The Creative Principles

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Abstract

The Theory of Inventive Problem Solving (TRIZ or TIPS), introduced by Genrich Altschuller, is a very useful tool for solving technical problems and triggering inventive ideas (Altschuller, 1973). Nevertheless, the scope of its use has so far been limited to technical areas. This paper describes how these 40 technical principles can be converted into 22 creative principles, which can universally be applied to a broad range of areas and disciplines. The conversion was achieved by subjecting the TRIZ principles to an abstraction process and a comparative transfer to five additional disciplines.

***Keywords**:* Problem solving, creativity, principles, disciplines, contrast, demarcation, force, directionality, repetition, order, periodicity, planning (preparing, forecasting), storing.

Plain Language Summary

This paper makes a fundamental contribution to the understanding of creativity by showing that 22 creative principles and their combinations underlie creativity, problem solving, and inventiveness. These principles seem even to be the theoretical roots of evolution in general (Servay, 2024).

Applying this knowledge in other disciplines beyond the technical fields demonstrates the generalizability of these creative principles and it suggests their validity across all disciplines. The creative principles therefore constitute a functional language that can be understood by all disciplines. This characteristic will accelerate not only cognition within the disciplines but also mutual exchange and mutual understanding, which is crucial to developing links between disciplines that are increasingly separated and that speak ever more specialized languages.

These insights could establish a foundation of learning, as we want our children to learn principles rather than facts. Therefore, this knowledge should be employed in teaching, as we especially want students to be able to transfer knowledge from one discipline to others. Offering a common language can bring the diverse disciplines together—at least on an abstract level—to expand the inventive space and even bridge the broad gulf that has historically developed between the sciences and the humanities.

Introduction

A Philosophical View

Creativity seems to be a fabulous, mysterious form of intelligence that is given to certain privileged people as a blessing. If you are not one of the lucky ones, you may have to spend your existence in a gray, non-sparkling world with limited fantasy. Is this really a fate that cannot be changed?

The creative principles tell a different story. The name "creative principles" is a contradiction. It combines limitless creativity with rule-obeying principles. However, these seemingly opposing aspects are able to generate the splendor of creativity.

Origin of the Creative Principles

In 1946, the Russian engineer Genrich Saulowitsch Altschuller was working as a patent examiner for the Russian Marine Corps (Altschuller, 1973, 2005, p. 129). At this time, he tried to find general rules that he expected to be the foundation of patents and that, he thought, should systematically lead to inventions. For this purpose, he investigated—together with others—around 200,000 patents (Altschuller, 2005, p. 13) in the fields of electrical engineering, acoustics, optics, and mechanics—consequently, mainly in the field of engineering. Thereby, he extracted 40 principles intended to systematically solve engineering problems. He summarized the lessons learned in the Theory of Inventive Problem Solving, abbreviated as TRIZ[1] or TIPS.

The basic idea of TRIZ is that a problem is typically based on a contradiction. Resolving the contradiction will lead to an invention (Ropohl, 2012, pp. 85–88). Altschuller and his former schoolmate, Rafael Borissowitsch Shapiro, compiled their findings into 40 abstract principles to solve contradictions (Altschuller, 2005, p. 11). They arranged the 40 principles into a matrix in which contradicting target parameters oppose each other in the two matrix dimensions.[2]

Because the TRIZ principles are preferentially focused on technical fields, several efforts have been undertaken to expand their applicability to other disciplines as well[3] (Altschuller, 2005, p. 21), but with limited success (Beckmann, 2015; Willms et al., 2000). To enable the transfer of the principles to other disciplines, further generalization and abstraction (Prätor, 1988) are required. "In an abstraction process, less relevant features are ignored while the characteristic features are extracted and pronounced. The decision which characteristics have to be emphasized, depends on the intention of the recognition" (Prätor, 1988, p. 130). This process ultimately led to the creative principles described in this paper.

[1] The abbreviation TRIZ is an acronym for the Russian expression "Teoriya Resheniya Izobretatelskih Zadach", which means Theory of Inventive Problem Solving.

[2] See *"Contradictions Matrix—TRIZ Tools Oxford Creativity," www.triz.co.uk.* The second dimension of the factors, which could be in contradiction with the TRIZ principles, will not be of interest for the discussion here.

[3] Dana W. Clarke, "It is the reader's responsibility to broaden thinking about the language of the principle and apply it to a particular field of work" (Clarke in Altschuller, 2005, p. 21).

Methods

Conversion of TRIZ Principles to Creative Principles

Since the target of this effort was to widen the scope of the applicability of the inventive TRIZ principles to a much broader range of disciplines. The TRIZ principles had to first be expressed in an even more abstract form, namely the creative principles.

TRIZ is a special type of System Theory, and Ropohl (Ropohl, 2012, p. 10) notes that for the development of an interdisciplinary System Theory (von Bertalanffy, 1969), it is also necessary to overcome the problem of different discipline-specific languages. Therefore, a similar problem is encountered upon transferring the TRIZ principles to other disciplines.

The ultimate goal was to obtain only one set of principles for all areas of expertise by finding universal forms of linguistic expression. This could be achieved by looking at each principle separately and trying to extract its abstract functional content. Subsequently, the functional content was transferred to the various languages of different disciplines. In an ideal case, one expression for one creative principle resulted when the expression seemed to be acceptable to all disciplines. In other cases, it seemed advantageous to list additional synonyms (e.g., force: attraction, motivation). In most cases, antonyms have also been identified within the set of 40 TRIZ principles so that opposing pairs could be combined in one creative principle (e.g., growth: expansion ↔ shrinkage). From this practice, redundancy emerged, resulting in a reduced number of 22 creative principles. The antonyms can be generated by combining a principle with the creative principle “contrast,” resulting in its antonym. So, for example, the generic term “demarcation” contains the antonyms connecting ↔ dividing. TRIZ Principles 5, 20, 24, 38, & 40 mean “combining,” and TRIZ Principles 1, 2, 3, 31, & 39 mean “dividing.” Due to the wider scope of the creative principle, dividing applies to a barrier or insulation, while combining applies e.g., to optically connect one side with the other, resembling transparency. Similarly, strong oxidants have been interpreted as forming oxide bonds, and bond formation, from a chemical point of view, means, connecting atoms.

The ultimately reworked set of principles has thus been named the creative principles.

In Table 1, the 40 TRIZ principles (Altschuller, 2005) are correlated with the 22 creative principles, which have been developed via abstraction of the TRIZ principles with the intention of framing these principles in the context of six different disciplines: music, the visual arts, architecture, technology, biology, and psychology.[4]

**[Table 1 see complementing *.pdf-file -
“Table 1 - The Creative Principles - T. Servay - March 2025.pdf”]**

Other TRIZ principles are combinations of two or more creative principles: for example 8, 9, 29, 30, 31, and 37. This shows that the TRIZ principles and the creative

[4] Six disciplines were chosen out of more than 24 core disciplines, depending on preexisting work on such principles in the disciplines, and because it would not be possible to discuss a broader range of disciplines in one paper.

principles rely on different sets of functional operators (40 versus 22), segmenting the inventions generating, multidimensional space. While the creative principles represent a generic set of 22 functional principles, the TRIZ principles also use combinations of functions, resulting in a set of 40 principles that are focused on engineering problems. Furthermore, there have been creative principles found during the analysis of the various disciplines—e.g., directionality, rotation, and crosslinking—that have no analogous TRIZ-principle. Directionality is implicitly contained in the creative principle of force since force always has a direction. Rotation[5] as well as crosslinking[6] are a composite of creative principles, but since they are frequently used, it is more convenient to list them together with the basic set of creative principles for easier recognition. Finally, some of the TRIZ principles have a very narrow meaning (due to the engineering focus), such as the TRIZ principles correlated with the creative principles of elasticity, contrast, order, growth, storage, and force.

Besides TRIZ, there is another creativity method developed by A. Osborn, the "Checklist"[7] (Herb et al., 2000, p. 22) that uses eight approaches to problem solving: adapt, modify, replace, enlarge, shrink, rearrange, invert, and combine. These solution approaches are very similar to some of the creative principles (e.g., elasticity, substitution/store, growth, order/inversion, connect).

Use of the Creative Principles in Various Disciplines

Let us look at one creative principle: for example, connect. As one of the demarcation antonyms, connecting has various discipline-specific meanings. Its functional meaning changes slightly from discipline to discipline. This is demonstrated in Table 2.

Table 2

The Meaning of "Connecting" in Various Disciplines

Connecting	
Discipline	**Meaning**
Technology	connecting of parts, gluing, welding
Chemistry	chemical bond
Biology	multicellular organism, multiplication, contact
Psychology	communication
Music	a sequence of notes, playing music together
Architecture	corridor, stairs, door, window

[5] Rotation is a *motion* that is *fixed* to a perpendicular (second *dimension*) point.

[6] Crosslinking means: splitting a pole at one end to form a branch and subsequently connecting two ends of two branches (two "y" form an "H"). Therefore, the first step of crosslinking is branching.

[7] According to Herb et al. (2000), the Osborn solution approaches are especially useful, if problem solving is jamming.

It requires a little training to become acquainted with the shifting meanings. For example, "connecting" in a technical field means connecting parts, welding, and gluing. In chemistry, it means forming bonds between atoms, and in biology it means a multicellular organism, sexual intercourse, or even skin contact. Meanwhile, in psychology, the dominant connecting activity is communication. "Connecting" has a very general and abstract level of meaning—an almost chameleon type of appearance. Nevertheless, its functional meaning in all these semantic relationships equals "connecting."

Creativity comprises a productive element, such as biological multiplication, a reaction forming a chemical bond, the sequence of notes forming a melody, or the construction of a building containing interconnected rooms. The connections between the rooms of a building are provided by doors and stairs as well as windows (Koolhaas, 2014, pp. 602–760). Windows create connections to the environment.

Problems can now be solved not only in technical fields by using TRIZ, but also in other disciplines by using the creative principles via similar processes as employed by TRIZ.

In addition, if such abstract principles can be found for all disciplines, then it might be possible, with the help of the creative principles, to find a foundation for a mutual interdisciplinary understanding of general functional mechanisms across disciplines.

Results

Representative Examples of Creative Principles in Music, the Visual Arts, Architecture, Technology, Biology, and Psychology

For the investigation of the six disciplines in connection with the creative principles, the following literature has been used: for music, (Bernstein, 1968, 1976, 1985); for the visual arts, Rudolf Arnheim (Arnheim, 2000; Ramachandran, 2012; Rauch, 2013); for architecture, Rem Koolhaas (Koolhaas, 2014; Semper, 1860); for technology, (Brennecke, 1981; Brentjes et al., 1978; Cameron & Neal, 2003; Feldhaus, 1976, 2013; Gimpel, 1981; McNeil, 1990; Mehl & Matz, 2000; Schiffer, 2000; Wilde, 2004; Ostwald, 1911); for biology, (Botkin & Keller, 2005; Dawkins, 2007; Fuchs, 2014; Kämpfe, 1985; Kleine & Rossmanith, 2014; Madigan et al., 2014; Munk, 2009; Wehner & Gehring, 2013; Weiler & Nover, 2008); and for psychology, (Böker et al., 2016; Cialdini, 2013; Ciompi & Endert, 2011; Darwin, 2000; Ekman, 2010; Gerrig, 2016; Jäncke, 2017; Klemenz, 2018; Largo & Czernin, 2018; Lynch-Fraser & Tiegerman, 1987; Petzold, 2003; Reik et al., 1974; Schmithüsen, 2015; Schütz et al., 2015; Snyder & Lopez, 2009). Leonard Bernstein (Bernstein, 1976, 1985, 1968) and Ramachandran (Ramachandran, 2012; Rauch, 2013) have previously tried to find some general compositional principles for music and constructional principles for the visual arts.

The 22 creative principles correlated with six disciplines resulted in 132 matrix elements. The full scope of the creative principles is too much to be presented here. Therefore, only nine selected creative principles are discussed here for the six investigated disciplines. This reduced 9 x 6 - matrix is represented in Table 3.

[Table 3 see complementing *.pdf-file -
"Table 3 - The Creative Principles - T. Servay - March 2025.pdf"]

More examples and the background of the creative principles are published in the form of a German book (Servay, 2024).

Contrast

Nothing can be detected by any sensor without contrast. Not even energy can be transformed into any other form of energy without contrast. This is also valid for our universe, which could never have been generated without any contrast or persist otherwise. All changes are initiated by contrasts. Contrasts are, therefore, fundamental for all disciplines.

Contrasts in music are, for example, pitch, loudness, tempo, and key. In the visual arts, they are exhibited as brightness and different colors that allow one to differentiate objects and group them. Furthermore, besides abrupt changes in optical and musical parameters, changes can also occur gradually as in a glissando.

In architecture, light plays a fundamental role. A building is only valuable if the interior can be illuminated[8]. This can be achieved through the integration of windows, doors, or artificial lighting. Windows can also supply the house regularly with fresh air. The introduction of additional floors into the building improves room efficiency, but at the same time, the inhabitants regularly have to spend energy to move between different floors. To ease the effort of moving from floor to floor, stairs with a gradual slope have been introduced to overcome the height differential (contrast).

In the technical field, any difference in parameters such as energy, force, motion, pressure, heat, lighting, and so on indicates a contrast. Electric charges and magnetic poles are characteristic for two extreme contrasts. Even electronic signals of computers are built on contrasts: zeros and ones.

The signal entry ports of living organisms are sensors, which essentially require a contrast of signals to supply the organism with environmental information. If we look at the inside of a single cell or bacterium, cell parameters—e.g., membrane potential, proton gradient, or turgor pressure—use the same principle of contrast to generate a response. Every living organism is an open-flow system that operates on the basis of a contrast between the incoming and outflowing effluent.

In psychology, drives result from essential, life-sustaining deficits (contrasts). Analogously, emotions arise in response deviations from expectations or assumptions and evaluations. Emotions, then eventually, trigger an action (Damasio, 2017). The goal of many processes in living organisms is to sustain a viable equilibrium between two or more parameters (homeostasis (Damasio, 2017, p. 52)). The same is true for psychological evaluations, e.g., where one seeks to achieve enhanced serenity, satisfaction, or justice. Psychological drives and emotions are analogous to contrasts in technology, where they initiate motion. Psychological balance is important in many cases, such as the balance between positive and negative feedback. Serenity, satisfaction, and justice are thus examples of similar equilibrium states.

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[8] Blind people are exempted here.

Demarcation

Demarcation is also a very basic principle, with the antonyms connecting and dividing. The expression "demarcation" is meant to signify the abstract functional synonyms combining, collectively, continuity, and transparent versus splitting, separating, sharing, resting, barrier, and insulation or being inert. Connecting and separating are mutually dependent on each other, as is clearly witnessed in architecture, technology, and biology.

Architecture is derived from separating and connecting elements, while separating and connecting technologies is as fundamental for their field as is biological reproduction via cell division. A building acts as a protective shell for human beings, and the inside is structured by separating elements (roof, wall, floor, ceiling, facade), which contrast with connecting elements (door, window, corridor, ramp, stairs, escalator, elevator). Some barriers have specific separation functions, such as thermal or acoustic insulation.

Connecting technologies (nailing, screwing, gluing, weaving, sewing, zipping) and separating technologies (sawing, cutting, splitting, punching, grinding, distilling) are very basic functions for generating technologies of greater complexity. These technologies have been critical for hunting, collecting and food preparation, and for the building of accommodations. Vessels exhibit both performance options. They can separate liquids and powders from the environment for storage, but vessels can also contain different ingredients to form, e.g., dough or soup. Separating (fishing nets, fish traps, pitfalls) or fixing tools, e.g., fishing hooks, have been used for hunting by limiting the mobility of the prey.

Biology has some similarities to architecture regarding the segmentation of space. Organisms are multicellular by nature, and cells can have specific functions, almost like rooms in a house. Each cell is enclosed by a membrane that protects it from the environment. Additionally, the nucleus inside the cell is surrounded by a separate lipid barrier. Differentiated cells can work cooperatively together, complementing their individual capabilities. On a macroscopic level, analogous organizational behavior can be observed in social animals by the division of labor. As seen in architecture, separating barriers demand, at the same time, connections. Therefore, various kinds of cell-to-cell contacts can be found, e.g., plasma bridges, plasmodesms (in plants) (Sitte et al., 2002), and tunneling nanotubes (Rustom et al., 2004) and gap junctions (in animals) (Goodenough & Paul, 2009).

The metabolism of an organism can be either anabolic, meaning assembling, or catabolic, meaning deconstructing.

Relations between people form the basis of social communities, and these interactions, which are dominated by various types of communication, are the major impetus for most psychological behaviors. Emotions are qualifiers of these relations (love, affection, admiration, respect, yearning, grief versus contempt, hate). Cooperation is also a psychological connecting phenomenon that leads to division of labor. The relations between social individuals can also be impacted negatively by a breach of loyalty or by fear of separation. Social isolation is one of the worst feelings for a social being.

A barrier can also mean a time gap between events, such as rest or sleep, during which the body has the opportunity to recover and recharge its energy sources.

Demarcation reflects an important aspect of evolution: separation is very important for preserving order. The hierarchical membranes around the nucleus and those around the cell are examples. The biological barriers of living beings are extended by additional protective shells for the body in the form of clothing, followed by architectural constructions, such as houses. Separating barriers for protection brings along the challenge of an open system to preserve an exchange with the environment. This means that connecting elements are required. Barriers in psychology are generated by distractions or social isolation—in their extreme forms.

Force

A force is typically generated by a contrast that has the tendency to equilibrate. The direction of the force is determined by the strongest contrast. Anything that needs to move or change requires a force. Therefore, force is most visible in technology, biology, and psychology, while architecture deals preferentially with static forces.

The field of mechanics is especially dominated by motion that requires forces. Even the first tools, hunting equipment, and vessels, relied on forces and motion. Traps usually try to restrict motion by imposing additional forces or barriers that require an overwhelmingly stronger force to initiate a sequence. An important basic technology for transferring forces over a longer distance is rope. Ropes are bidirectional and thus transfer force from one end to the other. Ropes can be regarded as a starting point of information technology, as they transmit a force "signal." In ancient times, ropes were used to operate draw wells and cranes, or to tie sacks, fix animals, or steer them with a bridle.

With progressing evolution, humans delegated force generation to draft animals, and later, these tasks were transferred to engines. Initially, engines were driven by water and wind power—comparable to sailing ships. With the Industrial Revolution, steam power took over this task, followed by internal combustion engines; now, we observe a shift to electric motors.

No less important is force for biology and life. Animals generate their forces by muscles, while plants prefer to use pressure, e.g., osmotic pressure and tugor pressure. The strength of these plant forces can be recognized indirectly through roots that grow through pavement or walls. At the cellular level, the proton motor force is known to be responsible for transporting molecules through cell membranes.

To understand the impact of forces in psychology, we must first understand the meaning of force in this discipline. A force can set something into motion. Psychologically, this means getting an action started. Before any activity starts, a person needs to be motivated to perform this action. So, basically, motivation is a kind of psychological force that makes people act. Motivation increases the likelihood that the biological energy required to perform the intended action will be liberated. Motivation is initiated by an emotion that controls the release of energy needed for an action or denies the energy supply by demotivation.

Psychological drives are also forces that originate from the two essential necessities of life: to self-sustain and to reproduce, which can hardly be controlled deliberately. Drives are typically implemented to sustain homeostatic equilibria[9] (Damasio, 2017).

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[9] "A state of equilibrium, as in an organism or cell, maintained by self-regulating processes: The kidneys maintain homeostasis in the body by regulating the amount of salt and water excreted." homeostatic equilibrium (Free Dictionary, n.d.).

Sympathy or love initiate social bonds with their attractive force, just like the formation of chemical bonds. This contrasts with antipathy, rejection, and contempt.

As mentioned above, architecture fights with only indirectly visible static forces to secure the integrity of a building. Motion happens only over a very long period, which typically surpasses our lifetime experience. These strong forces are closer to natural geological forces and exist on extreme time scales in comparison to our common, everyday experience. Structural engineering calculates the force distributions in the structure of a building. In this process, it is important to obey the material limits of the maximal load as well as external forces that may impact the building during its lifetime, even in catastrophic cases, e.g., storms, floods, or earthquakes.

Vertical connection elements in tall buildings serve to overcome the difference in elevation between floors, and for this purpose, force needs to be employed. For the first vertical connection elements, e.g., ramps and stairs, human beings had to use their own force, but later, elevators and escalators started to supply energy and forces for this service. We must not to forget the extra force, required to supply higher floors with potable water up and wastewater down.

In the static visual arts, dynamic forces can only be indicated or implied (Arnheim, 2000, p. 411). The observer needs to conclude that something is moving, e.g., a wagon on a hill signifying that it may roll downhill. Another example is a blacksmith with a lifted hammer that needs to come down soon—a deviation from its resting point on a static surface, such as a workbench. Labile arrangements make people think in advance about what will happen next, and this causes the observer to get an idea of motion dynamics. Facial expressions, postures, or body shapes can also trigger conclusions via emotions (anger, pity). Traces that have been left behind in the past allow future action to be predicted as well, e.g., of the emanating wake from behind a boat, a deformed object, or a swollen muscle.

Force mainly serves to generate motion. For this purpose, engines have been constructed in technology, muscles have evolved in biology, and psychological action is initiated by motivation or psychological drives. In architecture, on the other hand, the goal is to avoid motion in the building, which is caused by destructive rather than equilibrated forces. The visual arts can only stimulate the imagination to give the impression of motion via indicators of the moving forces.

Directionality

Directionality is a rather neglected principle, even though it is of the utmost importance, as it is inseparably paired with any force and motion. Motion in the sense of dislocation always has one single direction if undisturbed. This is also true for the directions of light and time. They are both unidirectional, causing light to travel away from the source and time to exhibit only one direction—into the future. Time is not reversible since unidirectional light can never come back. This close relation to force and motion explains why directionality is equally relevant for technology, biology, psychology, and architecture.

Motion has been at the core of technology, and this may remain true for some time. Beginning again with the discussion of simple tools, most basic vessels are filled in one direction and emptied in the other. Tools apply a directional force to objects. Hunting gear, such as arrows, fishing hooks, or fishing traps, works in one direction, especially with pitfalls or fishing hooks with barbs. Ropes are a very important directional connecting element. They serve to transfer force from one end to the other. This property made them indispensable for transporting cargo or people in three-dimensional space using draw wells, cranes, or elevators. Rivers are, by nature, unidirectional conveyor belts for boats and ships as easy means of transportation. Additionally, wind is exploited to move sailing ships in one direction[10].

On the other hand, there are seemingly non-moving parts that also employ unidirectional forces to bring information energy to another place, such as electricity. Neither the wire that transports the energy nor the atoms that constitute the wire itself move. Rather, only the electrons in the metallic wire dislocate.

Engines rotate in one direction that can be reversed in the case of an electrical motor.

Thermal energy or heat always moves from hot to cold. Typically, there is a hot spot and the environment is cold, so the heat dissipates omnidirectionally away from the hot spot. This happens in combustion processes or upon local friction (drilling, sanding, braking).

Architectural buildings are unidirectional; they are designed to support their load along the gravitational force, with the roof on top and the basement or ground floor as the foundation. Architecture mainly reflects the geometry of the human body with its head and feet, whose needs determine architectural planning. The connecting elements—doors between rooms, stairs between floors, or windows between inside and outside—are pre-oriented passages that only allow bidirectional motion. The window exhibits a diodic[11] property. During daylight, it transports light to the inside, but at night, the illuminated inside is visible to the outside, which is not always appreciated (blinds or curtains).

Biology had to adapt to the gravitational field on our planet. Therefore, large organisms impacted by this force had to cope with this unidirectional orientation. The large group of Bilateria exemplifies this adaptation to uniaxiality. Bilateria have the basic required structure of an open-flow system with an inlet and an outlet. They are constructed as unidirectional digestion tubes. Plants conform to the same unidirectionality: they are rooted in the ground and grow toward the sky.

At the level of a cell, membranes are composed of lipid bilayers, and the molecules of one layer oppose those of the other layer (2D-order structure). It is a bidirectional order structure. Similarly, one DNA strand is paired with a second one that complements the first (1D-order structure) and, as a consequence, replication can take place in a bidirectional fashion. A further example is the one-directional membrane potential.

The most relevant ingredients to psychology are bilateral or multilateral relations. These bidirectional relations are motivated by emotions and are strengthened by communication, which is, so to speak, the glue between the related persons. This is even indicated by the word "*di*alogue" as a bidirectional communication form. In any relationship, feedback is important, and it is even better if it takes place not only unidirectionally but in a bidirectional way.

[10] This is valid if the wind direction is stable and without extra innovative devices, e.g., a rudder.

[11] "diodic"-behavior means: it behaves like an electronic diode that turns alternating current (bidirectional) into direct current (unidirectional).

The visual arts are a form of expression, and they are therefore primarily directed toward an audience. The feedback of the audience is usually limited to applause or boos. Since people have heads with a face oriented in one direction, communication is usually carried out in a face-to-face orientation; therefore, a communication partner can easily be found in the face direction. Pictures are commonly oriented in portrait or panorama fashion, obeying the direction of gravity and following the orientation of our life on Earth. For the directions of motions, the same is valid as what has been said for force. From footprints, we can know where an animal was coming from and in which direction it was heading.

Music is directed along time, and this is why notes have to be arranged in the same manner, namely, as a sequence of notes. The sound seems to have a little more freedom since it can spread omnidirectionally in all three dimensions.

Like biology, architecture is forced to orient itself to gravity (the shape of the house) since it is designed to serve the needs of humans, and this is most often also valid for technology. In addition, the connection elements of architecture guide people in a bidirectional fashion. In psychology, directionality mainly plays a role in communication and creating persistent relationships.

Repetition

Repetition is important for all disciplines. A turning wheel is a cultural symbol of a repeating process. After one revolution, the same spot of the wheel returns to the starting point, again and again. In a comparable fashion, all cyclical processes repeat after passing a full rotation.

Since cyclical processes are of utmost importance to technology, repetition plays a major role in developing more efficient processes. Repetition is a fundamental principle of the conveyer belt, which turned out to be the key to mass production. Furthermore, the functional principle of any engine is based on at least one cyclical process (motors and power engines). Even tools (e.g., hammers, paddles) that were developed long before engines require the fundamental principle of a repeated cyclic process, even if it may not be as obvious as for the wheel. The hammer is lifted and then falls down in a controlled fashion to exert force on an object, such as a nail. When paddling, the driver has to stick the paddle into the front waters, apply force to the paddle, and move it back in the water, whereby the boat moves forward. To generate a continuous forward movement of the boat, the paddle has to repeatedly dig into the front waters, over and over again. In these cases, humans are still responsible for performing the repeated action rather than an engine.

Repetition is important even in non-moving parts. For example, in electronics, accumulators can deliver current, but as storage devices they must be charged again regularly. Most processes contain some repetitive elements that make the process economic and reusable.

Repetition is fundamental to cyclical processes. Cyclical processes are, so to speak, the reincarnation of repetition.

The rhythm of an engine creates an industrial sound that is often regarded as an unpleasant noise, although for others, it might be turned into enjoyable music. Leonard Bernstein (Bernstein, 1976, pp.145, 181) identified repetition as a fundamental principle of any type of music. Rhythm is representative of repetition, containing repeating bars as subunits. Octaves are also repeating units; only the pitch changes. Furthermore, tones can be sequentially repeated several times in a piece of music. Moreover, not only can tones be repeated; whole passages or even the melody can be closed into a loop to produce a cyclic form, e.g., a canon, fugue, or rondo. A canon is a polyphonic piece of music in which different parallel voices start with a respective time delay in relation to each other. The pitch of the voices can also be altered. The melody is repeated several times by the singers. Repetition is indeed a very basic principle in music.

Rhythmic cycles are also of crucial relevance to biology. As open-flow-systems, creatures need to regularly open-up while ingesting and excreting. On the other hand, they must reproduce to prevail. As the expression "reproduction" signifies, it is a repetitive act that repeats itself after each generation, and every time, the growth cycle starts again. During cell division, the DNA is replicated and thereby doubled to subsequently allow splitting of the cell into two separate and almost identical cells, each containing the full set of genes.

Cultural progress is founded on learning, which is the most important task of the brain and is achieved through repetition. The first stage of learning is imitation.

The development of psychological and social communities is based on mutual trust. Trust is built on repeated actions, such as rituals, enhancing the relationship. Thereby, past experiences serve as the predictive basis for future collaboration.

Architecture is the child of technology; this is demonstrated by the modular processes employed, e.g., bricklaying. This becomes obvious when the focus is on large, functional buildings. The economic principle forces architects to produce mass architecture with identical subunits, such as apartments arranged in long rows and multiplied across different floors. Other repetitive elements are contributed by connecting elements, such as stairs or escalators with repetitive steps. Ancient, splendid balustrades and ornamented facades with often organic filigree and repetitive patterns contrast with the plain and sober mass architecture of today (Koolhaas, 2014, pp. 137, 1202–1508).

Repetition is of crucial importance to enable efficiency in the repeated motion of engines or the periodic homeostatic processes of creatures. Even in learning, repetition is the key to success. On the other hand, repetitive and organic patterns and shapes can please our aesthetic sense. The continuation of a repetitive pattern provides predictability and possibly trust via continuation, which can generate a feeling of security. Repetition in time generates a periodic pattern, such as a rhythm, which reminds us of music.

Order

Order reduces complexity by segmenting the full scope into systematic arrangements, e.g., object arrangements. Order dominates the material world by assembling atoms or molecules into fascinating and almost perfect crystal structures. These arrangements form due to interactions between neighboring atoms or molecules. If part of the order is lost, e.g., by increased dynamics, order is reduced, typically in single dimensions. Such states are called liquid crystalline states, namely, smectic and nematic phases. These material properties surface regularly in chemistry and geology, which are not treated here, and less in more complex disciplines, such as biology or further evolved areas. Nematic and smectic arrangements are characteristic of rod-shaped objects or molecules. The least ordered structure is observed if the rods are all arranged parallel to each other. This kind of structure is called nematic. If the rod ends are arranged additionally in layers that extend more or less perpendicularly to the rods, the arrangement is called a smectic order structure. In the macroscopic world, we very often observe single layers of parallel rods, e.g., corn fields, woods, and lawns. Stacked layers resembling smectic liquid crystal structures are observed in wood storage piles, with all tree trunks possessing a similar length. Nematic-type orders can be found in tree trunk piles, where the ends of the trunks are not aligned.

Further simple order structures are known from 1D orders, e.g., a row of numbers or the letters of the alphabet. Such orders are called "sequences." A sequence can also be a time arrangement. Processes often happen in a sequential order, e.g., a watch is always passing from one to two o'clock, to three, four, and so on. A sequential order can be reversed, e.g., the mileage counter of a car can be illegally turned backwards. The reversion of a sequence is called inversion, e.g., a zipper that is closed in one direction will be opened in the other direction.

Order plays a fundamental role in our universe. The expansion of the universe is driven by the loss of order (entropy), while life must try to preserve some order. However, order should be less than in a crystal; otherwise, life would end. Life must find the right balance between "rigid" order and "liquid" mobility. Therefore, life aims to achieve some kind of order level between liquid and crystalline, a state that preserves order but allows motion, at least for the process of nutrition.

In biology, the crucial genetic information of a living organism is contained within its DNA sequence, as in a sequential computer program. The coding units are the opposing nucleotide pairs, which can also be present as inverted pairs. The DNA sequence is translated within a ribosome into a protein sequence. Like many other biological processes, reproduction follows a sequence of steps to achieve multiplication. A prominent ordered structural arrangement is formed by muscle tissue. While smooth muscle exhibits a nematic structure, skeletal muscle has a smectic order of sequential sarcomers, and parallel muscle strands are aligned with each other in layers that can be observed microscopically as orthogonal stripes (Wehner & Gehring, 2013, pp. 388–402). Not only can the motion of a muscle be reversed (contraction and expansion), but consequently, so can the motions of limbs.

The cell membrane exhibits a double-layered structure in which the second layer has an inverted orientation relative to the first.

Most technical processes occur sequentially. The conveyer belt stands as a symbol of this. For example, in ancient times, pumping stations that could lift water over large height differences were achieved by coupling several shadufs in a row. The serial arrangement allows for the repetition of a process, by which means the output of one process stage can be multiplied. This construction model is used for electronic building blocks, e.g., resistors, batteries, and accumulators.

At the beginning of technological development, it was recognized that an inverted vessel could result in a boat. An applied force triggers an appropriate counterforce (inversion). For example, to move a boat forward, a paddle or propellor has to move water to the rear end of the boat. Another example is firing off a cannon or a crossbow, which causes recoil.

Many technical processes are reversible, such as consuming from a storage vessel or an accumulator, which need to be recharged. In some cases, a process inversion even creates a new technology, e.g., a water mill turns into a noria, a motor is converted into a power generator, or a light-emitting diode has the inverse function of a photovoltaic element.

Psychology is rooted in afferent neurologic signals that enter the brain via the sensory organs. The result of the thinking process is leaving the brain to trigger body functions by efferent signals that are forwarded to the actuators. The actuators need to be coordinated to generate action sequences to fulfill the intent of a creature. However, the most relevant part of psychology is the relationship between several individuals who develop an organization with a social ranking.

Architecture creates order by structuring the available space, e.g., into functional rooms and floors. The corridor acts as a navigator for visitors of large buildings, such as hospitals, office buildings, and shopping malls (Koolhaas, 2014, pp. 903–1043). Vertical connecting elements—e.g., stairs, escalators, or elevators—contribute to the distribution of people to different floors. The stairs segment the elevation difference between floors into a sequential arrangement of small steps that can be overcome much more easily than the full height at once. An escalator can only work in one direction due to the one-way process of the conveyor belt, with the stairs mounted on top. Therefore, a second one must be installed.

Music is determined greatly by order. The notes of a song are arranged as a sequence that is further structured by a rhythm that supplies the basic structure of a musical piece. In compositions, filigree tools, such as rhythmic intertwining (Bernstein, 1968, p. 109), crab canon (Bernstein, 1968, p. 132), chiasmus, and permutations, are employed (Bernstein, 1976, pp. 81, 279, 349).

In music and the visual arts, order allows us to predict a pattern and thereby ease recognition.

Periodicity

Technology and architecture are subordinate to the biological needs of users or inhabitants. The rhythms of biology are imposed on a living organism by the environment, where astronomical periodicities have the greatest impact, with day and night rhythms, seasonal climate changes, or weather phenomena. Another important influencing factor is that an organism is an open-flow system. It needs to find a compromise between a closed and an open system to safeguard against its degeneration and, at the same time, it needs to get energy into and waste out of the body via an (at least temporarily) open-flow system. The change between opening and closing the system imposes a periodic rhythm on the system, e.g., for ingestion and excretion. Periodic behavior is characteristic for a back coupled system. Moreover, music that evolved on a more complex level of human cultural activities demonstrates that many systems are based on back-coupled systems from which periodically undulating signal patterns derive (Cramer, 1998).

Periodicity is an overwhelming topic in music (Gerthsen & Vogel, 1993; Müller, 2013) since music is carried by sound waves, and the level of the pitch of a tone depends solely on the frequency of the sound wave. The reciprocal description of frequency is wavelength, which is defined as repetition unit of the sinusoidal sound wave—from crest to crest. In a harmonic series, frequency increases in half-wavelength steps that can be visualized by a vibrating string of fixed length. In this arrangement, from one note to the next, the number of nodes increases by one. This will result in a pure-tone harmonic series of sound waves. Nevertheless, there are more periodic repetition patterns to be found in music, such as rhythm. In this case, repetitive bars of rhythmic instruments, such as drums, form a repetitive pattern and the bars are based on beats with characteristic pauses in between. Any mechanical vibration of air[12] generates sound. A vibrato imposes an additional periodicity on top of a continuously held tone. It creates a repetitive, small variation of the pitch, resulting in a lively, expressive mood.

Periodicity seems to be a connection point between the humanities and natural sciences, especially between music and technology (physics), as well as biology. Almost all technological processes run in a periodically repeating fashion since they are cyclic by their technical nature. The most prominent example is the wheel. Even its rotation speed is measured in rotations per minute. Thus, the periodicity is one rotation with one up and one down movement. Most mechanical technological processes are cyclic, including subordinated cyclic processes with the wheel at the hierarchical base. Other well-known cyclic processes are found in motors, rotary drives (e.g., bicycles and horse mills), power engines, and wind and water mills. However, mechanical processes that existed before the wheel are also cyclic due to their biological nature: e.g., sawing, cutting, weaving, paddling, and the zipper. Industrialization accelerated the introduction of cyclic processes, such as fabric manufacturing, the steam engine, and the railway. The later invention of electricity contributed the dynamo, which can alternately charge accumulators and, in a second phase, their current can be used. For the long-distance transmission of electricity, alternating current (AC) turned out to be the more efficient method. Sinusoidial waves with periodicity are also formed by water behind a boat on a calm lake and show a periodic wave pattern. Light waves of different frequencies exhibit periodicity-dependent colors.

Biology is determined by many cyclical processes, such as ingestion and excretion, the sleeping rhythm that is determined by day and night, and the vegetation period that alters with the (four) seasons, which are all imposed on life by periodic environmental changes. This extends to the organization of the single organism, where all the homeostatic equilibria must be maintained. Moreover, when an organism is generated, it goes through several growth phases and this pattern is repeated again and again over generations.

Architecture must serve the needs of its inhabitants. These needs include protection from the environment, the challenges of changing weather, and seasonal climate. On a daily basis, ingestion is supported by the kitchen and pantry, excretion by the toilet, and sleep by bedrooms. Daylight can be used for illumination via windows and shutters to protect from unwanted light or views. The heating and the air conditioner help to keep the body temperature constant, especially with changing seasons. All these needs have a periodic nature, as discussed for biology. The stairs ease switching between floors by periodically repetitive steps. By giving an additional periodic twist to the stairs in the horizontal direction, a spiral staircase is created that saves constructive space.

Life-sustaining needs, e.g., hunger, thirst, and body temperature, are controlled by homeostatic processes. If they get out of equilibrium, psychologic drives result that try to

[12] Possible is any sound transporting medium e.g., water.

counteract and reestablish the favorable equilibrium state. These parameters typically oscillate around the equilibrium state. Therefore, psychologic drives show circadian rhythms. Sleeping rhythms are important not only for organic recovery but also for the reevaluation of psychological experiences.

Planning, Preparing, Forecasting

Planning is relevant to all disciplines; however, for psychology, biology, and technology, it is of utmost importance.

Planning is very important for humans, because it determines what we are going to do in the future. The brain is always planning and preparing action in advance, even when we are not aware of it. It designs an action plan, in which the single components of movements are composed and coordinated with other action steps (e.g., speech, gestures, mimicking, walking, movement of the limbs) in order to arrive at the desired action. The muscles must be prepared for their action. Furthermore, the brain tries to forecast the psychological reactions of other people to allow for corrections to the plan. Such forecasting and planning activities lead to emotions of expectation, e.g., hope, joy of exploration, disappointment, and trust or mistrust (Servay, 2024).

Furthermore, relational emotions (care and grief) exhibit prognostic, expectant traits. For example, grief does not regret the satisfying past, but, rather, it anticipates the deprived future without a beloved person. In a similar way, care and responsibility are nourished by the will and plan to secure the strong development of offspring. The joy of exploration builds on potential successful discoveries that more than compensate for the effort and risk invested (Böker et al., 2016, pp. 235, 264).

In addition to these emotional aspects, forecasting can also play a role in morbid psychological disorders. In depression, for example, the world is viewed with a lack of perspective. On the other hand, during a manic phase, a patient with bipolar disorder fervently believes in a positive future (Böker et al., 2016, p. 431). A person with a borderline syndrome experiences an alternating bath of emotions, switching from fear of being abandoned to the fear of too much closeness. Both emotional extremes are relational emotions of expectation, which are indeed speculative forecasts (Böker et al., 2016, chapter 23.3, p. 581).

Likewise, the technical invention of tools and machines requires proactive planning of how the aid could efficiently contribute to support an action. For this purpose, a proactive idea was required, e.g., to use a concave shaped storage vessel. Storage rooms or storage buildings are additional examples. Complex equipment and engines demand functional flow plans to maintain an overview of their construction. In a society with specialized tasks, it is important to verify that a specific innovation will meet an appropriate market demand and ultimately allow for the development of a sales forecast.

The genetic material of a living creature, namely its DNA, contains the blue-print for that organism, including all its functional processes. As such it is the core of a living organism. For organisms, the forecasting of predator and prey behavior is of vital significance to plan hunting and defensive strategies. Subordinate planning steps then focus on preparing the motions to achieve a particular nutrition goal.

The forecasting of motions plays a central role in the phantasy of the observer for the impression of dynamics and expression in visual arts (Arnheim, 2000, pp. 371, 411). The impression of motion arises from a motionless image when the observer feels the need to extend a frozen motion state to a lively continuation. The needs for change evolve from the context of an image. The greater the necessity for the continuation of a motion and the more convincing the purpose behind the motion, the greater will be the dynamic impression and the livelier the representation. An example is an unstable center of gravity or a man with an angry face and a tense fist in the air, ready to strike. The expression of a person in mimicry and gesture as well as posture allows for a psychological analysis of the emotional state of a person and possibly his or her intention. It may also allow for the drawing of conclusions about occurrences in the recent past, e.g., that the subject suffered some type of loss.

The impression of motion is primarily generated by secondary effects, such as the preparation of motion (muscle tension) or ripple effects (e.g., V-shaped waves behind a boat). This means the impression is generated via the extension in time by imagination of preparing past and the subsequent future, namely, the forecast of how a scene will continue. Means of representation of visual arts, e.g., patterns, support viewers in recognizing shapes.

Complex buildings require the drafting of architectural blue-prints. The essential function of a building and the basic tasks of architecture involve the construction of an additional protective shell for the human body beyond clothing. Thus, architecture prepares to compensate for expected ambient inconveniences. Since the fire place was incorporated into shelters, historically, it has delivered energy for cooking and heating.

In the same way as visual arts, a piece of music is composed of a characteristic sequence of notes, which can be forecast from hearing only a few notes if the melody is already known. The written notes of a music piece are consequently a planning or forecasting tool that can be used to achieve coordination of an orchestra. The melody of a music piece is carried by the rhythm and is animated by its dynamics. Likewise, the repetitive rhythm is the time schedule of the basic structure of a music piece. The repetition unit of the rhythm allows the listener to predict the rhythmic pattern until a rhythm change occurs. The rhythm accommodates repetition, supports forecasting of the melodic pattern, and forms the basis for generating mutual trust between the performers of an ensemble.

Forecasting leads not only to a tangible plan (e.g., an action plan, a technical or architectural blue-print, DNA, or musical notation) but also leads to an expectation, resulting in emotions of expectation. Expectations can be of a new the building to serve as a protective shell. They may also result from expression and dynamics (as in visual arts and music). Functionality can be founded on technological and biological process plans. Positive forecasts provide security, while negative forecasts trigger negative expectations that demotivate, even though they should trigger a change or modification of the planned route into the future.

Storing

Storing is especially relevant for technology, biology, and psychology to provide a material, energy, or information buffer.

Energy can be captured very well in matter and can conditionally be released. Therefore, in technology, an energy storage vessel is typically connected to an engine to secure its constant operation. Such vessels can be, for example, fuel tanks, steam boilers, dams, nutrients in jars, or chemicals (Ostwald, 1911, pp. 65-75). A water mill or a turbine is supplied with energy from a dam or a river coming from a water depot. The energy is stored as the potential energy of the water and is released by lowering its altitude, e.g., from a mountain to a valley. Ancient weapons, such as bows and arrows or crossbows, are charged with energy by bending the bow and thereby storing deformation energy until the tension is released. The same principle is used for loop traps to catch animals. In newer developments, the deformation was transferred to more elastic and reversible metal springs as they are still used today, e.g., in automobiles to smoothen the ride. Another mechanical storage possibility is a pendulum. It switches back and forth between stored potential energy and kinetic energy during a swing. However, the kinetic energy is consumed over time by friction and thereby irreversibly converted to heat (Ostwald, 1911, pp. 54-58) (e.g., a flywheel). Kinetic energy storage indeed preserves energy via motion, e.g., planetary motion. Kinetic energy is, in the long run, always consumed by friction and consequently ends up as heat. After bows and arrows, weapons with gunpowder came into use. They contain an explosive powder mix of energy-rich chemical substances that are waiting only for a spark to ignite them, comparable to the gasified fuel in an internal combustion engine. Today, the storage of electrical energy is especially relevant, which can be achieved by accumulators. In addition, information storage plays an increasing role in our society. It started with our brain, then book printing followed, and it is now progressing toward dematerialization—for the time being, via electronic storage devices.

Biology focuses predominantly on material and energy storage, not to forget the genetic information stored in our DNA. The two fundamental processes of life, namely, self-preservation and reproduction, are conservation processes. They ensure that life can prosper over many generations, and they ensure as “storage processes” that life or its information can prevail beyond the individual’s lifetime. Genetic material, namely DNA, is probably the most important storage medium in biology. This is also the reason why DNA is protected in the innermost compartment of a cell—the nucleus—to protect it from destruction. During the lifetime of an individual, the second important process, self-preservation, comes to fruition. For self-preservation, the organism needs to permanently supply itself with resources, which serve as a source of energy and as building materials. Any organism needs basic materials, e.g., proteins, carbohydrates (polysaccharides), fats, nucleotides, and other storage molecules (ATP, GTP, glutamine, and others) (Madigan, 2014, pp. 80-183; Fuchs, 2014, pp. 258-292). These substances are temporarily accumulated in material-storing organelles (amyloplasts, oleosoms), depots, or storage organs (roots, tubers, seed, fat tissue, gut, spleen, liver, kidneys, lung, or red blood cells). Some storage organs may also contain other materials (urine, crushed food, blood, air for breathing), which are temporarily collected for further processing or excretion. The energy extracted from the food is stored as small energy packages in the universal biological energy carrier ATP (Madigan et al., 2014, p. 80). ATP can then be transported to a location in the cell, where energy is required and the ATP is consumed. The membrane potential is a further energy storage device that is present in cell boundaries. It also manages the exchange of substances through cell membranes. The contrast to storing is deletion or substitution, which also reflect the generation of mistakes or mutations. The detrimental process of making mistakes is the foundation of mutations, but at the same time, it is a unique chance for improvements and development. Nevertheless, it is of utmost importance that an organism possesses processes that allow for curing sicknesses, wounds, and diseases.

In psychology, the key storage device is the brain, which is used for information storage and processing. An even partial disorder or failure can lead to severe deficits, as can be dramatically seen in dementia. In the brain, for example, social norms and rules are memorized, which are developed collectively by society. They form the basis for our individual consciences and are therefore the framework for the superego, which demands the fulfillment of the social norms and rules. Emotions are an expression of summarized interim results of evaluating situations, which are captured to surface to consciousness. Emotions are therefore like an interim storage mechanism.

If energy supplies disappear because of exhaustion, pauses and sleep are required to regenerate the system.

Mistakes and violations lead to emotions such as embarrassment, exposure, shame, guilt, or loss, leading to grief, desire, loneliness, insult, boredom, or distrust, which belong in the complementary category of negative substitutions. Regret is a repair process.

Architecture, on the other hand, provides storage space for objects. Since architecture reflects, what its inhabitants need, storage rooms and compartments can also be found in houses and large buildings. In houses, especially in the last few centuries, pantries have typically been installed as a side room of the kitchen. Cellars have been preferentially used to store food or drinks that could be better conserved under cool and rather moist climatic conditions. The attic, on the other hand, is mainly used as a storage space for currently unused utensils, such as furniture, clothes, and so on. Storage functions have also been implemented as cupboards, cabinets, and shelves, or even as refrigerators instead of pantries and cellars. The second version of architectural storage focuses on energy storage (Koolhaas, 2014, pp. 1202–1508). Such functions are available for heat as boilers, tiled stoves, or hypocausts. Another long-term storage option is as fuel: oil or gas in a tank, such as firewood in front of the house or as coal in the basement. With growing networks in more modern times, gas or current is supplied to houses, like water via pipes, which provide a continuous supply of the energy carrier without consuming any storage space within the house. This, however, demands reliable supply from the community.

Music was learned from others and had to be memorized before written music was invented. With the invention of the phonograph (1877), sounds and melodies could be recorded and replayed as often as desired without the need to have an orchestra and singers available. Meanwhile, the sound carrier is only represented by an electronic data file that can even be transmitted through an electric cable or a fiber optics cable.

In technology, besides material storage, devices for the storage of various energy forms can especially be found (potential, kinetic, deformation, expansion, and electric energy). Since the invention of writing, other forms of information storage have complemented this scope. For the development of life by biology, information storage via DNA had to be developed along with processes to sustain self-preservation that require material—nutrition—as well as energy supplies. To secure a continuous and sufficient supply, sporadically captured gains had to be accumulated in a depot to cope with situations of low replenishment. Architecture served for a long time as material storage until the fireplace moved into the house, supplying the house with energy, heat, and light. Furthermore, energy has allowed information technology to be developed in buildings.

Psychology seems to focus largely on information storage, as do music and the visual arts.

Discussion

The goal of this engagement was to investigate the TRIZ principles for possible modifications to a more general set of principles that may also be understood and used in other disciplines beyond engineering. After efforts over many years, the adaption of the principles to six disciplines was finally successful and resulted in the transformation into the creative principles. The creative principles have been identified here in the six chosen disciplines: music, the visual arts, architecture, technology, biology, and psychology. While the TRIZ principles have been determined from an engineering-focused perspective—and in some cases, the viewing angle was very narrow—the creative principles have a higher degree of abstraction due to the transformation required to adjust them to various disciplines.

Now, the creative principles appear to be a set of basic functional elements that seem to have driven problem solving and inventions in history. They have demonstrated their validity, as shown here, in six disciplines, and they possess the potential to maintain their validity in many other fields.

Conclusions and Outlook

One major field of application will be to use the creative principles in problem solving and for generating creative ideas in an analogous manner as TRIZ. The conscious use of the creative principles can promote individual creativity, and new, unexpected inventions might be discovered.

Enhance Creativity

When searching for a solution to a problem or a new creative approach, a person may intuitively use only a handful of creative principles. An outrageously creative person may use twice as many different creative principles as an average person. The list of 22 creative principles offers additional creative approaches that do not belong to a person's intuitive repertoire. Consequently, alternative directions of thinking will be accessible to the individual. However, persons educated in the creative principles can now employ an even wider range of creative principles than before. Nevertheless, creative persons have internalized these principles into their unconscious thinking processes. Therefore, they are much faster than processing the challenge via conscious thinking. After some training, however, one may even surpass the creative potential of an intuitively creative person who does not know about the creative principles.

Potential to Measure Creativity

Creativity can now be measured with the help of the list of creative principles. The number of different creative principles a person typically employs to solve problems or be creative can now characterize individual creativity.

Application of the Creative Principles in Other Disciplines

Besides technical inventions, it is now also possible to use this creative potential in other disciplines, as demonstrated for the visual arts, music, architecture, biology, and psychology.

Learning from Other Disciplines

Finally, the transdisciplinary language of the creative principles allows us now to learn from strategies of solving problems in other disciplines (Ropohl, 2012). This also means to learn about the functional relationships of system elements of systems from other discipline (Servay, 2024).

In general, the creative principles play a major role in advancing and even enabling evolution, thereby creating and shaping our future.

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