, unity		
Kuhn (1977)	Consistency, simplicity	Accuracy, scope, fruitfulness	Sociocultural value
Weinberg (1992)	Simplicity, symmetry, theoretical rigidity: inevitability and necessity	Correspondence	×

‘Symmetry that is necessary for integration in scientific theories’ is discovered with the intuition that actual domains exist where conversions are allowed. It is the awareness that physical advancement consists of integration. It means that science advances through combining greater phenomena under a given law, just as Newton combined the earth’s and the planets’ dynamics into one.

What matters to Einstein is the belief in the unity of physics and the belief in the symmetry of pieces of data obtained from several areas of physics. For example, if the speed of light is visibly constant in a given system, it must be equally constant in another system (Fischer, 2001, p. 173). Above all, we can say that the symmetry of the speed of light is the foundation of the theory of relativity. In other words, everything derives from the fact that the speed of light is absolute (unchanged, limited).

As physical symmetry reaches the goal of integration, scientists strongly encourage the discovery of theories. Physics is a theory of physical technology that remains unchanged, despite the transformation of coordinates (that is, the change of the observer or the change of the experimental device). All permanence is regarded as natural symmetry. It also implies the sameness of physical laws when we move from one place to another in space and time. Additionally, it can refer to the fact that when we perform an operation to change a system, its properties remain unchanged. Over time, if the laws of the past match the laws of the future, that is symmetry. If the laws here are the same as those in another place in the universe, that is symmetry (Lederman & Hill, 2012, p. 85). Physical laws are constant and do not change with the passage of time. For example, on one hand, if you choose the Galilean transformation, you get the non-relative Newtonian dynamics. However, light does not match the values observed. On the other hand, if you choose the Lorentz transformation, you get Einstein's relativistic dynamics. A Lorentz transformation is a transformation equation that satisfies the requirement that the speed of light remains unchanged through the transformation of the space-time coordinates. In this sense, relativistic dynamics more accurately describe actual phenomena. By giving up the concept of absolute space and the Newtonian dynamics of the absolute, the speed of light gains the absolute status.

Similarly, symmetry in mathematics is discovered when it is known that seemingly different mathematical phenomena are in the same category as already known transformations and are included in a larger domain. Thus, a dynamic equation is expressed in the same form in all systems regardless of space and time, which is called form-variant. Today, the Lorentz transformation is viewed as the correct symmetry transformation of physical laws in motion (Lederman & Hill, 2012, p. 204; Castellani, 2002). In addition, that 'all observers find the speed of light constant' refers to a new symmetry, suggesting that the theory of relativity is abstractly beautiful. Physical symmetry recognizes that the advancement of physical theories lay in integration and moving toward symmetry to construct new theories. However, Lorentz and Pincaré's transformation formulas represent mathematical symmetry, as they expand the electromagnetic theory from transformation formulas in the same category.

Scientific symmetry change must be expressed in a mathematical expression. Even though a whole system is rotated at a certain angle, no physical laws change in the closed system. Similarly, even though a certain closed system is moved in space or in time, no change occurs to physical laws. The three instances correspond to the respective conservation laws of classical dynamics. Mobility in space corresponds to the law of momentum conservation, mobility in time corresponds to the law of energy conservation, and rotational motion corresponds to the law of angular momentum conservation. Einstein's principle of relativity shows the three symmetrical changes as combined in the domain of very high speed and the domain of electromagnetism (Hazen & Trefil, 1991, pp. 305–306). Physical symmetry must follow mathematical symmetry.

The Simplicity of Scientific Theories

Theories that explain large-scope phenomena with just a small number of premises are considered simpler and more graceful. The special theory of relativity speaks with the **simplicity** built on these two hypotheses (Zee & Penrose, 2007, p. 111).

The Abstractness of Scientific Theories

The Lorentz transformation is chosen by revising the Galilean transformation of classical dynamics, so that it may suit electromagnetics. Absolute space and absolute time have to be given up and space and time must be relegated to a relative status, so that the speed of light may obtain absolute status. However, when the speed is slow, it includes the Galilean transformation from classical dynamics. Accordingly, the reality that 'all observers find the speed of light constant' implies a new symmetry that shows that the theory of relativity is abstractly beautiful.

III. The Process in Which Scientific Theories Develop Aesthetic Values

1. Aesthetic Change through the Requirements of a Good Theory by Stephen Hawking, the Most Famous Scientist in Recent Times (Hawking & Mlodinow, 2008, pp. 13–18)

Numerous observations must be accurately explained (accuracy and scope as the external forms of a theory based on existing data) based on a model that includes a small number of random elements (simplicity as the internal form of a theory). Additionally, the results of future observations must be accurately predicted (prediction and scope as the external properties of a theory based on prediction data) (Hawking & Mlodinow, 2008, p. 13; with my parentheses).

For example, Aristotle believed in the theory of Empedocles, who argued that all things were made up of the four elements: earth, air, fire, and water. It was simple enough to make a good theory, but it failed to offer any clear prediction. In contrast, Newton's theory of gravity is based on a far simpler model. In other words, all objects are in proportion to the quantity of what is called mass and two objects attract one another with the force that is in proportion to the distance between them. Simple as it is, Newton's theory of gravitation very accurately predicts the motion of the solar planets (Hawking & Mlodinow, 2008, p. 13). Aristotle represented a qualitative, teleological world composed of various matters. Newton represented a quantitative, causal world made up of mass alone. The Newtonian theory was far simpler and demonstrated more accurate predictions.

Table 3. Change in the Internal or External Features of a Theory

	The components of a theory 'formal simplicity'	The external features of a theory 'prediction, scope'	The premises and internal features of a theory
Aristotle	All things composed of the four elements	Prediction not easy 'Weak prediction'	The metaphysical teleology that things have the *a priori* impulse to change 'Strong coherence'
Newton's theory of gravitation	The law of universal gravitation and Newton's laws in the quantitative world of mass	Very accurately predicts planetary motions 'Strong prediction'	Metaphysics that presupposes absolute space and time 'Weak simplicity' 'Weak coherence'
Einstein's theory of relativity	The essence of space-time and matter from the observation that the speed of light is constant	It demonstrates greater prediction than the Newtonian dynamics in the world with higher speed and greater gravity'Very strong prediction'	The theory and observation that the speed of light is constant and the hypothesis that inertia and gravity are the same 'Strong simplicity' 'Strong symmetry' 'Strong coherence'

Quantum dynamics	Energy is incontinuous in a small world like the atomic world according to the principle of uncertainty	Individually weak determinism with probabilistic prediction but overall demonstrates strong prediction	The wave equation is suitable for probabilistic determinism, but instrumental interpretation is more suitable than the theory of reality

The fact that Einstein's prediction agrees with our observations, whereas Newton's differs slightly, has served as decisive evidence of a new theory of relativity. For practical purposes, however, Newton's theory is normally used (Hawking & Mlodinow, 2008, p. 14). We can see that predictions are more accurate here than in Newtonian dynamics. Taking into account the fixed space and time of the metaphysical beliefs, Newton adopted the electromagnetic theory and the observational fact that the speed of light is constant; hence, his theory exudes simplicity.

Einstein said that he considered himself not as *a revolutionary* but as *a successor*. More specifically, he said that he was a continuum of the electromagnetic program that Faraday and Maxwell began. His realization that the contemporary electromagnetics and dynamics failed to satisfy the requirement of symmetry served as a decisive factor that led him to the special theory of relativity. The principle of relativity on which Einstein consistently insisted through his life's theoretical work is a kind of symmetry principle. Specific topics, such as natural simplicity, theoretic symmetry, or coherence, provide important motives when a scientist not only evaluates a theory but also conducts research with the belief in the validity of a scientific theory (Holton, 2000, pp. 159–161). As an important criterion and an internal feature of a theory for making an aesthetic judgment of the theory that influences such research motives, symmetry should comprise theoretic simplicity. Stephen Hawking (2008) emphasizes theoretic simplicity, rather than formal simplicity, as an important element that speaks of the aesthetic characteristics of a good theory.

Table 4. Changes in Aesthetic Expressions through Different Time Periods

Time period	Ancient Times and Middle Ages	Modern Era	Contemporary Era
Worldviews	Metaphysical idealism	Metaphysical mechanism	Dialectic materialism
Form and material	Form is reality	Between form and material, the latter prevails	Conflict and harmony between form and material
Objectivity and subjectivity	Superiority of objectivism	While subjectivity prevails over objectivity, both combine	Harmony between subjectivity and objectivity; psychological subjectivity prevails
Values	Cognitive values Internal values of a theory	Cognitive values External values of a theory	Non-epistemic values, the practical and empirical values of a

			theory

Aesthetic objectivity is a Pythagorean argument that suggests that the attributes of things include beauty. Harmony comes from order, which comes from proportion, which comes from measure. Harmony, proportion, and numbers are the objective bases of beauty. They said that order and proportion are useful, whereas disorder and lack of proportion are ugly and useless. The aesthetics of the Pythagoreans was cosmocentric. They thought that beauty was an attribute of the universe. They said that while humans did not create beauty, they discovered beauty in the universe. This means that the beauty in the universe would serve as the measure of beauty in all its forms. In contrast, the philosophy of the sophists was anthropocentric. They said, ‘Of all things, man is the measure’. Aesthetic subjectivism is naturally connected to their general naturalism. Namely, inasmuch as humans stand as the measure for the true and the beautiful, they serve as the measure of beauty. The sophists drew on the relativity of beauty as conducive to the subjectivity of beauty. The greatest influence in the historical development of the Western aesthetic theory was that Plato concurred with the Pythagoreans. Plato said, ‘There is no beautiful thing but has proportion’ and ‘Always and essentially, beautiful things exist.’ Beauty as per the sophists was not a matter of eyes and ears but of reason. Plato's authority awarded superiority to the objectivist theory in aesthetics for several thousand years.

The subjectivist thesis is frequently combined with relativism, pluralism, irrationalism, scepticism, etc. Subjectivism developed as the Renaissance carried the ancient ideas more than the influence of the late-Mediaeval nominalism, which followed in the footsteps of the sophists. However, modern Enlightenment flaunted irrationalist subjectivism in art, even though it was the era of rationalism in philosophy and science. Additionally, in the Romantic period, subjectivity combined the two ideas in the Kantian critique of judgment in the late years of the period (Tatarkiewicz, 1980, pp. 243–266).

In the transition to the 20th century, there was a strong tendency for psychological treatment of beauty. In contemporary aesthetics, it is neither aesthetic objectivism nor subjectivism, but it trends toward subjectivism.

Newtonian dynamics viewed the motions of all things based on the metaphysical assumption that space and time do not change but are fixed. This dynamics engages in observing the motions of objects such as the sun, the moon, and apples in a *box* that absolutely precludes any change in size and does not take the box itself as its research object. Newton conceived the universe as a vessel *qua* fixed space and time that contains the two different elements of matter and energy. In that universe, matter is static, is visible, can be touched, and has mass, whereas, energy is dynamic, is invisible, and has no mass.

However, there is a contradiction between the law of electromagnetism in the Maxwell equation that finds the speed of light as constant in Newtonian dynamics. Provided space and time are constant, the speed of light can increase to a certain speed above its own speed according to the law of convolution. As a result, Einstein thought that he had to change the *box* in which the physical phenomena were taking place. However, space and time had to change for the speed of light to be constant. This means that space and time change while influencing one another.

In the Newtonian dynamics, the apple hanging from a tree branch has *potential energy*, which turns into *kinetic energy* when it starts falling from the tree. When it falls to the ground, its kinetic energy is used as acoustic energy, thermal energy, etc. The energy of their sum is equal to the initial potential energy. This is the law of energy conservation.

Newtonian dynamics imply that the mass of matter does not change but is conserved. Separately, Lavoisier in France discovered *the law of conservation of mass*, which argues that the total of the mass is the same before a chemical experiment as it is after.

Newton believed that determinism was built on the assumption that these four elements existed independently. However, Newton's belief in the separate existence of worlds beyond our view precluded an integral explanation of nature.

However, Einstein argued that energy and mass are not separately conserved. He meant that *energy* and *mass* could be interchangeable in the equation of $E=mc^2$. Energy is merely concentrated energy. The only difference is that it is just one of the temporary conditions. When matter shucks off mass and gets the speed of light, we call it radiation or *energy*. On the contrary, when it condenses energy and takes some other form, we call it *matter* with mass.

A new theory or a new natural technology must agree with the earlier correct theories or technologies. If the special theory of relativity is valid, it must agree with Newtonian dynamics, which applies to speeds far below the speed of light. When it includes a special condition, that is, the condition that the speed of light is infinite or the speed of an object is slow, the special theory of relativity becomes the Newtonian dynamics. Yet, no matter what condition is attached to the Newtonian dynamics, it fails to deliver the special principle of relativity. Therefore, the special theory of relativity includes Newtonian dynamics. However, Newtonian dynamics cannot be said to include the special theory of relativity.

Niels Bohr argued that a new theory should not only more accurately present the atomic description of physical phenomena but also be applied to ordinary phenomena and be equally able to explain the earlier theories of physics. This is the correspondence principle, which is also applied to other theories, aside from quantum theory. For instance, the mathematical system of the theory of relativity both describes the motion of an object moving at high speeds and also delivers the correct result for low speeds.

In addition, the Newtonian universe, which lacks the relativity of time ($c=\infty$), is grounded in our daily experience. The correspondence principle that the speed of light is infinite shows the continuity of scientific change. It forms a new theory that expands into intuition and visual imagery through the abstraction strategy, called the corresponding limit. According to underdetermination of scientific theories, there is an unlimited number of theories that can explain any data set. While there is no way to avoid this, only those theories that include a specific hypothesis, like the principle of relativity, survive. Therefore, this supports the statement of Ernan McMullin, the philosopher of the reality theory, that the history of science has the essential continuity of the theoretical structure and delivers the evidence of abstraction, but it describes the continuity of a theory more than pessimistic meta-induction (Miller, 1998, pp. 312–315).

In 1915, Einstein said, with his general theory of relativity, that space and time are distorted and bent by the distribution of mass and energy in space-time (Hawking and Mlodinow, 2005, p. 38).

In summary, the theories inferred from the original system of premises are added to create a new system of premises, continuously producing new theories. As the elimination of even one of the produced theories topples the entire system of theories, the beautiful characteristic of the Einsteinian theory is a **necessity**. That entirely separate physical masses are interrelated suggests that they are oriented toward **symmetry** (i.e., their integration), and it shows **coherence** among the component theories. This means that space and time and mass and energy are related in a single line. The process leading to the formula is anything but complex or eerie. Starting from 'the speed of light looks constant to anyone' and completing one step after another, anyone can reach the same outcome. Replicability is a kind of **simplicity**. Here, the connection between space-time and matter is completed in the general theory of relativity that 'massive objects cause a distortion in space-time'. When scientific facts or laws are to be viewed in the context of not only nature and technology but also the beauty in a scientific theory, this means the expansion of the meaning of science. According to Feynman (2007, pp. 16–24), we understand through the theory of relativity how useful is the concept *the symmetry of physical laws*. He said that, in general, transformations that do not change the form of the basic law provide useful information.

IV. The Beauty of Scientific Theories and Science Education

1. Educational psychologist John **Dewey (1980)** drew three aesthetic theories from **the empirical and psychological aesthetic experience** (Girod, et al. 2003, pp. 578–579). It is subjective and psychological in that it prices aesthetic experience.

- First, that we are capable of aesthetic comprehension means that we have the power to change something into what we want.
- Second, that we aesthetically understand a thing means that we can integrate and bind them.
- Third, that we aesthetically understand an event means that it is psychological. We cannot help but admire and appreciate it.

2. **Example**, a historic experiment in which Eratosthenes measured the size of the earth

- First, the traditional concept of beauty is that it cannot be changed. Kant said that **beauty does not stand apart from the discovery of truth but accompanies it. It brings a new understanding (depth) of nature.**
- Second, for philosopher Heidegger, beauty is what reveals itself through the transfer in chaos.

Beauty is beautiful through the transition from archetype to diversity, from infinity to finiteness, and from the secular to the divine. He emphasizes that beauty reveals truth and good. In other words, the task of finding the definition of an object amidst undefined chaos is like finding what is concealed. Heidegger uses the term of *unconcealment* with more comprehensive significance, instead of definiteness.

What Eratosthenes teaches to us through his measurement of the earth from the perspective of educational aesthetic experience

Beauty depends on the manner in which what one wants to show is presented. **First, it speaks of depth, usefulness, and clarity (a traditional philosopher of science who emphasizes objectivity).**

The beauty of the experiment by Eratosthenes consists of simplicity and conciseness. Through just the act of measuring the length of a short shadow, one can discover the numbers related to the size of the universe.

Second, beauty involves the transition from archetype to diversity, from infinity to finiteness, and from the secular to the divine (Heidegger emphasizes

transfer and revelation).

1. The eternal and unchanging attributes of the universe are drawn from beings that are fleeting and unstable like shadows. Through the experiment by Eratosthenes, we can draw out the archetype (form) of the universe from the fleeting moment in various shapes (matter) that are like extreme chaos or a shadow, which disappears in the blink of an eye.
2. Eratosthenes' experiment makes us shift our gaze and find vastness amidst tiny things. This experiment broadens the horizon of our knowledge and it approaches a simple question in a new way: what is a shadow and how does it come to be?

In addition, we come to realize that the specific, transient length of the shadow is closely related to the round shape of the earth, the size of the earth, the long distance between the earth and the sun, the motions of the two celestial bodies that endlessly change their locations, and all the shadows on the ground. The transition from finiteness to infinity occurs.

Further, the transition from the secular to the divine occurs (i.e., from the earth where experience is possible to the mathematical and divine). According to Plato, God is a mathematician. In ancient Greece, people wanted to explore something that did not change, which was initially expressed as matter or an atom. Pythagoras and Plato named it mathematics. The world of mathematics was a divine world.

Third, beauty does not stand apart from the discovery of truth, but it accompanies it. It brings a new understanding (depth) of nature. Kant connects subjective and objective values.

1. Through experimentation, people came to understand irrefutably and clearly the fact that the sun is far away from us, that time passes in a circle, and that the earth is round.

These experiments tell us that small things, transient things, and things in all dimensions are ultimately connected. These experiments changed the quality of the human experience around the world.

IV. CONCLUSIONS AND SUGGESTIONS

When a new scientific theory is presented, scientists want to know if it is close to the truth. The most direct way to prove this is by testing the theory through prediction. However, results from such a prediction are hard to calculate accurately, and competing hypotheses may come up with the same result. Moreover, expected results may be obtained by mobilizing auxiliary hypotheses.

However, it is not hard to understand whether a theory is beautiful. A lot of scientists can tell how close a theory is to the truth by means of aesthetic judgment. Dirac believed that beauty is evidence of truth. That beauty lies in one's equations is more important than making them correspond to empirical data. For instance, he said that he was confident that Einstein's general theory of relativity was a beautiful theory. Steven Weinberg said that the beauty in our theories shows the theories' closeness to the fundamental laws of nature.

Moreover, as argued by educators, beauty is the moment of transition through aesthetic experience. They say that a new world is experienced through learning. Educators of science should encourage learners to feel such beauty.

Clearly, in the past, we understood that scientific discoveries enabled favourable conditions for survival. Today, however, it is not clear if that is the case. A completely unified theory may not be of great help for our survival. For example, Newtonian

dynamics, a partial theory, may be more pragmatic than the theory of relativity, an integrated theory.
Since the beginning of civilization, however, people have been discontent with events they cannot explain. People have sought to understand the fundamental order of things. Human aspiration for such knowledge serves as the foundation that justifies our continuous inquiry for an integrated and unified theory.

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