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ORIGINAL PAPER

Understanding the Scientific Creativity Based on Various Perspectives of Science

Jun-Young Oh[1]

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Abstract
The objective of our study is to explore scientific creativity with a focus on intellectual (thinking) skills in the cognitive aspect by analyzing scientific theories, which are basically the creativity of historical great scientists, Galileo, Newton, Einstein While our study laid stress on the cognitive domain, exploration of the creativity of great scientists is also connected with affective characteristics (motives, task commitment, etc.) and their environmental factors (incubation period). Great scientists of the science history were aware of the discrepancy issue among different fields of study and long searched for solutions, which they held in their minds. As a result, they created a certain hypothesis using the abstraction strategy in which they leave only the considerations suitable for the world view of the time. Then, they conducted a thought experiment that justified it. The reason why it was difficult for general people to understand was that there was a domain transition beyond materials obtained in the abstraction process. Furthermore, they all had strong motives for the future as well as task commitment. Knowledge is a product of natural selection, and the fusion of knowledge that does not presuppose the unity of knowledge is meaningless.

Keywords Creativity · Kuhn's scientific revolutions · Abstraction strategy · Thought experiment · The fusion of knowledge

1 Introduction

Historically, Aristotle's universe focused on natural motion. Once violent or unnatural motion turns into natural motion, it is never reversed. These principles are confirmed by our observations; although they are consistent with our common sense, they are not correct. For example, when someone rolls a rock, it eventually

✉ Jun-Young Oh
jyoh3324@hanyang.ac.kr

1 Institute for Integrated Science Education, Dankook University, Jukjeon 16890, Republic of Korea

stops. Its natural position is above the ground. Inversely, we have never seen a rock rolling unnaturally or endlessly. In addition, common sense tells us that heavy objects fall faster than light ones rather than at the same speed.

However, such an example is the only one we can think of at first. We create a framework of our knowledge by looking at the world around us and then use that framework to understand the entire world. This common-sense worldview is broken down by original thought experiments and profound mental abstraction. This requires a unified wisdom of creation (Miller 2000, pp. 3–4) rather than general common sense. Thanks to such abstraction, Galileo's law of inertia, which ignores friction and air resistance, and the law of free fall, according to which all objects fall at the same acceleration, are counterintuitive. Above all, we have geometry, which helps us to choose only a few of the numerous hypotheses in science.

In terms of scientific methodology, scientists collect data, examine the information, create theories that explain it, make verifiable predictions, and validate these predictions to approve the theory. This is known to be the essential aspect of scientific progress. In addition, there are few problems if the inductive method is used, where the same law of nature is produced from the same data. However, even the same data can be interpreted differently depending on the theory held by different scientists (Miller 1996, p. 113). Furthermore, the use of analogy and metaphor (Oh 2017) as well as abductive reasoning, which highlights creative inference (Magnani 2004; Oh 2016), result in transitions in which domains are crossed over. For example, Galileo, using analogical thinking, imagined space geometrically from the solar system to the atomic model, and, using abductive inference, calculated a new law of free fall based on Aristotle's law.

For the general public and students studying science, science can be seen as having a very different explanatory framework than their own explanations that are developed from what they encounter in their everyday lives. This is because they use creative methods like abstraction, metaphor, and analogy, which go beyond the data; they assume that the data are used in an idealized world instead of the real world.

Creativity is novelty and utility (Sternberg et al. 2004, p. 250; Oh 2008). The integration of such novelty and utility shows its practical aspect. This study intends to present which methodological strategy is necessary to reveal this aspect, during interactions between individual capabilities and processes. Creativity has various aspects, and thus, it is manifested by the interaction of multiple elements in the "cognitive," "affective," and "environmental" aspects (Cho et al. 2008, p. 43). However, the objective of our study is to explore scientific creativity with a focus on intellectual (thinking) skills in the cognitive aspect by examining scientific theories that are creative outputs of great scientists from the past.

There is the matter of where to find scientific creativity.

First, scientific theories generally do not match our common sense. Therefore, we must determine how creativity is related to scientific methodologies used by scientists. To begin with, as scientific theories formed are based on scientific views, they are not likely to be considered as creative activities. We examined the so-called theory of scientific revolution by Kuhn formed by historical and social activities.

Second, these scientific theories are empirically successful. This success is important in terms of novelty and utility.

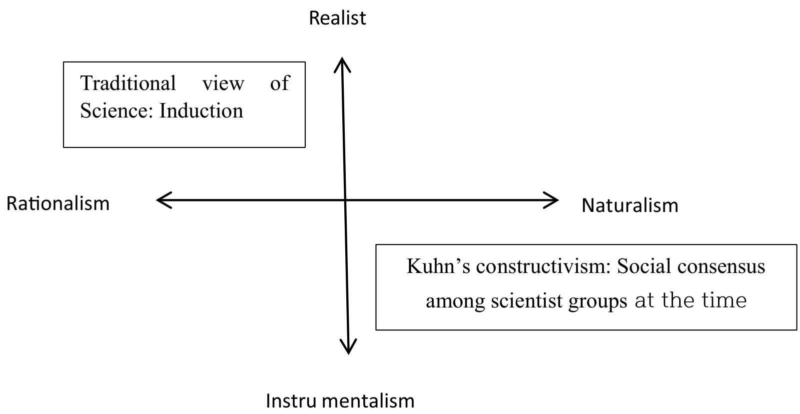
Third, this study explores whether scientific creativity is manifested with focus on characteristics of theories produced by the great intellectual skills of the past.

2 The Traditional (Received) View of Science and Kuhn's Constructivist Viewpoint

2.1 The Traditional (Received) View of Science: Inductive Methodology

To begin with, we must thoroughly review induction, which is a scientific methodology of the traditional philosophy of science based on the commonsensical view of science and perceive its problems (Ladyman 2002, p. 95). Meanwhile, the concept of Kuhn's "essential tension" that claimed the historical philosophy of science provides the motive for the proper understanding of scientific creativity (Yi 2007).

Received view believes that scientific theories exist independently regardless of human society and discovers certain laws and theories of science by observing various situations as much as possible or generalizing results from controlled experiments (refer to Fig. 1). In other words, "if A is countlessly observed in various



x-axis = With what value are theories judged? (theory's value):
Rationalism: Data first (cognitive value)
Naturalism: Social consensus (non-cognitive value)
y-axis = How do theories exist? (theory's truth):
Realist: Scientific theories exist independently regardless of human society.
Instrumentalism: Scientific theories are the tool to explain phenomena and are constructed within human society.

Fig. 1 The traditional (received) view of science & Kuhn's constructivism conditions and the observed A has all of B's characteristics, then all A has B's characteristics (generalization)" (Chalmers 1999).

The view of traditional science and Kuhn's constructivism.

Since value is the product of human subjectiveness and is in fact considered a unit of existence in the objective world, science, which seeks to explore objective facts based on the distinction between object and subject, is clearly distinguished from value, which is on the side of the subjective. Thus, modern traditional science was of the view that science is independent of value. This means that science is considered independent of negative values, namely the bad, the ugly, or the undesirable.

The involvement of human subjective ideas in scientific fact cognition means that values, the product of human subjectivity, are necessarily involved. These values are commonly used by scientists in determining the most plausible scientific theories about the world. For example, scientists can be of cognitive value because they are used in the process of gaining scientific knowledge about the world. However, they are of ethical or social value. These values are called non-cognitive values. In most cases, the claim that scientific facts should be value-neutral implies that we should avoid undermining the objectivity of scientific facts. According to Kuhn, scientists' values play an important role in deciding whether to embrace a new paradigm. He stresses that psychological and social factors, as well as epistemological ones, influence scientists in choosing or rejecting certain theories (Ladyman 2002, p. 105).

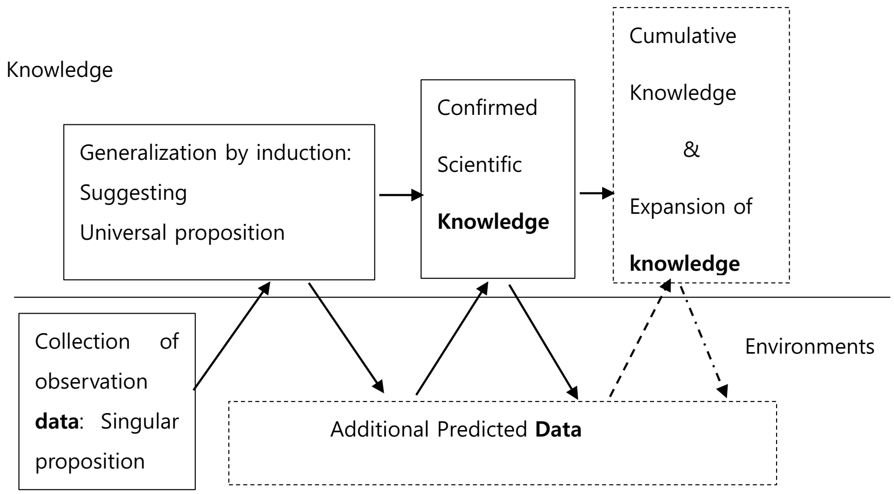


Fig. 2 The traditional view of science is a cumulative development of scientific theories

2.1.1 Criticism of the commonsensical view of science formed by induction (refer to Fig. 2)

First is the theory-ladenness of observation. Our observation is affected by the theories that we already know or our thoughts, which makes objective observation impossible.

Second is a matter of probability. No matter how many times we observe and how many singular statements we obtain for generalization, there is still a possibility that it is not true.

Third is that scientists who properly learned induction are equal by principle in terms of producing scientific knowledge and can replace one another. What is more necessary is the number of scientists rather than scientific creativity. However, scientists such as Newton and Einstein that showed remarkable scientific creativity in terms of the history of science are displaying more inductive skills.

Conclusively, induction is imperative to and instrumental in science; however, approaching the absolute truth with conclusions derived by inductive thinking is difficult. In other words, even scientific knowledge by observation is bound to change occasionally (Park, p. 159).

Therefore, we can see that we need creativity that tracks the hidden meaning behind data by certain creative activities, rather than forming scientific theories by induction that anyone can know in a way that is predicted by data in the commonsense view of science.

Students have difficulty learning scientific theories because these contradict our common sense. In other words, scientific theories are part of an ideal or a physics world, not an empirical world. The difficult part of learning scientific theories is in understanding the physics world. How we connect our research to education depends on how we form this physics world through difficult scientific theories and enable students to understand them. Many of the intellectual activities by Galileo, Newton, and Einstein are connected to thought experiments with the justification of hypotheses by abstraction, rather than direct experiments for justification of hypotheses by induction. This research must be applied to science education rather than topics pertaining to natural scientists and science educators.

2.2 Kuhn's Constructivism (Theory of Scientific Revolution)

Scientific theories are constructed within human society, as they must convey human values. They are constructed by the consensus of scientist groups at the time and justified by the data. Consensus comes first.

After the revolution, another style of normal science begins, based on a new paradigm. Also, if you go a little bit further into that new normal science, you will inevitably encounter anomalous cases, face a crisis, and eventually be replaced by other paradigm. The history of science is interpreted as repetitive like a picture, and the future is predicted implicitly in that way.

Kuhn emphasized that, in scientific research, the open-minded research attitude called "divergent thinking" that thinks freely and considers various alternatives without prejudice is very important, as well as the research attitude called "convergent thinking."

Normal science period: Mature science such as natural science studies' best practices are already resolved by accepting certain paradigms to solve certain problems, thereby slightly transforming them to explain new problems. This refers to the ability to utilize most of the knowledge we already have to solve the new problems, which is known as "**convergent thinking**," a type of creative problem-solving skill.

Revolutionary science period: This is the period in which an alternative paradigm beyond the existing one is presented. In scientific creativity during the period of a scientific revolution, "**divergent thinking**" performs a key role (refer to Fig. 3).

However, convergent thinking is also necessary for the period of revolution. To achieve a revolutionary change in science, convergent thinking is as important as divergent thinking. The ability to precisely understand and critically analyze the essence of existing theories is an extremely important part of scientific creativity.

True great creativity comes from the **essential tension between tradition (convergent thinking) and revolution (divergent thinking)**. Kuhn thought that the

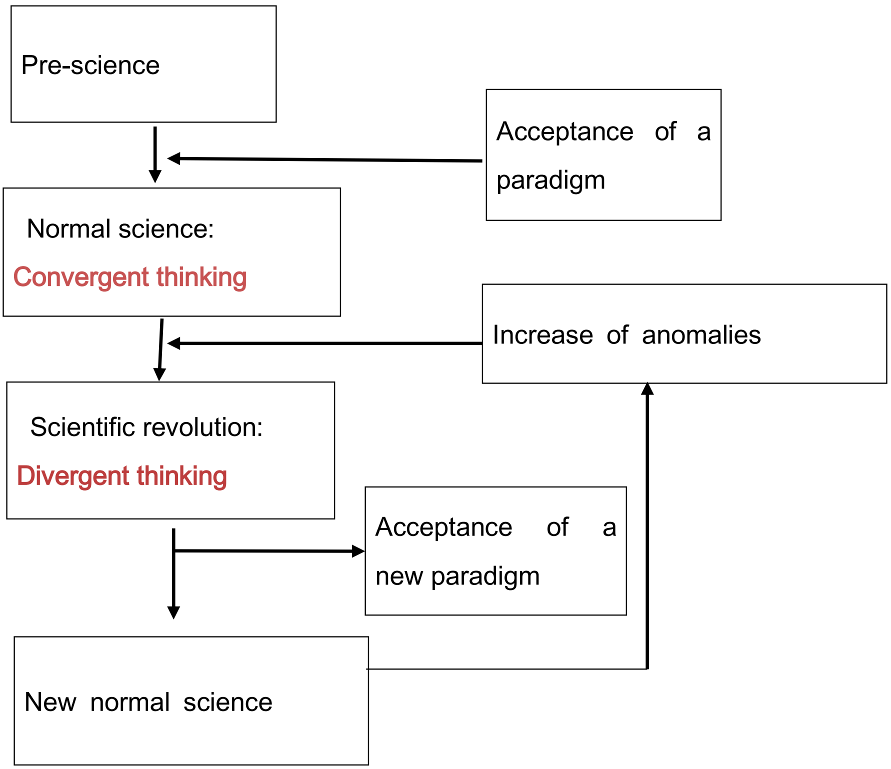


Fig. 3 Scientific revolution and divergent thinking

symmetrical relationship between divergent thinking and convergent thinking forms "essential tension," which is combined and eased by various research activities to discover new theories. Here, creativity is stimulated by sociocultural values. Scientific theories produced by sociocultural and historical values have the advantage of being much more practical in terms of novelty.

"Divergent thinking generally resists the accepted ways of doing things and seeks alternatives. Convergent thinking, the basis of which is to assume that there is a *correct* way to do things, is inherently conservative; it begins by assuming that the way things have been done is the right way. Divergent thinkers are better at finding additional ideas, whereas convergent thinkers have a more difficult time doing so. Convergent thinkers run out of ideas before divergent thinkers. However, convergent thinking strengthens the ability to bring closure and to conclude problems" (Kim and Pierce 2013).

Scientists use both divergent and convergent imagination in their research process. They solve problems by using both appropriately. However, since the two types of imagination are essentially contradictory, what Kuhn called the "essential tension" arises in the process of using both. Successful scientific research requires both types of imagination, but the key is how to harmonize them.

Under what circumstances should we use divergent imagination and convergent imagination? In Kuhn's view, a scientist who productively manages the "essential tension" when doing scientific research is one with creativity in the true sense.

For example, those who completed the revolution that Copernicus started were Newton and later scientists rather than Copernicus himself. In that sense, we can see Copernicus as a transitional figure. He skillfully used convergent imagination based on the scientific framework he wanted to overcome, and at the same time used divergent imagination to create an alternative scientific framework. Copernicus' greatness should be found in the excellent performance of his transitional role.

By appropriately combining contrasting types of imagination, he could transform the core of the problem by managing the "essential tension." Notably, the example of Copernicus is the usual way in which a great scientific revolution takes place. In one of his first papers, Kuhn (1963, p. 234) contrasted convergent and divergent thinking and dealt with the "essential tension" in scientific research. He thought both types of thinking were crucial for scientific progress. Convergent thinking is as important as divergent thinking in scientific creativity, which is essential to effect revolutionary change in science (Kuhn 1970, p. 226; Riegler 2012, p. 235). While divergent thinking is the ability to create new ideas, concepts, and theories by combining existing ideas, concepts, and theories in various combinations, it is an ability that only scientists who have mastered convergent thinking and understand existing theories accurately can wield. Scientists who have created a new scientific paradigm that replaces an existing one were skilled at both divergent and convergent thinking.

2.3 Convergent Thinking and Divergent Thinking as Intellectual Skills

Divergent thinking is a method to solve various problems. However, convergent thinking comes up with a single answer. Divergent thinking draws tremendous and diverse responses to individuals. When used in creativity tests, differences among individuals are caused by fluency (amount and number of thoughts), originality (unusual or unordinary thoughts), and flexibility (diversity of category) (Runco 2007, p. 10).

The process of understanding and applying principles through learning and solving problems requires a type of convergent thinking whereas solving many anomalies requires divergent thinking in which there is a domain transition, which adopts theories or laws from other domains to solve problems. However, this thinking occurs in a cycle.

The source of scientific creativity can be understood in the context of research activities and specific the practice of scientists. Creative thinking is the type of thinking through which we can solve problems in new and original ways or create new possibilities, which is appropriate and socially valuable achievements. In science or mathematics education for the gifted, creative thinking is as important as logical reasoning, and its scope includes divergent thinking and convergent thinking. Moreover, convergent thinking is a precondition of divergent thinking. These two types of thinking have a tense relationship (refer to Fig. 4).

For example, Copernicus who claimed heliocentrism is the person who best knew about Ptolemy's geocentrism, and Einstein was well aware of Newtonian dynamics as well as its problems.

Newton's greatest achievement, for example, is considered to be the discovery of universal gravitation. After this discovery, Newton established the three laws of motion and completed the modern system of classical mechanics that began with Galileo. In addition, his concept of absolute time and space, that is, the idea that time and space exist independently and have absolute coordinates and structures, has been a firmly established paradigm in physics for hundreds of years.

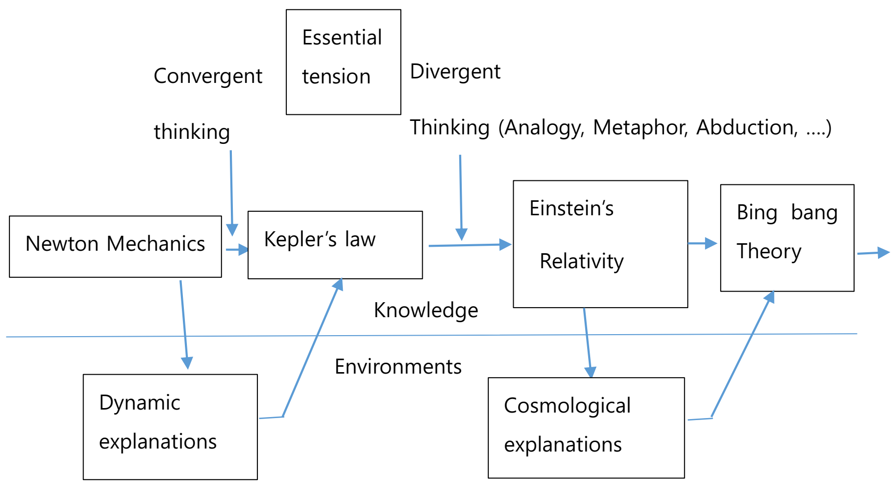


Fig. 4 Relationship between convergent thinking and divergent thinking

Einstein is represented by his theory of relativity, which began by breaking the absolute notion of time and space in Newtonian classical mechanics. Because he had a precise understanding of Newtonian mechanics, he needed a new absolute theory to resolve the conflict between Newtonian mechanics and electromagnetics. In other words, based on the constancy of light speed, according to which "the speed of light is the same regardless of the observer's point of view," he showed that absolute coordinates do not exist in time and space and that they are not completely independent entities but are closely connected and mutually dependent.

Kim (2009) defines creativity in three levels that include intellectual skills, such as "narrow creativity: divergent thinking," 'wide creativity: divergent thinking and convergent thinking," and "creative problem solving." Here, "creative problem solving" is problem-solving in an open scene and not a pattern of human information processing. Moreover, Treffinger (2016) emphasizes the balanced application of divergent thinking and convergent thinking through the historical analysis of creativity education in the US.

The key to divergent thinking is "novelty," which is more elaborately explained by "elements of divergent thinking." Elements of creativity (or divergent elements) generally include fluency, flexibility, originality, elaboration, and abstractness (refer to Table 1). They also include non-intellectual elements, such as sensitivity or future orientation (Kim 2019, p. 276; Cho et al. 2008, p. 404).

E. Paul Torrance, the author of *Torrance Tests of Creative Thinking* (TTCT: Torrance 1974, 2008) was one of the pioneers of divergent thinking who put all pieces where they belong and supported creativity throughout his life. While Guilford was the initiator of scientific research on creativity, E. Paul Torrance was the most popular global proponent. He took the initiative to attract global attention to creativity (Kafman 2016, p. 78).

The preceding account indicates that he was not indifferent to academic conflicts, abstracted these conflicts according to his metaphysical beliefs to resolve them, and conducted thought experiments to justify them—this is the thinking process. While our study has emphasized the cognitive domain, exploration of the creativity of great scientists is also connected with affective characteristics (motives, task commitment, etc.) and their environmental factors (incubation period). Prabhu et al. (2008) also claimed that intrinsic motives, which are affective characteristics, help manifest creativity more than do extrinsic motives.

2.4 Creativity from Evolutionary Perspectives

Darwin said, In his book "The Origin of Species," first of all, a species variation occurs by accident, and this variant naturally selects or survives depending on the surrounding conditions. These strains not only become environmentally adaptable during heredity, but also over-proliferate, resulting in competition for survival. Therefore, the species that adapts best to the environment and occupies an advantageous position in the survival competition with other species survive. This process is called "natural selection".

Table 1 Creative components of intellectual (thinking) skills in the cognitive aspect

Component	Divergent thinking	Convergent thinking (critical thinking)	Valuation (may be included in convergent thinking)
Characteristic	Creating many diverse ideas (Mednick 1962)	Critical, judgmental thinking (Carson and Runco 1999)	Selecting what is useful with focus on the originality of the idea (Runco 1999)
Nickerson et al. 1985)	Divergent thinking creates new ideas, while convergent thinking evaluates the novelty (originality) and appropriateness (utility) of outputs and creates newer, more appropriate ideas by discovering problems or deficiencies		
	Complementary with tension (strained relation)		

There are three basic elements in the process of evolution by Darwin's natural selection (Sober 2000, p. 9).

First, there must be a variation between the objects being considered.
Second, the variation should be accompanied by a difference in fitness.
Third, the characteristics must be inheritable.

In short, evolution by natural selection requires that there be a heritable variation in fitness.

Therefore, for this, Darwin independently distinguished the two processes by which the evolution of species occurs (Korean Whitehead Society 1999, p. 102). In other words, what has resulted in the diversity of our present nature, and limits such infinite diversity?

(1) Producers that create diversity.
(2) Filter to filter out diversity.

(1) is a randomly occurring variation, and (2) is a natural environment.

Darwin did not ask about the cause of the variations. His interest was "Why are certain variations preserved?".

This is the core of his theory of natural selection. (1) is the creative ability, and (2) is the ability to solve problems well. If only the difference in adaptability worked, nature would not have been able to evolve life beyond bacteria.

According to Dawkins (1996, p. 282), there is a lot of debate about what is important in these two processes.

Here, we can say that (1) is divergent thinking and (2) is convergent thinking in the creativity process.

Kuhn argued that these two thoughts have an essential tension relationship.

Apart from their importance, these two processes can be said to be a dynamic relationship with each other.

3 Characteristics of Creativity: Focusing on Scientific Success Such as Great Scientists Based on the History of Science

Creativity can generally be defined as the ability to create a new and original product that satisfies the limitations of the task (Lubart 1994). "Product" here means any kind of idea or work. Narrowly speaking, there can be a variety of new or original methods within one domain. For example, it could be (1) a repetition of a known idea in a new way; (2) a step forward while maintaining the trend of the field or leading the field in a new direction; or (3) an integration of various trends within a field (Sternberg et al. 2002). In addition to novelty, the second element is that creative ideas are distinguished from strange ideas. Of course, strange ideas can be new, but they are creative only if they are new products that are effective and appropriate in a given environment (Sternberg et al. 2004; Hennessey and Amabile 1988; Runco and Jaeger 2012).

For creativity, the interaction between ability and process is emphasized. Regardless of ability, there are general methods and processes through which individuals display their creativity (Stern et al. 2004, p. 250). In other words, emphasizing form more than content, eliminating non-essential things, and choosing adequate problems are the characteristics of excellent scientific creativity (Miller 1996, p. 417). The two elements that are the key to the definition of creativity are novelty (original and different) and utility (valuable). We explore the characteristics of scientific creativity that appear in objective cases of success in scientific theories, such as theories by Galileo, Newton, and Einstein.

First, other obstacles to motion are merely obstacles, which make the formula complicated and must be considered later. Galileo realized that the core problem of motion is the "simple" case of falling in a vacuum, not falling in viscous medium or current. For this simple case, there is a need for the recondite assumption that free fall is equivalent in a vacuum regardless of weight. This is in line with the assumption that the speed of light is observed consistently by all observers in a vacuum in Einstein's theory of special relativity. In conclusion, there is an excellent abstraction ability that removes unimportant elements.

Second, the long incubation time shows that the best combinations selected during the network thinking period are elements adopted from completely different domains. A sudden realization is clearly the result of a long networking process. The pattern recognition based on symmetry is a key factor in understanding problem-solving. Above all, there must be a value in diversity that includes all forms. Young (1962) stated that "intuition of insight" does not appear by accident rather the ideas undergo the process and premise of creation, which requires an incubation period.

Figure 5 shows that at an early stage of life, creativity develops at a "superficial" or "general level" until at some point in life people choose a "specific domain." As they grow older and gain more experience, they show greater interest and focus on the relevant domain, developing expertise and becoming more domain-specific.

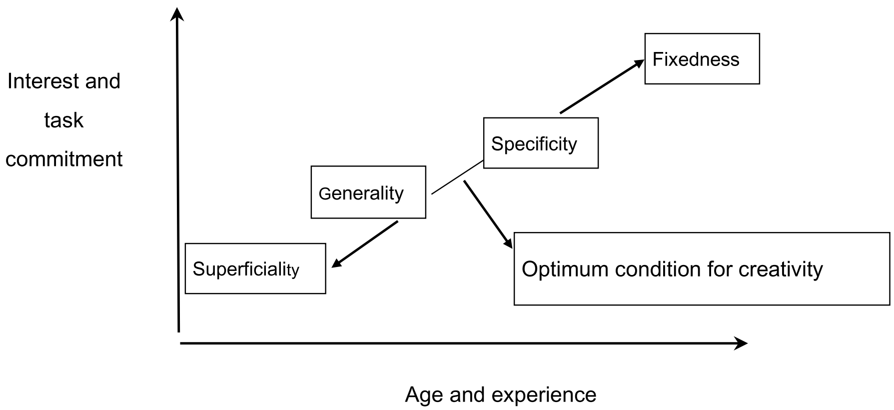


Fig. 5 Domain specificity and domain generality in creativity (modified from Stern et al. 2004, p. 255)

However, excessive domain specificity rather makes them difficult to be "creative" as they are too fixated on a specific domain.

People who constantly use domain-general techniques and approaches may become superficial whereas those who have focused on a single domain or a specific task for a long-time experience functional fixedness. Rather, some point between generality and specificity can be the optimum condition to produce a creative output. This hybrid view respects viewpoints suitable for multiple domains, while not overlooking the importance of specific expertise and task concentration (Stern et al. 2004, pp. 255–256). When observing the surface of the moon through a telescope, Galileo described it as accurately as possible using his attributes as an artist, which means he integrated another domain. Moreover, Einstein's theory of special relativity began at the age of 16 when he was not yet fixated on a specific domain. Famous science historian Westfall finds the source of the law of universal gravitation (active principle) in Newton's study of alchemy based on the similarity between the concept of alchemy and the concept of universal gravitation (long-distance gravitation) (Hong et al. 2005, p. 118). Newton used all domains given to him in the process of forming the concept of universal gravitation.

Third, these scientists valued thought experiments rather than a direct experiment, as well as the notion of intuition and aesthetics. In addition, they need patience and self-control required in learning difficult topics. Einstein liked to visually express declaratory knowledge into concrete facts and skillfully used the thought experiment that is procedural knowledge as a strategy for creative problem solving (Miller 1996, p. 442).

Aristotle could not leap to the level of Newton or Galileo's dynamics through imagination. It is not because he "disregarded facts," as claimed by seventeenth-century criticizers. Rather, it is more related to his desire to be too faithful to facts. For example, Aristotle was not aware that he must discount some aspects of common sense to create the perfect law of motion, and these aspects serve as the major reason why Aristotle's physics could not develop further into modern science. For instance, without considering an idealized world, which is frictionless motion in a perfect

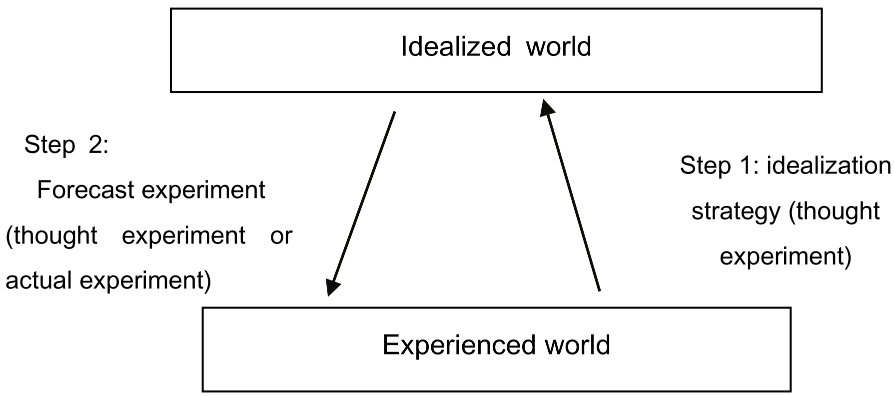


Fig. 6 Galileo's scientific exploration and deduction strategy

vacuum, Galileo strictly adhered to only commonsense observation data (refer to Fig. 6).

Fourth, there is Piaget's theory of cognitive development. The basic assumption of this theory shows that there is a parallel relationship between the cognitive structure and the history of dialectical science. For example, Piaget claimed that specific conflicting objects must be established as preconditions of scientific development. Einstein's abstract theory of special relativity came through specific objects (those in motion and clocks) to resolve the conflicts of Newtonian dynamics and electromagnetism regarding constancy of the speed of light. This includes sensitivity and future orientation.

The great-minds approach to investigating creativity studies characteristics of creative people and their products, elements largely drawn from biographical data and self-reports (welling 2007).

Our research emphasized the cognitive domain, but it also found that great scientists' exploration of creativity also involves interactions of affective characteristics (motives, task commitment, etc.) and their environmental factors (incubation period, refer to Table 2).

Great scientists of the past were aware of the discrepancy issue among different fields of study and long searched for solutions and kept their minds focused on them. As a result, they created a certain hypothesis using the abstraction strategy in which they considered only those that were suitable for the world view of the time. Then they conducted a thought experiment that justified it. However, this process is dynamically repeated countless times. The reason why it was difficult for general people to understand was the domain transition beyond materials obtained in the abstraction process. Furthermore, they all had strong motives for the future as well as task commitment (refer to Table 2).

According to Tang and Kaufman (2017, p. 204), there are four individual characteristics of a creative scientist: personality, thinking skills, research skills, and originality. Thinking skills, in particular, are the best criterion to identify a creative scientist (Shin and Park 2021). In other words, thought experiments that justify the abstraction ability emphasized in this study are the characteristics of important and creative scientists.

According to Qian and Alvermann (1995), students who believe that knowledge is simple and unchanging do not like to give up on their existing concepts, change the concepts, or explain what they understood. On the other hand, students who believe that knowledge has totality and is changing had an interest in learning the changes in concepts. Therefore, students' metaphysical beliefs turned out to affect their studies. Likewise, in terms of scientists' abstraction ability, metaphysical beliefs of a new world view became the start of a new concept, which indicates that these beliefs have become the foundation of abstraction.

Galileo's abstraction ability derives from Aristotle's teleological world view in which stability comes first on Earth since one's own position is important; this has changed into the world view of relative space in which, like the heavens, motion also comes first on Earth, and thus there is no superior space. Therefore, the original law of inertia in which natural motion is possible on Earth as in the heavens could be abstracted.

Table 2 Elements of creativity through scientific activities and outputs of great scientists

Divergent thinking	Interdisciplinary conflicts <cognitive>	Source of abstraction ability <cognitive>	Thought experiment <cognitive>	Incubation period <environmental>	Task commitment <affective>
Galileo kinematics	The discrepancy of natural motion in the heavens and on earth by Aristotle	Considering the same phenomenon in the inertial frame	The thought experiment of inertia, etc	Lifelong	Strong
Newtonian dynamics	The discrepancy in physics on earth in the heavens by Aristotle	Considering fixed, absolute space–time, quantitative world	Newton's thought experiment: Firing a cannonball horizontally → the cannonball can revolve	Until Halley's proposal (20 years)	Strong
Darwin's theory of evolution	Acquired characteristics of Lamarck's law of use and disuse explain species diversity but are not consistent with genetics	Transition and natural selection by Malthus's theory of population	Artificial selection	Lifelong (20 years)	Strong
Einstein's space–time (theory of special relativity)	The discrepancy of Newtonian dynamics and Maxwell's electromagnetic theory	Considering absoluteness of the speed of light	Optical clock, etc	Since boyhood (10 years)	Strong
Einstein's space–time (general theory of relativity)	The discrepancy of the inertial frame and non-inertial frame	Considering the sameness of gravity and inertial force	The orbit of light and spacecraft in accelerated motion	Since the announcement of the theory of special relativity (10 years)	Strong

Newtonian dynamics could be abstracted based on Aristotle's teleological and qualitative world view in which the Earth is subject to decay and change is still at the center of the universe. It is a world view characterized by a perfect heaven and its own position. It is a quantitative world based on causation with a deterministic world view, equivalent in both the heavens and the Earth. Since the absolute speed of light according to the observer's motion could not be explained, Newton's theory of absolute time and space adopted a dialectical world view, as did the theory of special relativity, in which the universe of the observer in motion is relative to time and space that changes rather than being fixed, and the general theory of relativity, in which time and space with mass are distorted because mass is energy as well.

In Darwin's theory of evolution, Lamarck's theory of change through use and disuse can explain the diversity of nature, but acquired characteristics are not inherited. Therefore, according to Darwin, transition can explain diversity, and characteristics that adapt to the natural environment through natural selection are inherited. This is possible as the view changed into a probabilistic world view with more incidental elements added compared to a deterministic world view (Author 2019).

The history of science shows that great scientists had the abstraction ability according to the changes in the individual or social world views of the time.

Creativity Through Galileo's Formularization of the Law of Inertia from a Cognitive Perspective

The experience of those who have broken boundaries between domains should be used as examples of creativity (Root-Bernstein and Root-Bernstein, 1999, p. 419). Galileo was able to engage in innovative work because he could fuse concepts and tools from various fields. Thus, this study explores Galileo's view of creativity

from a cognitive perspective.

3.1 Mathematical Abstraction

(**Galileo**) argued that there is a tendency on the Earth to continue in motion, just like in the celestial bodies, if the forces that interfere with motion are eliminated.

He focused on objects' tendency to move, which applies equally to both worlds (inertia).

3.2 Galileo's Kinematic Explanation: How Rather Than Why

Everything is made of the same material (the quantitative world of mathematics).

Therefore, all objects have the same rate of acceleration.

Celestial bodies and earthly objects are made of the same material (the quantitative.

world of mathematics).

Thus, if there is no friction on the ground, continuous circular motion will be.

possible, just as in the celestial sphere.

A scientific revolution was taking place from Aristotle's common sensual qualitative world to Plato's abstract quantitative world, shifting from the question of why to how. Instead of viewing space as qualitative, it was derived from the geometricization of space, namely the Pythagorean and Platonic traditions. The belief was that the.

universe was not simply there but was orderly. An orderly universe is predictable and displays causality, where effects follow causes (Miller 2000, p. 105). All scientific theories and laws are remarkably powerful and insightful mathematical abstractions. Finding.

simple principles through the complexity of reality requires great genius.

As these abstractions become more advanced, the domain of generalization expands.

Root-Bernstein (1991) approached abstraction as a process of simplification and "elimination of unnecessary detail to reveal underlying order, pattern or structure"(p. 87).

We think that structure, that is, the relationship between entities, once mathematically and metaphysically discovered, can be more clearly demonstrated in a simplified.

representation leaving out unnecessary detail.

3.3 Idealization (Justification of Mathematical Abstraction Through Thought Experiments)

3.3.1 Ignoring Friction Friction Through a Thought Experiment

If an object is moved with the same force on a horizontal plane, the smoother the surface is, the longer the distance and the time it moves (**reconstructing the world of common sense**).

If friction on a plane is the only cause that obstructs the object's motion, and if the surface is gradually smoothed to approach zero (**Ignoring the friction that prevents motion on a horizontal plane**), the distance and duration of the object's motion will increase and become infinite.

Thus, it is possible to imagine that in an idealized horizontal plane, all objects have an inertia that enables them to continue to move.

Expanding further, **the law of inertia can be established** using an idealization strategy in which all forces, including gravity and friction, are eliminated. In other words, the law of inertia is from a theoretical world that expands to the idealized world.

3.3.2 A Predictive Experiment of Actual Phenomena Through Visualization

Experimental prediction: If kinetic components are decomposed, and if it is correct that only the surface and horizontal components, which have nothing to do with the nature of tending toward the center of the Earth, move at a constant velocity (<u>visualization</u>), then air resistance will be low; and if a heavy object is dropped from the mast moving at a constant speed, it will naturally fall directly under the mast.

Experiment results: Indeed, it falls approximately under the mast. Thus, on a horizontal site such as the Earth's surface, the hypothesis is correct that a moving object continues to move without exerting any force on it.

3.3.3 Extension: Supporting Copernicus' Heliocentrism Based on the Earth's Rotation using Analogical Inference

Additionally, if a ship has the same linear rotation speed as the Earth, an observer on the ship, or on the Earth's surface, will make the same observation whether the Earth moves, rotates, or does not rotate. This is the basis of Tower's argument that.

the Earth does not rotate because an object dropped from a tower falls.

toward a point right under the tower. All objects except the sun move.

Just like objects fall from the mast on a ship with a constant velocity, the horizontal component for objects falling from a tower with a constant linear velocity was considered natural motion. Eventually, he claimed that circular motion was possible on the Earth just like the moon revolving around the Earth. As there is no difference between the laws of motion in the celestial system and those on the Earth, he supported.

heliocentrism because the Earth was no different from other planets.

3.4 Galileo's Law of Relativity

Motion at a constant velocity is not physically different from being at rest. In fact, the difference between the two is entirely relative to the reference system of motion.

(Ladyman 2002, p. 110). In other words, it is not known which system moves. This is the relativity of space. Einstein, who had this Galileo's principle of relativity in mind, questioned the reason why it should be limited only to mechanics' experiments. On the basis of his analogy, he paved the way to an extension to the integration of mechanics and electromagnetism. Therefore, Galileo's principle of relativity is a very important.

beginning in modern physics, the theory of relativity (Fig. 7).

3.5 Galileo's Creativity

1. Galileo's strategy of abstraction and idealization.

Aristotle's failure to leap to the same level as Newton's and Galileo's dynamics through his imagination was not because he "disregarded" the facts as 17th-century critics had. Instead, it is more likely that he tried to be too faithful to the facts. For example, Aristotle was unable to recognize that some aspects of common sense had to be discounted to create a complete kinetic theory (abstraction), which is why Aristotelian physics could not develop into modern science (Gottlieb 2000, p. 242).

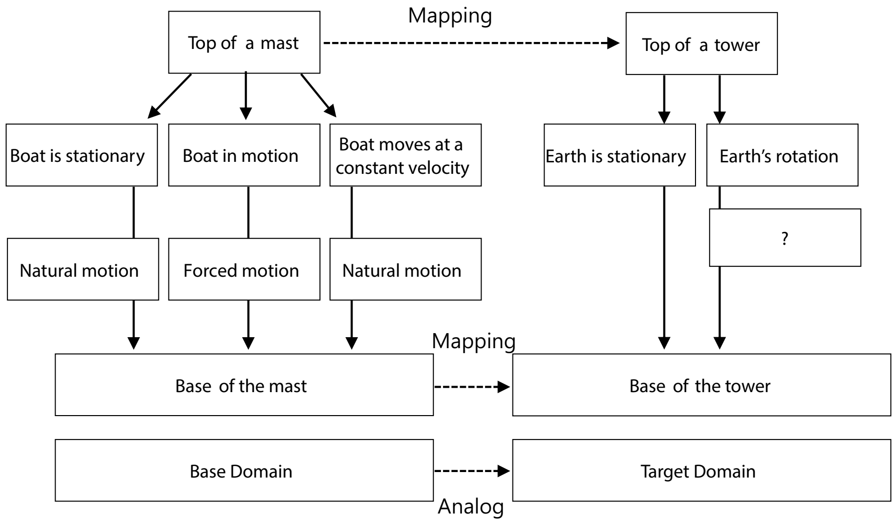


Fig. 7 Galileo's resolution of the tower argument using an analogy

2. Visualization skills and Analogical Inference.

This shows that the horizontal component of velocity is constant. Many authors have referred to analogy as a key concept in creativity. It implies the transposition of a conceptual structure from one habitual context to another innovative context. The abstract relationship between the elements of one situation is similar to those found in the innovative context (Welling 2007, p. 168). It is also time to recall other situations where the new situation has previously encountered but is superficially completely different, but shares an abstract core. For example, we can recall an adage, "Never try to catch a falling knife" in the context of a stock market crash. In this context, you are moving from a narrow space where time has passed quickly to a large space that flows relatively slowly. Using this context requires considerable abstraction (Stender 2013; Oh 2018). In other words, in order to solve Top's argument, a ship moving at a constant speed was used, and it was directed to the Earth's surface of a wider space.

3. The integrative capacity of opposites.

According to Galileo's law of relativity, it is impossible to distinguish a static world from a dynamic world in the inertial system. There was a shift from the static world of Aristotle to a new dynamic world. The dynamic world encompasses the static world, demonstrating an integrative capacity of opposing views.

4. by applying the law of inertia, it shows an assimilation that solves the arguments of the tower and the creativity that brings about a change in the cognitive structure

toward the heliocentric belief that all the planets revolve around the Sun of the solar system.

Galileo's explanation can be interpreted as a kind of symmetry. This is because the behavior of objects does not change even if the world is changed to "a world in which everything in the world moves at the same speed". This transformation is called Galileo's transformation. The symmetry that appears in this transformation is called Galileo symmetry. In other words, the laws of physics do not change due to Galileo's symmetry. Symmetry means' change that doesn't change'. In an expanded interpretation of its meaning, symmetry is a concept that humanity has developed for many years to understand and create order, beauty, and perfection (Wilczek 2015).

4 Conclusion and Suggestion

For creativity, the interaction between ability and process is emphasized. Regardless of ability, there are general methods and processes through which individuals display their creativity (Stern et al. 2004, p. 250). In other words, emphasizing form more than content, eliminating non-essential things, and choosing adequate problems are the characteristics of excellent scientific creativity (Miller 1996, p. 417). The two elements that are the key to the definition of creativity are novelty (original and different) and utility (valuable). We explore the characteristics of scientific creativity that appear in objective cases of success in scientific theories, such as theories by Galileo, Newton, and Einstein.

First, scientists had an excellent abstraction ability to eliminate unimportant elements depending on the society's or their own world view at the time. They made judgments based on sociocultural values of the time; above all, they sought to resolve conflicts among different domains. Other obstacles to motion are merely obstacles, which complicate the formula and must be considered later. Galileo realized that the core problem of motion is the "simple" case of falling in a vacuum, not falling in a viscous medium or current. For this simple case, there is a need for the recondite assumption that free fall is equivalent in a vacuum regardless of weight. This is in line with the assumption that the speed of light is observed consistently by all observers in a vacuum according to Einstein's theory of special relativity. In this way, it can be said that the abstraction of a region goes beyond the boundaries between fields.

Darwin's theory of evolution claims that all animals and plants share the same ancestors, and life has become more diverse through adaptation and change by nature, not by creation of God. *On the Origin of Species* published in 1859 became the "final blow" that ended the domination of the Bible as well as anthropocentricism. Darwin read the Malthusian theory of population and discovered the mechanism that he named "natural selection," similar to artificial selection (Henry 2012, p. 233).

While the results of this study suggest that alternative conceptions of natural selection transcend racial, ethnic, and/or class boundaries, they do not imply that the same pedagogical strategies and curricular frameworks will be equally effective for ameliorating alternative conceptions of natural selection in these different student populations (Nehm and Schonfeld 2008, p. 1158).

Second, the long incubation time shows that the best combinations selected during the network thinking period are elements adopted from completely different domains. A sudden realization is clearly the result of a long networking process. Pattern recognition based on symmetry is a key factor in understanding problem-solving. Above all, there must be a value in diversity that includes all forms. Young (1962) stated that “intuition of insight” does not appear by accident; rather, the ideas undergo the process and premise of creation, which requires an incubation period.

At an early stage of life, creativity develops at a “superficial” or “general level,” until at some point in life, people choose a “specific domain.” As they grow older and gain more experience, they show greater interest and focus on the relevant domain, developing expertise and becoming more domain-specific. However, excessive domain specificity makes it difficult for them to be “creative” as they are too fixated on a specific domain.

People who constantly use domain-general techniques and approaches may become superficial, whereas those who have long focused on a single domain or a specific task experience functional fixedness. Rather, some point between generality and specificity can be the optimum condition to produce a creative output. This hybrid view respects viewpoints suitable for multiple domains, while not overlooking the importance of specific expertise and task concentration (Stern et al. 2004, pp. 255–256). When observing the surface of the moon through a telescope, Galileo described it as accurately as possible using his attributes as an artist, which means he integrated another domain. Moreover, Einstein began work on his theory of special relativity at age 16 when he was not yet fixated on a specific domain. Famous science historian Richard S. Westfall finds the source of the law of universal gravitation (active principle) in Newton’s study of alchemy based on the similarity between the concept of alchemy and the concept of universal gravitation (long-distance gravitation). Newton used all domains available to him in the process of forming the concept of universal gravitation.

Knowledge is a product of natural selection, and the fusion of knowledge that does not presuppose the unity of knowledge is meaningless.

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