THE INTERACTION OF ART AND SCIENCE

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Abstract—The author presents the view of science and art as functionally interdependent. Science relies on the imagination of art for new hypotheses; art relies on the critical reasoning of science to awaken the imagination into activity. The author proposes a 'black box' mechanism for the interaction of science and art in the preconscious minds of individuals. The conscious minds of individual scientists and artists act as projection mechanisms for the preconscious contacts of science and art.

Do art and science interact? If so, how?

Two opinions dominate the debate. One holds that art and science are polar opposites and any similarities between the two are coincidental [2]. The other claims that art and science are only different expressions of a single underlying voice and that similarities between the two are clues to this voice [3].

I shall show how both positions are mistaken. Both are based on the false assumption that rationality (cognitivity) and irrationality (imagination) are exclusive opposites. The assumption is mistaken because it denies the reality of the occurrence of correspondences between art and science. The alternative view that I shall present of the functional interdependence of rationality (cognitivity) and irrationality (imagination) admits the reality of correspondences.

Several correspondences can be seen between the arts and sciences.

First: The Renaissance was not just a rebirth of interest in Greek culture, but a revolution in the sciences and the arts. Copernicus and Galileo began the scientific revolution that culminated in the works of da Vinci, Michelangelo and Rembrandt.

Second: The scientific and artistic revolutions can be seen to turn about the same point. The discovery of linear perspective and the development of optics allowed for the three-dimensional interpretation of the images of the surfaces drawn by Brunelleschi and Dürrer and the reading of images on the lenses of Galileo's telescope [4].

Third: The fundamental problem propelling the scientific revolution was the renewed discussion of the cosmological question, Where are we? The answer suggested by Copernicus and developed by Galileo demanded the refutation of the Aristotelian cosmology. Unlike Aristotle, we believe we are on a planet that moves about the sun in an infinite universe governed by democratic laws [5]. Prior to Copernicus's work, Brunelleschi overturned the Greek and medieval methods for composing space on the canvas. No longer were objects positioned according to importance; no longer did objects fill the canvas surface according to some hierarchical scheme of value. Rather, objects filled the space of the canvas according to their relationship to the eye of the beholder, as defined by a universal scheme of perspective.

Fourth: The Einsteinian revolution demanded the overturn of Galilean–Newtonian space and time [6]. We move in a finite, and expanding spherically symmetrical universe where our motion interacts with the very structure of space and time. The Impressionist–Cubist revolutions demanded recognition of

In this second half of the twentieth century, how should the Two Cultures of Snow's dichotomy be related? [1] Aldous Huxley

Fifth: The Einsteinian revolution was a result of renewed discussion of the question, Where are we? The answer required the same stretch of imagination necessary to see objects in Impressionist–Cubist canvases and to see stories on film. We must be able to translate constant relationships between objects into variable spatial–temporal frameworks [7].

These correspondences in the histories of art and science lead to the question, Why have artists and scientists, working within their own traditions and institutions, combatted similar problems and developed similar ideas? Locally, the histories of art and science have developed within parochial interests. Though Galileo enjoyed the works of da Vinci and Michelangelo, he was consumed with the refutation of Aristotle and the development of a Copernican universe. Though Einstein enjoyed Mozart and played the violin, his intellectual development can be traced as attempts to find comprehensive physical laws for electrodynamic, gravitation and quantum phenomena.

Historians of science and art traditionally write histories of their subjects without mentioning parallel developments in the other field. From an interdisciplinary perspective, similarities between the two fields stare us boldly in the face. Are these parallels merely coincidences? [8] Or are they clues of a deeper underlying voice that motivates developments in both fields?

No, to both questions. My thesis is that it is the interaction of art and science that leads to parallel developments in both domains.

TWO CULTURES: ART AND SCIENCE AT OPPOSITE POLES

...the intellectual life of the whole of western society is increasingly being split into two polar groups.—C. P. Snow [9]

This view holds that science is rational and art either irrational or nonrational. Science aims to capture truth, while art is content with appearances. Or, science is guided by cool, detached, objective procedures; while art is guided by hot, subjective intuition [10].

Science is commonly viewed as the process of uncovering the deep structures of nature through rational means. Rational methods involve linguistic precision, impartiality and repeatability. Rationality requires the controlled use of language and impartiality toward the results of objective procedures based on repeated and controlled interventions with natural processes. As Aldous Huxley explained,
For science in its totality, the ultimate goal is the creation of a monistic system in which—on the symbolic level and in terms of the inferred components of invisibly and intangibly fine structure—the world’s enormous multiplicity is reduced to something like unity, and the endless succession of unique events of a great many different kinds gets tidied up and simplified into a single rational order...[11]

Supposedly art is nothing like this. First, it involves subjectivity—reliance on the tastes and wishes of the artist. Second, linguistic precision is not required. It is through the passionate use of artistic media that inspired visions are attained. The results of art are not disconnected from the personalities of the artists. The processes used in the arts require the total engagement of the artist. Huxley also described this personal necessity, of the most extravagant foolhardiness, becomes an artistic duty, a kind of categorical imperative [12].

From these common views of reason or science, and intuition or art, we have the following polarities: Science is conceptual, dispassionate and critical. Art is nonconceptual, passionate and engaged. Science, unlike art, demands civilized qualities of mind and results in a product totally unlike works of art. Art demands the union of ego and object, and results in works that literally say nothing, but which bring the subject into direct contact with the other. Science demands the separation of self and object and results in works that depict objects abstractly as radically separate from the human and the natural.

ONE CULTURE: ART AND SCIENCE UNIFIED

There are two monist views of the unity of art and science. Cognitive monism treats art as a subdivision of science. Aesthetic monism treats science as a subdivision of art. The first considers art a means to attain truth through rational or cognitive methods. The second considers science an intuitive method for seeking harmony or order. According to both types of monism, the error in viewing art and science as polar opposites is in assuming that the differences between art and science are essential, rather than simply differences of degree.

Cognitive Monism

Cognitivist monism views art as different from science only in the degree of its precision and universality. Art expresses universal concepts through particulars. Therefore, art imprecisely and ambiguously expresses truths. The problem is how much the ambiguous symbolism of art prevents it from expressing scientific truth. Critics of the cognitivist view argue that, at best, art can express nonscientific truths because its ambiguous symbolism allows it to reach truths unavailable through the literal symbols of science.

I want to put this issue aside and concentrate on the cognitive aspects of art according to the (monistic) view of art as a science. Art uses symbols or signs to represent truths. The symbols or signs may be natural or cultural. In either case, art expresses or represents truth in a manner that differs from science, but this difference is secondary to the features that art and science share. Both art and science aim to convey truth or express knowledge.

According to Nelson Goodman:

This subsumption of aesthetic under cognitive excellence calls for one more reminder that the cognitive, while contrasted both with the practical and passive, does not exclude the sensory or emotive, that we know through art is felt in our bones and nerves and muscles as well as grasped by our minds...[13].

In reply to the view that art touches only the surface of things and science goes deeper, monists offer two arguments. (1) Both science and art can be shallow if they are applied only to the surface of things. The deep or hidden entities of scientific theories are convenient fictions for correlating empirical phenomena like ideal types used by artists. (2) Art may delve deeply into a subject. The surface of the art object indicates a hidden order, like the correlations of physical phenomena in science.

Cognitivists also refute the view that art springs from irrational intuition. In expressing knowledge, it is unimportant whether the sources of art differ from the sources of science. The romantic view of the artist swept away by a passionate vision is false. The artist subjects his intuitions to critical control. His intuitive vision must pass the critical tests of his standards as a trained artist and of the standards of his public.

Cognitivists may disagree about how art expresses or represents truth and how art relates to the mind of the artist; however, they agree on the fundamental point that art and science do in fact express knowledge. The artist is a scientist in his own manner.

Aesthetic Monism

According to aesthetic monists the scientist is an artist in his own manner. Science, like art, is irrational. Though science appears to be cool and rational, and scientists profess to be objective and detached, in reality scientists are passionate. Theories are accepted or rejected according to aesthetic standards of simplicity and unity. Theories are discovered and proposed according to irrational beliefs and visions.

Science is not thus the simon-pure, crystal-clear fount of all reliable knowledge and coherence... Its method is not that of detachment but rather of involvement. It rests, no less than our other ways of achieving meaning, upon various commitments which we personally share [14].

Where art and science differ, according to aesthetic monism, is in subject matter. Science gives truths about nature; art gives truths about the meaning of life.

Aesthetic monism acknowledges as the common view that science and art differ radically in their expressive means. For this reason aesthetic monism grants some credence to this view as descriptive of appearances. Why do people tolerate the illusion that art and science are radically different? The illusion is due to their exclusive focus on finished theories. We tend to ignore the historical and creative processes in science. Instead we explore science after the dust has settled. This leads to the illusion that science is objective and rational.

...the layman's and the practitioner's knowledge of science is based on textbooks... Textbooks, however, being pedagogic vehicles for the perpetuation of normal science, have to be rewritten in whole or in part, whenever the language, problem-structure, or standards of normal science change... Once rewritten they inevitably disguise not only the role but the very existence of the revolutions that produced them [15].

We have reviewed four positions or theories (see Figs 1 and 2): (1) Art and science are rational. This is contrary to the view that (2) Art is irrational and science is rational. Also contrary to (1) is (3) Art and science are irrational. This in turn is contrary to the view (4) Art is noncognitive, and science is cognitive.

However, both (1) and (3) support the approach (I) that art and science are one. On the other hand, (2) and (4) are logically independent and support the approach (II) that art and science are two. Also, approaches (I) and (II) are contrary. I propose that art and science form a functionally interdependent relationship. This view undercuts the above opposi-
tions. Furthermore, this view allows us to treat the correspondences in the development of art and science as real. The view of art and science as one treats correspondences as merely different expressions of a single underlying unity. The opposite view of art and science as two treats correspondences as coincidences. However, the alternative view (Approach III) of art and science as functionally interdependent takes correspondences between art and science as real events. Approach III contradicts Approaches I and II, corrects statements 1 through 4 (above), and proposes the following statements (1') as mutually supporting: (1') Art and science are partly rational; (2') Art is mainly irrational and science mainly rational; (3') Art and science are partly irrational; (4') Art is mainly noncognitive and science is mainly cognitive (see Figs 1 and 2).

**ART AND SCIENCE ARE FUNCTIONALLY INTERDEPENDENT**

Art and science interact through their functional interdependence: art is present as creative imagination in science; science provides reality testing or rationality for art. Although the function of art is to produce imaginary worlds and the function of science is to test theories for contact with reality, these functions are interdependent. Science prompts art to create new visions; art provides science with visions for articulating and testing.

According to Karl Popper's view of scientific discovery, new theories are discovered through creative acts of intuition. There is no logic or rationality in discovery, only in testing or criticism. The logic of testing helps us determine whether our creative insights have any bearing on reality. Creative insight provides theories for testing. Thus, in science, rationality and imagination are functionally interrelated. Rationality plays a destructive, or critical, role: it examines the products of our imagination and may destroy them by finding they fall short of reality. Imagination, or creative intuition, plays a constructive role: it presents novel ideas about reality as possible solutions to the problems of science [16].

This view of imagination and rationality interacting within science can be applied to analyze the way art and science interact with each other.

**The Roles of Imagination and Rationality in Science**

Following Popper's view, rationality has a destructive role in science, while imagination has a creative role. Imagination provides tentative solutions to problems; rationality destroys mistaken solutions by uncovering errors. In contrast to its role in art, imagination in science is restricted to producing articulate theories for testing.

Rationality in science aims to eliminate error and so destroy false theories. The aim of science is the discovery of truth. However, rationality in art points out the weaknesses of imagination and encourages imagination to create worlds that momentarily defy (rational) articulation.

Apart from its role in articulating the products of imagination as theories and in testing theories, rationality also helps guide scientific practice. Rationality is applied to evaluate scientific practice. We use rationality to set up guidelines for deciding whether it is better to eliminate a false theory or to examine it for any truths before we eliminate it from the body of scientific knowledge [17].

**The Roles of Rationality and Imagination in Art**

Rationality plays an indirect role in art. Critics and aestheticians influence the course of art through discussing the nature of art, applying proposed standards of art, and evaluating particular works of art [18]. The critical discussion of art guides both the formation of the artist's ideas and the artist's expectations. Furthermore, though a work of art is not in itself a test of a theory of art, some works of art can be discussed as if they were tests. In short, rationality in art involves a critical appreciation of works of art. This critical appreciation indirectly affects artists both in their projected work and in the completion of the work.

Imagination in art has a direct and powerful influence. The artist delineates inarticulate ideas and problems of the imagination. The problems delineated in a work of art are beyond articulation. The delineation of inarticulate ideas merely embed rather than solve the conflicts or problems within the work of art. The work of art is the height of irrationality. Ideas and problems are inchoate, inhibiting their straightforward presentation and intellectual evaluation [19].

Ironically, the role of rationality in art is to find out how irrational a work of art is—the more irrational, the more it performs the function of art. In this way, rationality functions to stretch the imagination. Stretching the imagination is an inexhaustible goal. Works of art that are easily understandable or have become thoroughly clear through critical analysis cannot stretch the imagination. When a new style escapes understanding, it stretches the imagination.

Imagination, rationality, and works of art thus form an interdependent system. Imagination forms the matrix of inarticulate ideas and problems that works of art delineate. By delineating these problems and ideas, works of art stretch and transform the matrix of imagination. Science is an abstraction of the role of rationality in art, and art is an abstraction of the role of imagination in science. Consequently, art and science form an interdependent system.

I do not know whether science can progress without art, or whether art can progress without science. I assert only that art and science do interact, not that they must. Furthermore, I assert only that this interaction does lead to their mutual progress; not that mutual progress must happen through their interaction.
SCIENCE AND ART AS AN INTERDEPENDENT SYSTEM FOR THE PROGRESS OF IMAGINATION AND INTELLECT

Science (the institutional structures and social constructions that guide the activities of individual scientists) destroys the products of imagination, the worlds created or inspired by artists [20]. Art (the institutional structures and social constructions that guide individual artists) revives and refreshes imagination. Art provides science with an ocean of inarticulate problems and ideas. Science uses these as inspiration for articulate problems and ideas for critical examination. I return to the correspondences mentioned earlier to illustrate this interdependence of science and art. Modern science and art provide articulate and inarticulate discussions, respectively, of the cosmological problem. Where are we? The Aristotelian imagination became petrified in the astrology of pre-Renaissance civilization. Aristotle's theory of motion came under the criticism of late medieval philosophers [21]. These events allowed the imaginations of Brunelleschi and Dürer to stir scientific intuition to develop a new image of the universe. When this image became ossified in nineteenth-century academic art, the criticism by Mach and Poincare of Newtonian space released the imagination to develop a new image of the cosmos [22]. The imagination-stretching work of the pioneers of film [23] and the Impressionist-Cubist forerunners of twentieth-century painting indirectly stimulated the scientific intuition of Einstein.

WHERE ART AND SCIENCE INTERACT

An important and obvious question still remains. Where do science and art interact? By focusing on how problems motivate science and art [24], I will conclude with my black-box theory of the location for the interaction. This discussion will attempt only to pinpoint where the interaction occurs. It will not describe the mechanics of the insides of the box.

Hindsight allows us to understand more clearly the problems motivating both artists and scientists. Hindsight reveals that there is an objective content in the problems guiding the work of scientists and artists that is incompletely known to the very people caught up in these problems. Consequently, it would be a mistake to identify the conscious problems, the questions consciously asked by scientists and artists, with the objective problems of their historical situation. Furthermore, scientists and artists are often caught in a web of personal problems below the threshold of their awareness. This means that to identify objective problems either with preconsciously pursued problems or consciously pursued problems is an error.

To illustrate, Freud claims that da Vinci was motivated by repressed homosexuality as revealed in the memory of a childhood dream [25]. However, biographers of da Vinci comment that his notes and manuals contain indications of other motivations—an interest in technical and scientific problems [26]. Historians of thought reveal another dimension to the interpretation of da Vinci's interests: the current state of the sciences and arts has evolved from the tasks of constructing a new Platonic cosmology and a humanistic ethic [27]. I believe that Freud, the biographers of da Vinci, and the historians of thought are not contradicting each other. They are discussing different levels of problems: preconscious, conscious and objective, respectively.

Each artist and scientist is motivated by three levels of problems. The most obvious is the conscious level revealed in the notes and writings of the artist and the scientist. The two remaining levels are less obvious: (1) below consciousness are preconsciously pursue problems revealed by psychoanalytic studies, and (2) beyond consciousness are objective problems revealed by historical and epistemological studies. These three levels interlock and conflict. Thus, it is a mistake to invent a zeitgeist, or uniform explanatory principle for an epoch. The unpredictable intervention of consciously articulated problems, and the alogical interjection of preconsciously formed problems refute the illusion of historicism. This illusion is created by using hindsight to describe history as a logical outcome of the dynamics of objective problems [28].

Given these three levels of problems, I theorize that the problems of science occur mainly on the objective level and are introjected by the consciousnesses of scientists into preconsciously pursued problems. The problems of art occur mainly in the preconscious level and are projected by the conscious efforts of artists onto the objective level as intellectual problems.

Introjected scientific problems interact with preconsciously pursued artistic problems in the black box of preconsciousness. The outcome of this interaction is new preconscious problems for artists and new objective problems for scientists.

Let me elaborate on the functional and structural aspects of the role of preconscious problems.

Preconscious problems are inarticulate and form the stratum from which conscious and objective problems are articulated. These problems are, structurally speaking, structureless. To attempt to articulate them would drive one ever deeper into their labyrinths. However, preconscious problems function as the basis from which conscious and objective problems are drawn. These preconscious problems become further entangled when objective problems are introjected into preconsciousness, becoming the basis for new and richer conscious and objective problems. In short, I have three theses about the structure and function of preconscious problems. Preconscious problems are: (1) amorphous—when one attempts to confront them directly, one further enters and further misunderstands them rather than resolving or grasping them; (2) the source of objective and conscious problems; (3) generative of new preconscious problems in the contact with introjected objective problems in the preconsciousness of individuals.

Describing the content of objective problems involves describing the current state of background knowledge of what is known and what inconsistencies exist in the current scene. Individual scientists know only a fragment of the

Fig. 2. Approach I (art and science are one) is contrary to Approach II (art and science are two). Approach I contains two contrary statements: (1) Art and science are rational is contrary to (3) Art and science are irrational. Approach II contains two mutually supporting statements: (2) Art is irrational and science is rational and (4) Art is noncognitive and science is cognitive. However, Approach III (art and science are functionally interdependent) contradicts Approaches I and II and asserts the denial of statements (1) through (4) (see Fig. 1) as follows: (1) Art and science are partly rational. (2) Art is mainly irrational and science, rational. (3) Art and science are partly irrational. (4) Art is mainly noncognitive and science is mainly cognitive. (Graphics by Bela Henter.)
background knowledge they collectively use in their research. Objective problems are best revealed through hindsight. Historians are able to present them fully only after scientists have solved them and have gone on to new problems [29]. What then are the problems we consciously pursue?

The problems artists and scientists consciously pursue are on the surface very different. The scientist asks questions about how processes develop. The artist asks questions about how to construct objects. The problems that concern artists are largely technical. However, the objects they produce may have no practical use beyond giving pleasure. Scientists, too, are often concerned with technical problems. Sometimes artists are concerned with scientific questions, for instance, about the optical effect of various colors. Scientists too are at times concerned with technical problems. Sometimes artists are concerned with scientific questions, for instance, about the parsimony of an explanatory scheme.

How important are conscious problems in the development of art and science? How important are conscious problems for the interaction of art and science? Conscious problems serve as the projector of objective problems—the core problems for scientific development—into the preconscious. And, conscious problems serve as the projector of preconscious ideas—the struggles with preconscious problems—as iconologies onto the objective level.

The minority role of conscious problems is shown by the fact that, although individual scientists know little of the total field of knowledge, they can make contributions that far exceed their own understanding. Similarly, often scientists and artists know very little of each other’s domains, yet from hindsight it appears that art and science have kept up with and influenced each other.

The problems of art occur on the preconscious level. Artistic problems are conflicts among preconscious imagination-schemata. The work of art indirectly articulates preconscious problems. Some works of art bring the problems to a resolution by modifying the prearticular content of imagination. Though the problems of art are preconscious, its styles and iconology are objective. This is the reverse of science. The problems and theories of science are objective, but the imagination-schemata of science are preconscious [30].

The artist attempts to articulate preconscious problems by adopting styles and iconographies that occur on the objective level. The scientist attempts to resolve objective problems by drawing insight from the images that occur on the preconscious level [31].

We now know that science and art cannot have contact on the objective level, because only the problems and theories of science and only the iconologies and styles of art are found there. Science and art do not have contact on the conscious level because individual scientists and artists are ignorant of their own domains, and more ignorant of other domains. Do science and art have contact on the preconscious level? Yes.

CONCLUSION: WHERE SCIENCE AND ART INTERACT

How should the Two Cultures of Snow’s dichotomy be related? There is very little we can or should do. The individual artist and scientist have much to master in their own cultures in order for each to understand their own traditions and current problems. Ironically, even though there are few social structures for interaction among artists and scientists, science and art do interact.

The preconscious contact between scientific problems and iconologies results in a functional interdependence between science and art as abstract institutional constructs. The functional interaction and the preconscious contact of science and art are extraconscious. However, the mutual progress of science and art depends on the decisions of individual scientists and artists to courageously and honestly pursue their interests and questions [32].
24. See K. Popper [19].

**GLOSSARY**

**Aesthetic Monism:** The approach that reduces science to art, rationality to irrationality.

**Art:** The abstract entity (as opposed to works of art and individual artists), composed of the institutional structures, philosophies, iconologies and traditions, that shapes and is shaped by the activities of individual artists. (see *Science*.)

**Cognitivist Monism:** The approach that reduces art to science, irrationality to rationality.

**Contradictory:** Two statements are contradictory if and only if the falsity of one implies the truth of the other.

**Contrary:** Two statements are contrary if, though both cannot be true, both can be false.

**Consciousness:** An object of consciousness is one of which the individual is fully aware.

**Culture:** A system of traditions, mores, philosophies, ethics and institutions.

**Historicism:** The approach to history which seeks universal laws of a deterministic nature.

**Iconologies:** The philosophies, theoretical viewpoints and religious ideas customarily associated with certain images or icons. Hence, iconographies are those images customarily associated with certain philosophies, religious ideas.

**Imagination (schemata):** The patterns or structures in the imagination of individuals.

**Introduction:** The process whereby self-attributes are transferred to external phenomena. The transfersences that occur when describing natural phenomena, i.e. "a nightmarish forest", can be both false and poetic.

**Schemata:** The patterns that cohere thoughts, perceptions and images—in the conscious and preconscious, and in abstract logical structures.

**Science:** The theoretical systems, philosophies, traditions and institutional structures that are both products of and produce individual scientists. (See *Art*.)

**Projection:** The process where phenomena in the external world are impressed on our imaginations, self-awareness, and behaviour. (See *Project*.)

**Objective:** Whether material or logical (theoretical), an entity is objective when it has a status independent of the perceptions and comprehensions of individuals.

**Polarism:** I distinguish this term from “dualism” because monists are polarists in that they assume that two entities when opposed must be exclusive, whereas “dualists” seek some form of interaction between opposites.

**Preconsciousness:** I prefer this term to “unconscious” because it indicates, unlike “unconscious”, that the object that is preconscious lies within our minds ready to be exposed to full awareness. The unconscious wants to hide from consciousness, whereas the preconscious wants to come into the light of focal attention.

**Problem-situation:** The assumptions, approaches and theories that form the logical network of an intellectual problem. Intellectual problems are contradictions. When the contradiction goes to the core of some widely held and respected system of thought, the contradiction is labelled a “dilemma”, or a “paradox”. When the contradiction, or problem, occurs in some borderline system of thought, the contradiction is labelled an “absurdity” within the system. The two-cultures problem is the contradiction between the statements that (1) the arts and sciences are equally worth knowing and (2) immersion in one field excludes anything beyond shallow familiarity with the other. Thus, the two-cultures problem is a dilemma. The obvious way out of this dilemma is to assert that art and science are really one culture. To know one is to know the other. This attempted solution fails in that it tends to downplay the special features and functions of each field. The other obvious way out is to accept that art and science are two different one-way streets. This tentative solution also fails because it ignores all similarities, or treats them as happenstances. However, the dilemma disappears once we recognize that it is based on the mistaken polaristic assumption that if the cultures are two, they are at exclusive or isolated poles. Hence, art and science can be different yet can cooperate. Though we have to immerse ourselves in one culture or the other, our very immersion in our own culture can help advance the other culture.

**Projection:** The process whereby self-attributes are transferred to external phenomena. The transfersences that occur when describing natural phenomena, i.e. “a nightmarish forest”, can be both false and poetic.