

Research Article

The Engel's Biopsychosocial Model in Engineering: Humanistic Education for Engineers, a Systemic View and Practice

Orlando Lopez-Cruz* 

School of Systems and Emergent Technologies, El Bosque University, Bogota D. C., Colombia

Abstract

A research on the endogenous nature of the biopsychosocial model in engineering shows that, except for a period of time after the Second World War in the twentieth century, pointed out that those human actions identified as engineering actions have always been framed by history (time, chronological components), cultural issues (traditions, customs, beliefs, habits, future expectations, level of education, and marital status in the case of individuals), economic context, social aspects (family ties in the case of individuals, community relationships, religion, for example), affiliations, and political tendencies. An Analytical–synthetic method was used to collect and study institutional and theoretical documents. In addition, abduction as a mode of inference (Peirce's method), since abductive conclusions provide the starting point for retroductive inferences. This rationale challenges engineering thinking and engineering education to educate engineers as more than artifact builders, but as world citizens, wide-view professional with abilities and capabilities to design situated technological objects according to a complex view of the present and future. In other words, to educate engineers in the biopsychosocial and cultural approach to develop not only to teach technical abilities, but to develop life-long capacities to transform and construct a sustainable world it is not only relevant for the twenty first century but it is inherent to the nature of engineering.

Keywords

Biopsychosocial Model, Biopsychosocial and Cultural Approach, Engel's Model, Philosophy of Engineering, Engineering Thinking, Engineering Knowledge, Engineering Education

1. Introduction

Both practices of medicine and engineering have evolved peculiarly since Second World War through the same process: moving from instrumentalist reductionism to systemic action conducted in the context of complexity. While other human knowledge bodies have used complexity or systemic thinking to approach their subject of knowledge from a different perspective -like Humanities that have dealt with complex

thinking to understand human values, beliefs, and expressions, to make sense of people and the world around them- both medicine and engineering have been concerned with the way their professionals act in relation to their professions. To put it simply, how the actions conducted by professionals of these two bodies of knowledge look for effectivity through systemic thinking -not the aim of looking for sense of abstractions-.

*Corresponding author: orlandolopez@unbosque.edu.co (Orlando Lopez-Cruz)

Received: 13 October 2025; **Accepted:** 27 October 2025; **Published:** 9 December 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

Since the biopsychosocial model is at the foundations of the new paradigm in medicine [1, 2] proceeds a chronological review of its appearance on stage.

Two main roots are behind the conception of human beings as situated wholes in medicine. First, via changing the notion of disease and illness of human. Second, because of the preceding declaration of a new concept of “system” referring to the development of an Aristotle's conception of uniqueness and integrity of things and actual reality. The change of conception of disease and illness in human beings, beyond the conception of “dysfunctionality” or “malfunction” of an “element of a set” known as human body, has its roots in one the ideas of the neurologist Victor Frankl: the ‘somatopsychospiritual’ as the essence of humanity [3]. In turn, neurologist Roy Richard Grinker Sr. coined the term “psychosomaticsocial” [4, 5], and first used the term biopsychosocial [4, 6], and, G. L. Engel [1, 7, 8] proposed a biopsychosocial model.

On the Engineering side, after the end of the Second World War, a report of the Office of Scientific Research and Development [9] contributed to reduce Engineering to applied science, that is, reducing engineering to the application of Mathematics, Physics, and Chemistry. However, the end of the 20th century saw a profound crisis in engineering [10] and brought the birth of a philosophical branch: philosophy of engineering [11-15, 17] understanding engineering beyond applied sciences.

However, up to our knowledge, no study has been conducted revealing the biopsychosocial model as an engineering foundation. Before the recent recognition of the social nature (i.e. social from the inside, not the application to social ends) of engineering [18] through the concept of risk and risk taking, the relation between engineering and social sciences was understood as just a social commitment: an external relationship between engineering and society. Social issues were considered as externalities to engineering actions. Needless to say, environmental commitments were considered furthest from engineering.

This study fills a partial gap in the understanding of engineering practice as biopsychosocial in nature. This is to assert that the biopsychosocial model is inherent to engineering. Furthermore, the biopsychosocial model has been part of engineering before the model were accepted in medicine because of the classical seminal work [1]. Even more, this research demonstrates that, except in the period following World War II, engineering practice has always responded to cultural, economic, political, and social contexts, and not only to isolated technical practices of its environment, which continues to be a cultural and educational bias in different parts of the world. Just to emphasize, although the term “biopsychosocial” has become popularized in medicine, biopsychosocial and cultural considerations have been taken into account since the transformative and conscious action of the human kind on the environment and on itself became distinguishable. Recently, this has been emphasized: numeral

2 of criterion 2 of ABET (Accreditation Board for Engineering and Technology), states as one of the student outcomes the ability to conduct its actions to “... *meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors*” [19].

Therefore, the biopsychosocial model is endogenous to engineering, it is not a prosthesis, it is not exogenous. This is to say that it is inherent to teaching engineering design and, accordingly, fundamental to the engineering practice. This makes engineering products more than artifacts: engineering results are truly technical and technological objects [20, 21] incorporated into ecosystems.

The document is structured in six parts, in addition to this introduction. A conceptual and theoretical framework followed by the materials and methods section introducing the methods of this research. Then, results are presented and a discussion on them is exposed. Then, conclusions review the results of this research and recommendations on further research are formulated.

2. Conceptual and Theoretical Framework

This section introduces concepts used during the retroduction inference [22-24], includes a timeline that elucidates and wideness the comprehension of the biopsychosocial model, the biopsychosocial and cultural approach, and refers economic theoretical issues used during this research.

2.1. The System Concept for the Biopsychosocial Model

The concept of system in General Systems Theory [8] as well as the biopsychosocial model [1] precedes the «biopsychosocial and Cultural model» at El Bosque University [25]. Consequently, it is relevant to state the concept of «system» that leads to the “fortunate definition of man as a biopsychosocial entity” [26]. That is, as an indivisible and inalienable unit of his context [27], that is, the human being as an entity in the biopsychosocial and cultural model. Neither human beings nor their actions should be “analyzed” outside its psychosocial context. Doing so risks loss of integrity.

While systematic and systemic sound similar and both adjectives are related to the noun “system”, they are chronological and philosophical different. When the vision of a phenomenon or the design of a technological object is carried out systematically, this means that the procedure consists of dividing the whole into its parts, which attends the Cartesian analytical method. This is also called the mechanistic approach, which has been successful since the work of Gotfried Leibniz and Isaac Newton in physics and mathematics. Consider classical mechanical physics, specifically static models, in which the systems under study are bodies connected by

ropes and pulleys. Typically, the mass of the ropes is neglected, and the friction of the rope on the pulleys is also neglected, disregarding the environment of the mechanical system. In the systematic approach, the attention is focused on the components of a system discarding or neglecting interactions between components.

In contrast, since Von Bertalanffy's ideas [2], when the system is observed or designed without disregarding the interactions between components, but considering the components as well as their interactions and dynamics, it is said that there is a systemic approach: an approach to the whole and its surroundings. The context cannot be disregarded without paying a price for the omission. This is vitally important when considering living beings and their environments (ecosystems). For instance, mind is an emergent phenomenon, not a component of a human being. Brain and mind are different.

But this is also the case in engineering. The people who will be users of the technological object involved in the situation in which that object is embedded cannot be overlooked. Furthermore, the design of technological objects cannot ignore environmental conditions such as pressure and temperature. Air (and wind) cannot be ignored, as in the iconic case of the Tacoma Narrows Bridge, and even less so can air and wind, the environment in general, be ignored when designing an aircraft fuselage or wing profile. On the contrary, the environment must be included in the design, even considering changing environmental conditions. A *ceteris paribus* approach is not appropriate in engineering design.

For reasons of focus, references to the concept of "system" prior to the 20th century, especially to the Cartesian, analytical notion of the first half of the 17th century, and the distinction between the systematic approach and the systemic approach [28] will be omitted. This could lead to the risk of omitting Aristotle (384-322 BC) despite his relevance to the notion of system in the 20th century, but it's well worth-it.

It is relevant to this research to focus attention on the period of time of the last eighty years: 1945 to 2025: while Germany's unconditional surrender to the Allies was signed on May 8-9, 1945, and Japan signed its surrender on September 2, 1945, a biologist [7] defined the concept of a system as "a complex of interacting elements". Period. Not as a set.

After the von Bertalanffy's conceptualization the key concept is "complex," which does not mean difficult and is definitely not synonymous with complicated [29]. The meaning of «complex system» means two things at once. First, emergence, meaning that the interactions between components (of the system) give rise to emergent behaviors characterizing the identity of that system, which leads to the widely known expression that a change in a component of a system could lead a change in the whole [30]. Second, invariance. The principle of invariance means that the state of a system is preserved -the system remains unchanged- despite changes in its parts. This means that even the disappearance or change in a component of a system, the whole system preserves its

identity [30-33]. The second seems to contradict the first, and vice versa. But that is only apparent. This is the seed of complexity needed to "allow" self-replication, self-organization and adaptability characterizing living and social systems. Just to avoid the tendency to think of the notion of "set," as if the concept of system were necessarily linked to the concept of set, the 'parts' of the system will be referred insofar as "components", not as "elements" since they are constituent parts. In other words, they are constituent components of a system because they interact, they compose the system as a unit, as a whole, as a distinguishable entity in a frame of reference of time and space, and this makes it possible to measure the values of the components of the system and, eventually, to characterize that system.

When viewed as a system, a human being is an entity, a unit which loses its identity when split apart (analyzed). Human beings "are fully biological and fully cultural beings that carry within themselves this original duality..." [34]. Each human being manifests itself on different scales "... is at the same time an individual, part of a society, part of a species. We carry this triple reality within each of us" [34]. Thus, every person, inwards and outwards, along with every situation and phenomenon of reality in the light of systemic thinking, is constituted by a finite natural number "n" of "interacting" components. The assumption of finitude of the number of components does not affect the generality of the concept and is useful in practical terms. These interactions between components give rise to the 'organization' of the system [35] within a specific time-space framework. Within this time-space specification, the "n" components can be measured in 'm' different ways, where "m" is a natural number. The 'sharpness' of the measurement, which could well be observed in terms of precision, accuracy, scale, frequency, and even units of measurement, is better referred to as space-time resolution [35].

The founding document of systems thinking [7] denotes by Q_i the *i*-th measurement function of the "n" components, where the subscript 'i' refers to each of the "m" measurements. But to simplify, without affecting the generality of the concept, it is assumed that $m=n$, so that there are as many components in the system "n" as there are measurement functions for those components " Q_n ." As stated, the system is a distinguishable entity in time and space: the space-time specification of the system [35], and can be subject to measurement. The rate of change over time of these measurement functions is denoted by (Leibniz notation) dQ_i/dt , from which the measurement of the rate of change of the system [7] results as a system of differential equations. This is to remind that 'organization' together with 'dynamics' of a system, both make up the concept of system, not a naïve notion of set.

2.2. The Biopsychosocial Concept Before Engel and at El Bosque University

General systems theory [7, 8] precedes and underpins the

conception of the human being as a situated entity. This conceptual background -besides his personal experiences- could have led the neurologist Victor Frankl, to state the 'somatopsychospiritual' as the essence of humanity [3]: the integral conception of mankind as biopsychospiritual human beings (Table 1). Later, neurologist Roy Richard Grinker Sr.

first used the term biopsychosocial [4, 6] to refer to psychoanalysis as an open system by virtue of the evolution of structural theory, ego psychology, and concepts of adaptation. He had previously coined the term "psychosomaticsocial" in a formal communication addressed to the Chicago Psychoanalytic Institute in 1952 [4, 5].

Table 1. Timeline relating the system concept in general systems theory and the biopsychosocial model.

Year	Concepts / Facts
1945*	System [7].
1946	Somatopsychosocial essence of humanity [3].
1952	Psychosomaticsocial. Formal communication addressed to the Chicago Psychoanalytic Institute in 1952 [4, 5].
1966	Biopsychosocial [4, 6]. First documented use of the term.
1977	Biopsychosocial [1].
1977	Founding of the Colombian School of Medicine - biopsychosocial and cultural approach.
1997	Recognition as El Bosque University, through Resolution 327 of February 5, 1997, Ministry of National Education of Colombia.

*According to the year declared in cited documents.

The foregoing may constitute the framework in which the seed of Engel's biopsychosocial model took root [1] contrasting the reductionist-biological, medical or biomedical model of medicine. This novel idea found fertile ground in the Colombian School of Medicine, now El Bosque University, which incorporated psychosocial and community dimensions "with a historical-cultural and humanistic component" [2].

This was achieved by harmonizing

«...three fundamental elements of medical practice: 1) development of general skills necessary for appropriate professional medical practice; 2) technical education that enables the use of the foundations provided by science and technology for the development and application of knowledge, and in turn, expands that foundation through research and development; and 3) humanistic education to guide students in ethical professional practice» [36].

The biopsychosocial model [1, 2] is a systemic view of an individual (or, in general, a specific situation) demanding: (i) avoid systematic, analytical procedures where the integrity of the individual, or in general "the system", is at risk [7, 8] and, (ii) keep in mind that the system being diagnosed or it is under study (and being designed for the case of engineering) is the system itself but, what the system is (or is to be) beyond its frontiers in time and space, also.

Therefore, based on the model, the biopsychosocial and cultural approach consists of addressing the system (whether diagnosed, studied, or designed) without dividing it into elements or parts, that is, avoiding treating it as a set, and taking into account as many environmental issues as possible: its history (time, chronological components), cultural issues

(traditions, customs, beliefs, habits, future expectations, level of education, and marital status in the case of individuals), economic context, social aspects (family ties in the case of individuals, community relationships, religion, for example), affiliations, and political tendencies.

It is well known that human cognition [37] and behavior seems to be the result of an evolutionary process (permanently) emerging less from biological issues and more from the concurring issues previously listed in the biopsychosocial approach. This allows that the evolution algorithm speeds up the variation-selection loop [38-40] when compared to the DNA-based biological "retention" phase of the algorithm. That's the relevance of the conceptualization of the biopsychosocial model when understanding the evolution (along existence of the human kind) of the engineering practice from artifacts to technical objects [20, 21] and engineering knowledge from technical-technological abilities to an engineering body of knowledge [16] nowadays.

2.3. The Engineering Crisis at the End of the 20th Century

While formal education in engineering at university levels begins since Napoleonic times by the end of eighteenth century, engineering practice has been conducted as an integral part of individual as well as social collective activities since ancient times, even before the traditional historical milestones in Medicine. However, the end of the 20th century brought to light the engineering crisis in underdeveloped countries, including Colombia [41, 42], with no apparent change in this

trend [43, 44] during the first quarter of this century. The crisis can be characterized in terms of its factors and symptoms or manifestations.

This happened at the same time of the emergence of the new philosophical branch of Philosophy of Engineering around 2010. A systemic vision brought to light the deficiency of the definition of Engineering in terms of the traditional cartesian, analytical, systematic thought, reducing engineering to the simplistic view of application of scientific and mathematics knowledge, reducing the ethos of engineers to problem-solvers.

2.3.1. Factors of the Engineering Crisis

There may be multiple factors that lead to an engineering crisis in a country or region, such as the predominance of imported technology without adequate adaptation and assimilation processes, even though this has been warned [45-47] in underdeveloped countries. However, five factors are highlighted: (i) Proliferation of engineering schools, (ii) ideological understanding of what engineering is, (iii) restriction of engineer training to technical skills, (v) lack of relevant research in engineering.

2.3.2 Proliferation of Engineering Schools

The proliferation of engineering schools, without due quality control, has led to the graduation of professionals who have not achieved the relevant competencies, nor have developed fundamental abilities in engineering [48]. This has resulted in substandard professional performance that is not competitive with international standards, which in turn leads to a loss of social appreciation for engineering and its professionals [42], a perception of incompetence among graduates, underemployment and even unemployment among engineering professionals, and a perception of low quality among engineering schools. This situation negatively affects the possibilities for economic growth in underdeveloped countries.

2.3.3. Ideological Understanding of What Engineering is

Regarding the meaning of engineering, folk beliefs says that “engineering comes from ingenuity” or reduces engineering to one of two things: first, only the technical work of the engineer. As if the intersection of an engineer’s knowledge and skills in one discipline with those in another discipline were meaningless. Second, defining engineering as the application of mathematics and scientific knowledge. This naïve statement ignores the very fact that all professions apply scientific knowledge, and, everyone use mathematics and science in one way or another. Neither mathematics nor science are the core of engineering [10, 49, 50].

Accepting this rather naïve statement as a dogma not only leaves engineering without its own body of knowledge [16, 17] but eliminates the possibility of engineering research. How-

ever, evidence shows that engineers do research. It has been shown that restricting engineering to mathematics and science knowledge prevents engineers to think out of the technical box [46]. This lack of identity is exacerbated when engineering is defined as the process of “solving problems” or developing, delivering, or providing “solutions to problems.” The definition of engineering in terms of “solving problems” or “fixing problems” is ideological [50-53] and does not characterize what engineering is, nor what engineers do.

2.3.4. Restriction of Engineering Training to Technical Skills

Engineering education in many underdeveloped countries has been restricted (mainly) to technical training. This education usually prevents a systemic vision since it is focused in developing technical skills. Engineering education is not only the development of technical skills, as previously stated. The absence of systemic thinking abilities can lead to unexpected outcomes, many of them undesirable, which are ideologically referred to as “*edge effects*”. Adverse consequences may arise in environmental, social, or public health negative impacts.

Besides, specialized training in technical skills results in professionals who have difficulty relating to other professions [42]. Furthermore, ignorance or limited exposure to the arts and humanities produces professionals with low aesthetic and ethical capacities, which results in engineering products lacking of these aspects.

Moreover, strictly technical training does not include motivating creativity, which is one of the characteristics that precede innovation capabilities, leading to the contradiction of assigning the social responsibility to engineers in producing innovation, but reducing or restricting them the capabilities to generate or drive it.

Limiting the training of engineers to technical skills alone isolates them from national and global realities. Engineering education lacks of developing critical thinking abilities which es related to the political, economic, and social phenomena that shape the scenarios of all engineering activities.

2.3.5. Lack of Relevant Research in Engineering

As a result of the above, engineering education limited to technical skills undermines or fails to develop research capabilities in engineering. On the one hand, a biased education leads engineers to fail in distinguishing between the process of ‘browsing’ and the process ‘generation of new knowledge’, on the other hand, in this way, engineers are unable to generate new engineering knowledge.

In an attempt to research, knowledge limitations -because of improper education- lead engineers to the “automatic use of the scientific method”. That is, the blind faith in the method of science to generate new scientific knowledge. In some way, engineers are trained to use the scientific method as a recipe for trying to generate new engineering knowledge. This is not only a paradox, but it also generates a kind of stunting, sub-

normal education at master and doctoral-level in some universities third-world countries. This results in a loss of international competitiveness for engineering research when comparing to developed countries.

Restricting engineering research to the scientific method (mathematics and natural sciences), reducing it to the recipe of “stating a research question-hypothesis-testing”, or debating (or biasing the debate) if engineering research is whether qualitative, quantitative, or mixed research, or to discuss whether the deductive or inductive method is more appropriate, is not only an epistemological contradiction, but also partly explains why, in addition to ignoring the relationship and responsibility of engineering to economic growth and national development, what is expressed by market agents as “disconnection of engineering education from reality,” or (i) mixing the priorities of engineering research with the generation of accounting profits by research centers, (ii) confusion between technological development as a process that affects the economy in the long term, and the short-term vision of calling the product of that production process “technological development”. This allows us to observe that there are at least three categories of countries and companies: (a) those that produce technological development, (b) those that transfer technology, and (c) those that blindly buy and consume the products of technological development [42]. Either fortunately or unfortunately, the classification cannot rely on any engineering ‘variable’, but rather on the results of a variable on the macroeconomic scale that is usually unknown in traditional engineering training: the trade balance, or net exports, which is a macro variable of the economics yield formula (1) through the expenditure approach when calculating a country’s Gross Domestic Product (GDP), which is a macro variable of gross domestic product (Yield). In other words, the total economic output of goods and services of a country.

$$Y = C + G + I + (X - M) \quad (1)$$

(X-M) is a “proxy variable” being the capability of an economy to increase X as the latent variable. This allows to classify economies as well as firms according to those three categories.

3. Materials and Methods

This study began from the belief that the biopsychosocial and cultural approach was exogenous to engineering, understanding that the biopsychological model aroused in medicine came from the neurologist Engel [1], and inspired the birth of the Colombian School of Medicine in 1997. This led to ask what biopsychosocial stands for and where the biopsychosocial came from. However, new concepts about engineering [10, 11, 15-17] did not fit into the mechanistic tradition where the biopsychosocial and cultural model from which the biopsychosocial model was supposed to rescue engineering. Then, an insight came when a document written by one of the

founders of the Colombian School of Medicine declared the special role of the general systems theory in the creation of the biopsychosocial and cultural model and its corresponding approach [25]. This fact led to the research methods.

1) The peircean pragmatism method [22] with abduction as a mode of inference, since abductive conclusions provide the starting point for retroductive inferences [23, 24]. This method provides a coherent and solid foundation to infer from evidence what the action is intended for. In this case, the fact that the biopsychosocial model is at the heart of engineering even before the term started to be used in engineering. In addition, elucidates the line of reasoning that makes coherent grounded arguments and conclusions. All of these because *"The real is that which is not whatever we happen to think it, but is unaffected by what we may think of it (...) This thing out of the mind, which directly influences sensation, and through sensation thought, because it is out of the mind, is independent of how we think it, and is, in short, the real"* (CP 8.12) *"the real" means that which is independent of how we may think or feel about it"* (CP 8.13) [22].

2) Analytical-synthetic method: This to collect and study institutional documents, theoretical documents: academic books and papers related to the research topic. This included discussions with members of the Tactical Committee of the Systems Engineering Program, at El Bosque University.

The starting point (i.e. the deep-rooted belief at El Bosque University that the biopsychosocial and cultural approach was exogenous to engineering) was decomposed in finding documents regarding the meaning and origin of the biopsychosocial model and its related concepts in academics, this is schools of medicine, and, on the other hand, the way the model was adapted to the Colombian School of Medicine giving rise to the biopsychosocial and cultural model and its approach. The analytical method was completed gathering documents relating the evolution of engineering up to its actual stage, from previous research.

By framing chronological-historical facts and academic events in medicine and engineering, and the discussion of preliminary results with members of the of the Tactical Committee of the Systems Engineering Program, it was possible to synthesize the results presented and open up research opportunities based on these findings.

4. Results and Discussion

The biologist model (also known as medical or biomedical model in medicine) gave rise to a crisis in medicine education and medical practice [54, 55].

Afterwards, Medicine practitioners found that the biopsychosocial approach to disease and illness [1], based on the General Systems Theory [7, 8], a model giving importance to the person as whole entity [2, 36, 56] from the systemic point of view, allowed better results than the traditional model.

This led to the founding of a School of Medicine where students were thought to look at their patients not only as

integral persons next to their own personal environment, instead of beholders of diseases or illness [25, 57], the Colombian School of Medicine, since 1997 El Bosque University.

The School of Engineering was created by 1997 at El Bosque University. Since then, has been evolving from the traditional – science applied- view, to an integral critical view of the engineering action.

First, joining to the general discussion of academicians about what engineering is and what is the meaning of producing new knowledge specific to engineering, which implies an epistemological and, therefore, methodological questioning.

Then, after inquiring the crisis in engineering, searching for coherent views of engineering to the principles of this University, and, afterwards, implement a curriculum [58] overcoming the paradigm of engineering as -just- applied science. This not to abandon the study of mathematics and science, but to make conceptual and contextual approaches of engineering design and methods harmonized to mathematics and science knowledge.

This implied organizational changes at the School of Engineering from somewhat independent Departments and engineering curricula towards an integrated School of Schools: the School of Territorial Systems, School of Organizational Systems, and the School of Systems and Emergent Technologies. Needless to say, a recursive and hologrammatic structure which is a bet for a complex (social) organization, consistent with the systemic vision. This evidences, also, the new Philosophy of Engineering [11-13, 16, 17, 59] approach.

Besides the demonstration, by evidence, that the term biopsychosocial precedes the well-known publication [1] in Medicine, the work has shown that by no means the biopsychosocial model and the biopsychosocial and cultural approach is exogenous to engineering. Historical evidences as well as philosophical conceptualization have shown that the biopsychosocial model and its correspondent approach is endogenous to the engineering concept and practice [17], in spite of the bias coming from political and economic interests after the second world war of the 20th century, which favored science over engineering, relegating the latter to an auxiliary discipline of science: engineering as "just" applied mathematics and science. Different engineering curricula show their specific emphasis as well as its engineering fundamentals and courses conceptualizing mathematics and science concepts -i. e. not just "applying" math and science- in order to produce the best change of ill-defined "situations" with available resources [60, 61]. Understanding engineering actions as intervening an identified (real) situation to change it into a new (and real) situation [10] harmonized and harmonizing (not destructing) either the actual context of the identified situation neither its future (i.e. making it sustainable).

5. Conclusions

Since a modern concept of a system was established, fol-

lowing the analytical, systematic ideas of the Renaissance [7, 8, 16, 62], both Medicine and Engineering resolved their own crisis. First Medicine, by the way of a new conception of disease and illness beyond the reductionist idea of malfunctioning of organs [1, 2], lead Medicine to change its research and practice focus from disease and illness to health and, at the same time, from particular organs or pathologies to the focus of the individual as a system: a situated human being conceived as a whole, as an entity from the biopsychosocial model [1] and the biopsychosocial and cultural approach [2, 25, 27, 36] in teaching and medical practices.

The relevance of the biopsychosocial and cultural approach is undisputable, beyond all question contrasting to the traditional biomedical, reductionist-biological, medical approach of mechanistic nuances.

On the engineering side, as discerned and reasoned, a reductionist, mechanistic and technical restrictive view coming specially from the biases of the post-World War II period in the 20th century [9] made engineering practice as a highly focused application of Scientific and Mathematics knowledge, isolating engineering practice from a systemic view that could explain, partially at least, the "border effects" or "undesired effects" of the products of engineering as air pollution, water contamination, for instance. This happens when the action of engineering ignores the environment where the technical or technological object [20, 21] produced in the engineering process will be operating or will be in use.

As it has been annotated, the absence of literature regarding the relationship between engineering and the biopsychosocial model brings an opportunity to wide research on the fundamental concepts of engineering, the fundamental knowledge of engineering which, clearly, is not mathematics or science, since as it has been mentioned, is a recent myth coming from a situation at the juncture between the Second World War and the Cold War [9]. Once again, this is not to assert that engineers do not need to know mathematics or science, but to assert that any professional of the twentieth century has to know and apply mathematics and scientific knowledge in one way or another.

Philosophy of engineering [11, 16, 17, 19] emphasizing structural differences between science and engineering [10] comes to remind the social nature of engineering [18], with engineering actions beyond problems solving [50] and causing to change the ethos of engineers from just problem-solvers applying mathematics and science (and some technical knowledge) to committed professionals with the economic development of society.

This challenges engineering thinking and engineering education to educate engineers as more than artifact builders: instead, as world citizens with abilities and capabilities to design situated technological objects in the context of sociotechnical systems and the approach of complex social systems according to a complex view of the present and future. In other words, this research has shown the need and the possibility to educate engineers in the biopsychosocial and

cultural approach to develop not only to teach technical abilities, but to develop life-long capacities to conceive and conduct their actions according to a systemic framework considering history (time, chronological components), cultural issues (traditions, customs, beliefs, habits, future expectations, level of education, and marital status in the case of individuals), economic context, social aspects (family ties in the case of individuals, community relationships, religion, for example), affiliations, and political tendencies, since the biopsychosocial model has been endogenous to engineering, with the exception of the previously mentioned period after the second world war.

6. Recommendations

A wider and deeper epistemological research seems to be necessary. Besides propositional knowledge (i.e. scientific knowledge ‘par excellence’), usually provided by scientific methods, that just describe, explain or predict systems both since the systematic approach and, even, since the systemic approach, there is a need to get know-how knowledge (prescriptive knowledge) involved in the process. The lack of the explicit know-how knowledge in engineering research may explain why, when designing complex social systems, information systems for instance, the systematic approach has proven ineffective. Classical scientific knowledge tends to ignore interactions between components, or just focus on causal relationships which, whether numerous or not (so-called ‘multi-causal’ relationships), are insufficient to account for the complexity involved in information systems.

On the other hand, the systemic approach accounts for interactions, even if they are few or even unique, as well as for the components of a system. However, in the case of engineering actions, these must be preceded by know-how knowledge: prescriptive knowledge, which provides the possibility of framing contexts, determining possible alternatives, and focusing on ‘how to do’ in order to achieve results.

A possible trend of research comes when engineering information systems, not just as a sociotechnical system [32], but as a complex social system where the interacting components: people, organizational processes -often referred as business processes-, information and communications technology infrastructure (ICT-Infrastructure), data and information, and software, brings to reality the possibility to effectively support not just knowledge-based economies [63] but knowledge-based societies.

Another potential and demanding research trend has to do with the role of the biopsychosocial model, the biopsychosocial and cultural model and, therefore, the biopsychosocial and cultural approach in design science research [32, 64, 65] when dealing with engineering information systems, understanding this engineering process as dealing with people in complex social systems.

Abbreviations

ABET Accreditation Board for Engineering and Technology

Acknowledgments

I express my gratitude to the members of the Tactical Committee of the Systems Engineering Program at the School of Systems and Emergent Technologies, El Bosque University, for their critical comments and constructive feedback regarding the development and conclusions of this research.

I am also grateful to the anonymous reviewers for his/her comments and suggestions.

Author Contributions

Orlando Lopez-Cruz is the sole author. The author read and approved the final manuscript.

Funding

This work is not supported by any external funding.

Data Availability Statement

No numerical data was used. Further text references are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

References

- [1] Engel, G. L. The need for a new medical model: a challenge for biomedicine, *Science*. 1977, 196 (4286), 129-136. <https://doi.org/10.1126/science.847460>
- [2] Matiz Camacho, H. “Training and dissemination of the biopsychosocial and cultural approach at El Bosque University” (Formacion y difusion del enfoque biopsicosocial y cultural en la Universidad El Bosque). In: Cardenas Lopez, H. I. c. Bogota D. C.: Universidad El Bosque, 2016, 49-65.
- [3] Frankl, V. E. The doctor and the soul. An introduction to logotherapy. Knopf, 1988; Random House Group: 1946.
- [4] Lugg, W. The biopsychosocial model—history, controversy and Engel. *Australasian Psychiatry*. 2022, 30(1), 55-59. <https://doi.org/10.1177/10398562211037333>
- [5] Grinker Sr, R. R. Training of a psychiatrist-psychoanalyst. *Journal of the American Academy of Psychoanalysis*. 1994, 22(2), 343-350. <https://doi.org/10.1521/jaap.1.1994.22.2.343>

- [6] Grinker Sr, R. R. Open-system psychiatry, *American Journal of Psychoanalysis*. 1966, 26(2), 115.
<https://doi.org/10.1007/BF01873427>
- [7] Von Bertalanffy, L., Zu einer allgemeinen Systemlebre, *Deutsche Zeitschrift für Philosophie*. 1945, 18, (3/4). (Towards a General Systems Theory). Also published as: An outline of General System Theory, *British Journal of the Philosophy of Science*, I. 1950. Published also as: von Bertalanffy, L. Some System Concepts in Elementary Mathematical Consideration, Chapter 3. In: von Bertalanffy, L. *General System General Systems Theory: Foundations, Developments, Applications*. New York, N. Y. George Braziller: 1969, 54-88.
- [8] Von Bertalanffy, L. *General Systems Theory: Foundations, Developments, Applications*, New York, N. Y.: George Braziller; 1969.
- [9] Bush, V. The endless frontier, report to the president on a program for postwar scientific research. Office of Scientific Research and Development. United States Printing Office, Washington D. C.: 1945.
- [10] Poser, H. On structural differences between science and engineering. *Society for Philosophy and Technology, Quarterly Electronic Journal*, 1998, 4 (2), 128-135.
- [11] Bucciarelli, L. *Engineering philosophy*. DUP Satellite; an imprint of Delft University Press; 2003.
- [12] Goldman, S. L. Why we need a philosophy of engineering: a work in progress. *Interdisciplinary Science Reviews*. 2004, 29 (2), 163-176. <https://doi.org/10.1179/030801804225012572>
- [13] McCarthy, N. What use is philosophy of engineering? *Interdisciplinary Science Reviews*. 2007, 32 (4), 320-325.
<https://doi.org/10.1179/030801807X211847>
- [14] Verbeek, P-P. *Accompanying Technology: Philosophy of Technology after the Ethical Turn*, *Techné: Research in Philosophy & Technology*. 2010, 14 (1), 49-54.
<https://doi.org/10.5840/techné20101417>
- [15] Lopez-Cruz, O. The scientific pretensions of engineers: a study of the epistemology of engineering. (Las pretensiones científicas de los ingenieros: un estudio a la epistemología de la ingeniería). *Hojas de El Bosque*. 2017, 3(5), 52-59.
<https://hdl.handle.net/20.500.12495/5033>
- [16] Lopez-Cruz, O. (2020). From philosophy of technology to philosophy of engineering. *Revista Colombiana de Filosofía de la Ciencia*, 20(41), 63-111.
<https://doi.org/10.18270/rcfc.v20i41.3385>
- [17] Lopez-Cruz, O. An essential definition of engineering to support engineering research in the twenty-first century, *Journal of Philosophy*. 2022, 10 (4), 130-137.
<https://doi.org/10.11648/j.jip.20221004.12>
- [18] Ross, A., Athanassoulis, N. The social nature of engineering and its implications for risk taking, *Science and Engineering Ethics*. 2010, 16 (1), 147-168.
<https://doi.org/10.1007/s11948-009-9125-6>
- [19] ABET Engineering Accreditation Commission. (2023). "ABET criteria for accrediting engineering programs." Baltimore, MD. 2023.
- [20] Simondon, G. *On the Mode of Existence of Technical Objects*. Translated from the French by Ninian Mellamphy with a Preface by John Hart University of Western Ontario, June 1980: Aubier, Editions Montaigne, Paris: 1958.
- [21] Simondon, G. On the mode of existence of technical objects. *Deleuze Studies*. 2011, 5 (3), 407-424.
<https://doi.org/10.3366/dls.2011.0029>
- [22] Peirce, C. S. Charles S. Peirce, *Collected Papers* (8 vols.), Harvard: Harvard University Press, 1931-1958. (Usually referred as CP).
- [23] Ayim, M. Retrodution: The rational instinct, *Transactions of the Charles S. Peirce Society*. 1974, 10 (1) 1, 34-43.
- [24] Ritz, B. Comparing abduction and retrodution in Peircean pragmatism and critical realism, *Journal of Critical Realism*. 2020, 19 (5), 456-465.
<https://doi.org/10.1080/14767430.2020.1831817>
- [25] Otero Cadena, M. Prologo. In: Cadenas Lopez, H. I. *The biopsychosocial and cultural approach in the training of health professionals at El Bosque University. Origins, developments and challenges. (El enfoque biopsicosocial y cultural en la formacion de los profesionales de la salud en la Universidad El Bosque. Procedencias, despliegues y desafios*. Bogota D. C.; Universidad El Bosque, 2016, 13-15.
- [26] Aristizabal Aristizabal, G. Presentacion. In Cardenas Lopez, H. I., Aristizabal Tobler, C, and Mosquera Soto, B. *Reflexiones sobre un Programa*. Bogota D. C.: Universidad El Bosque, 2023.
- [27] Guerra, A. El modelo Biopsicosocial y cultural. In: Donoso Suarez, I. A. *El paciente desde la perspectiva biopsicosocial*, Bogota D. C.: Universidad El Bosque, 2010, 21-29.
- [28] Lopez-Cruz, O. On the systematic and the systemic, *Journal of Technology*. 2002, 1(1), 47-50.
- [29] Ramirez Avila, G. M. Complex and complicated: specialization and interdisciplinarity (Complejo y complicado: especializacion e interdisciplinariadad), *Revista Boliviana de Educacion Superior en Ciencia*. 2006, 6. 21-29.
- [30] Erdi, P. *Complexity explained*. Berlin, Heidelberg: Springer Berlin Heidelberg: 2008.
- [31] San Miguel, M., Johnson, J. H., Kertesz, J., Kaski, K., Diaz-Guilera, A. Challenges in complex systems science. *The European Physical Journal Special Topics*. 2012, 214(1), 245-271. <https://doi.org/10.1140/epjst/e2012-01694-y>
- [32] Gregor, S., Chandra Kruse, L., Seidel, S. Research perspectives: the anatomy of a design principle. *Journal of the Association for Information Systems*, 2020, 21 (6), 1622-1652.
<https://doi.org/10.17705/1jais.00649>
- [33] Sole, R. *Complex networks: from the genome to the Internet (Redes complejas: del genoma a Internet)*. Tusquets Editores S. A.: 2016.

- [34] Morin, E. The seven types of knowledge necessary for the education of the future. Originally published in October, 1999 by United Nations Organization for Education, Science and Culture, - 7 place de Fontenoy - 75352 Paris 07 SP - France. © Unesco: 1999.
- [35] Orchard, R. A. On an approach to general systems theory. In: von Bertalanffy, L., Ashby, W. R., Weinberg, G. M. Trends in General Systems Theory, John Wiley & Sons, Inc.: 1972.
- [36] Escobar Triana, J. Humanistic and social education for physicians: the experience of the Colombian School of Medicine. The Journal of medicine and philosophy. 1996, 21(6), 651-657. <https://doi.org/10.1093/jmp/21.6.651>
- [37] Tomasello, M. The cultural origins of human cognition. Harvard University Press. 248 pp. Harvard University Press: 2000.
- [38] Braitenberg, V. Selection, the impersonal engineer, Artificial Life. 1998, 4(4), 309-310. <https://doi.org/10.1162/106454698568611>
- [39] Dennett, D. C. Darwin's dangerous idea: Evolution and the Meaning of Life, The Sciences. Simon & Schuster (original hardcover) 1995, 34-40.
- [40] Mayr, E. The ideological resistance to Darwin's theory of natural selection. In Proceedings of the American Philosophical Society. 1991 135(2), 123-139.
- [41] Aldana Valdes, E. Crisis in Colombian Engineering at the end of the 20th Century? (¿Crisis de la ingeniería colombiana al final del siglo XX?). Revista de Ingeniería. 1999, 9, 7-17. <https://doi.org/10.16924/revinge.9.2>
- [42] Valencia Restrepo, D. Crisis and future of engineering (Crisis y futuro de la ingeniería). Ingeniería y competitividad. 2000, 2 (2), 63-68. <https://doi.org/10.25100/iyc.v2i2.2344>
- [43] Serna, E., Serna, A. Is engineering in crisis worldwide? A review of the literature (¿Esta en crisis la ingeniería en el mundo? Una revisión a la literatura), Revista Facultad de Ingeniería Universidad de Antioquia. 2013, 66, 199-208. <https://doi.org/10.17533/udea.redin.15236>
- [44] Serna, E., Serna, A. Engineering crisis in Colombia – State of the issue (Crisis de la Ingeniería en Colombia-Estado de la cuestión). Ingeniería y competitividad. 2015, 17(1), 63-74. <https://doi.org/10.25100/iyc.v17i1.2201>
- [45] Lane, P. J., Koka, B. R., Pathak, S. The reification of absorptive capacity: A critical review and rejuvenation of the construct, Academy of management review. 2006, 31(4), 833-863. <https://doi.org/10.5465/amr.2006.22527456>
- [46] Lopez-Cruz, O., Garnica, N. J. Engineering organizational absorptive capacity for effective knowledge transfer. In International Conference on Software Process Improvement. Cham: Springer International Publishing, J. Mejia et al. (eds.), Trends and Applications in Software Engineering, Advances in Intelligent Systems and Computing 688. 2018. https://doi.org/10.1007/978-3-319-69341-5_17
- [47] Pu, K., Liu, W. Is absorptive capacity the "panacea" for organizational development? A META analysis of absorptive capacity and firm performance from the perspective of constructivism, Plos one. 2023, 18.2: e0282321. <https://doi.org/10.1371/journal.pone.0282321>
- [48] Panaia, M. Los graduados en ingeniería en el mundo, Perfiles. 2013, 8(19), 1-2.
- [49] Koen, B. V. Debunking contemporary myths concerning engineering. In Philosophy and engineering: Reflections on practice, principles and process. Dordrecht: Springer, 2013, 115-138. https://doi.org/10.1007/978-94-007-7762-0_10
- [50] El-Zein, A. H., Hedemann, C. Beyond problem solving: Engineering and the public good in the 21st century, Journal of cleaner production. 2016, 137, 692-700. <https://doi.org/10.1016/j.jclepro.2016.07.129>
- [51] De Vries, M. J. Engineering science as a "discipline of the particular"? Types of generalization in engineering sciences. In Philosophy and engineering: An emerging agenda. Dordrecht: Springer Netherlands: 2009, 83-93.
- [52] Goris, T. V., Dyrenfurth, M. J. Concepts and misconceptions in engineering, technology and science. Overview of research literature. In Proc. Amer. Soc. Eng. Educ. IL/IN Sectional Conf. Valparaíso. 2012, March.
- [53] Lerch, C., & Dmitruk, A. E. On Training Engineers for the New Century (Acerca de la Formación de los Ingenieros para el Nuevo Siglo). In Grinsztajn, F., Imperiale, M. & Autoridades UNLAM (2017), Enseñanza de la Ingeniería Hacia un Modelo Pedagógico Transformador 125. Universidad Nacional de la Matanza, San Justo, Buenos Aires, Argentina: 2017.
- [54] Frankel, R. M., Quill, T. E., McDaniel, S. H. (Eds.). The biopsychosocial approach: Past, present, and future. University Rochester Press: 2003.
- [55] Longino, C. F. The old age challenge to the biomedical model: Paradigm strain and health policy. Routledge: 2020.
- [56] Fink, P. J. Changing Values in American Society and American Psychiatry, Psychiatric Annals. 2014, 44(5), 248-252. <https://doi.org/10.3928/00485713-20140502-08>
- [57] Cardenas Lopez, H. I. The biopsychosocial and cultural approach in the training of health professionals at El Bosque University. Origins, developments and challenges. (El enfoque biopsicosocial y cultural en la formación de los profesionales de la salud en la Universidad El Bosque. Procedencias, despliegues y desafíos). Universidad El Bosque, Bogotá D. C.: 2016.
- [58] Lopez-Cruz, O., Ortiz, C. H. Educating computer engineers as innovation managers: Transformers of lives, builders of possible futures. Mexico. ANFEI Digital 2017, 7.
- [59] Kroes, P., & Meijers, A. (Eds.). The empirical turn in the philosophy of technology. Amsterdam: JAI-Elsevier: 2000.
- [60] Koen, B. V. Definition of the Engineering Method. ASEE Publications, Suite 200, 11 Dupont Circle, Washington, DC 20036: 1985.
- [61] Koen, B. V. Toward a definition of the engineering method, European Journal of Engineering Education. 1988, 13(3), 307-315.

- [62] Hidalgo, A The "System" of General Systems Theory: A Critical Re-examination, El Basilisco. 1978, 1, 57-63.
- [63] Leydesdorff L. The knowledge-based economy: Modeled, measured, simulated. Universal-Publishers; 2006.
- [64] Hevner A, Chatterjee S. Design research in information systems: theory and practice. Springer Science & Business Media; 2010 Jun 14.
- [65] Lopez-Cruz O, Munoz V. Worker, work and society: A relationship that becomes more complex through interaction. Journal of Technology. 2006, 5(2), 59-77.

Biography



Orlando Lopez-Cruz is a professor at El Bosque University, School of Systems Engineering and Emergent Technologies. He completed his PhD in Engineering from Pontifical Xavierian University in 2018 (Laurate Thesis), and his Master in Management in National University of Colombia (Bogota campus) in 2004. Dr. Lopez-Cruz has been member of El Bosque University Directive Council, on two occasions, as teacher representative. In addition, former member of the Researchers & Instructors Network (RIN) of the Institute of Studies of the Public Ministry in Colombia, IEMP, which stands for «*Instituto de Estudios del Ministerio Público*» in Spanish. In addition, former Editor-in-Chief of the *Journal of Technology* ISSN 1692-1399. He currently serves on the Editorial Boards of numerous publications and has been invited as a Technical Committee Member at international conferences.

Research Field

Orlando Lopez-Cruz: Design of computational complex systems models, Complex thinking and organizational knowledge transfer, Processes-structures design for innovation in organizations, Philosophy of engineering.