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SHORT PAPER

The Triple Helix of Knowledge: Synergies and Potentialities among Engineering, Art, and Education

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ABSTRACT

This analysis explores the "Triple Helix of Knowledge," examining the synergies between Engineering, Art, and Education, with knowledge as their common denominator. Engineering, rooted in ingenuity, focuses on applying scientific principles to solve problems. Art, stemming from skill and craft, involves mastery for creative expression. Education, encompassing upbringing and development, refines cognitive, practical, and social competencies. All three share a semantic foundation in cultivated skill, novelty generation, and human potential development. The paper proposes this model, building on the Sabato Triangle and the later Triple Helix model of innovation. It argues for a reengineering of engineering education, emphasizing adaptability, critical and creative thinking, and general life skills over encyclopedic knowledge. The integration of art into STEM (STEAM) is highlighted, advocating for a holistic approach that cultivates consciousness and prepares individuals for an AI-driven world. The ultimate goal is to foster professionals who integrate head, heart, and hands, ensuring innovation and relevance in a rapidly changing society.[1]

KEYWORDS

engineering, education, art, innovation, STEAM

1 SEMANTIC PERSPECTIVE

To begin this analysis, it is pertinent to delve semantically into the key terms: Engineering, Art, and Education. From this perspective, it is possible to identify a significant interconnection between these concepts, centered on the notions of specialized skill, creative capacity, and the development of human potential, although manifested through differentiated domains and methodologies.

Firstly, engineering, etymologically linked to the Latin word ingenium, which denotes ingenuity and natural ability, is defined by the systematic application of scientific and technical principles for the conception, design, and materialization of functional and efficient solutions to specific problems. It therefore implies the development and application of highly specialized technical and practical skills. Similarly,

[1] This text is the speech delivered by the author on the occasion of his appointment as member of the National Academy of Engineering of Argentina.

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the term "art," derived from the Latin "ars," which originally referred to skill, technique, or craft, shares with engineering a semantic root associated with the mastery of particular competencies for the production of an artifact or an expression. Finally, education, although its primary etymology refers to the concepts of upbringing and intrinsic development, implicitly entails the acquisition and refinement of various skills and competencies, whether cognitive, practical, or social.

Secondly, creation and innovation constitute a relevant semantic nexus. Engineering, in its essence, demands the ideation of novel solutions and the implementation of original methodologies to address existing challenges or anticipate future needs. Art, for its part, is based on creativity as a driving force for the expression of ideas, emotions, and perspectives through various media, resulting in works that transcend mere reproduction. Education, in its primary function, aims to stimulate creative capacity and innovative thinking in individuals, providing the cognitive and methodological substrate for the generation of new ideas and approaches.

Finally, the development of human potential emerges as a point of semantic convergence. Engineering, while oriented towards the production of objects and systems, demands and cultivates the intellectual capacities and logical reasoning of its professionals. Art stands as a way for the manifestation of the expressive and communicative potential of the human being, allowing the exploration of subjectivity and the transmission of meanings. Education, whose central objective lies in the comprehensive development of the individual, seeks to cultivate their cognitive, emotional, social, and ethical faculties, promoting the actualization of their inherent capacities.

In summary, from a semantic perspective, engineering, art, and education interrelate around the notion of cultivated skill, the capacity to generate novelty, and the fostering of the intrinsic capacities of the human being. While engineering specializes in the ingenious application of technique for the resolution of practical problems, art focuses on creative and aesthetic expression, and education is oriented towards the holistic development of the individual, all three share a common substrate in the transformative action of the human being on himself and his environment.

2 BACKGROUND

From another point of view, links can be found between many of these concepts in the well-known Sabato Triangle. Indeed, it was Jorge Sabato who, in 1968, in a publication together with Natalio Botana, postulated the importance of the relationship between the scientific-technological system, the state, and industry, with innovation as its axis [1]. Later, in the mid-90s, Etzkowitz and Leydesdorff revisited the idea, although without crediting the aforementioned precedent, by proposing the triple helix model of innovation, which relates to university, industry, and government [2]. The idea behind the triple helix metaphor is that universities, businesses, and governments assume some of each other's capabilities, although each maintains its primary role and distinctive identity. In reality, the idea of using the triple helix as a model is based on an invention from the Babylonian era used to raise water from one level to another, which was the basis of a hydraulic system for agricultural innovation that irrigated common farms. It is based on these antecedents that I propose the idea of using the triple helix model to describe how knowledge, like water in the aforementioned invention, can be permanently elevated to higher levels through the appropriate interaction and mutual reinforcement of technology, represented by engineering, art, and education.

In reality, the relationship between education and engineering is nothing new. Indeed, since the mid-18th century, when the National School of Bridges and Roads was created in France, engineering became a discipline developed in academic settings. Since then, the dominant educational model has been that of knowledge transmission. Teachers, mostly expert professionals in the discipline, transmit their knowledge to students who are required to assimilate said knowledge as faithfully as possible. The idea of universities as centers for knowledge creation was introduced by Oxford and Cambridge in England, pioneers in research and experimentation in the university sphere. However, many others, especially in the Ibero-American sphere, maintained the doctrinal and dogmatic transmission of knowledge. Against this tradition, the University Reform of 1918 emerged in Argentina; despite this, research and the creation of new knowledge continued to be restricted to researchers and the centers where they carry out their activity, but on very few occasions was this logic transferred to the classrooms, where the transmissive model was maintained, and to a large extent still is today.

In the 1960s, Peter Drucker coined the concept of the knowledge society [3]; in parallel, other authors speak of the information society, but it is from the generalization and massification of the Internet, hand in hand with the invention of the Web by the British Tim Berners-Lee, that these concepts take on a tangible and widely verifiable dimension. The advent of this new information and knowledge society simultaneously generates opportunities and challenges. Barely at the beginning of this century, and alerted by the demonstrations organized through incipient social networks, Howard Rheingold, in his book "Smart Mobs," expressed, "Technology has allowed humans to achieve powers that only a few generations ago we attributed to the gods. The question is whether we have the wisdom to use our instruments of power without amputating anything vital." [4] What would this author say today, just twenty years later, in the face of what generative artificial intelligence is generating?

3 ENGINEERING AND EDUCATION

Faced with these challenges, it is inevitable to ask whether the current educational system is prepared to face them. As the journalist and writer Andrés Oppenheimer says in his book "¡Basta de historias!," "the quality of education is the key to the knowledge economy," [5] and that quality depends on several factors:

1. **The adequacy of study programs to the real needs of the society that supports educational institutions:** Many of today's study programs are encyclopedic and rigid. The speed of social and technological changes requires focusing on those fundamental concepts that will not change over time and on developing the skills required to perform effectively in this volatile, uncertain, complex, and ambiguous society. Therefore, study programs should be less pretentious in terms of how much content they include and more flexible to allow their rapid adaptation to the demands of a technology that is advancing at breakneck speed.
2. **The preparation of teachers to deal with this new reality:** As we have evidenced in a recently produced work by the Institute of Engineering Education of this Academy, there are serious deficiencies regarding the preparation of engineering teachers. As historian and writer Yuval Harari says in his book "21 Lessons for the 21st Century," "teachers often lack the mental flexibility that the 21st century demands, because they are the product of the old education system" [6]. And the

most worrying thing is that young teachers, who are now having their first experiences as such, generally repeat the practices of their older colleagues because they do not have the necessary training and orientation to generate new ways of teaching.

3. **The necessary resources to carry out educational activities in an appropriate manner:** It is clear to everyone that quality education requires the necessary and sufficient resources to carry out its activities effectively. This is even more imperative in the case of engineering due to the need for classrooms, workshops, and laboratories that satisfy the need to interact with technology and for the implementation of active and student-centered learning, in simpler words, learning by doing. Unfortunately, today we are witnessing, in Argentina and many other countries in the world, policies that reduce state contributions to universities, whether public or private, with the consequent negative effect that this situation generates.
4. **The connection with the socio-productive environment:** As previously stated, the relationship of the university with the socio-productive environment is one of the pillars of quality education integrated into the society that supports it. In this sense, it is essential to include strategies such as authentic learning, understood as that which is based on real-life situations and contexts, that is, that in which students apply their knowledge and skills to solve existing problems or create tangible products. This strategy is, in engineering, as necessary as it is useful.

In summary, the training of engineers for the 21st century must be updated and adapted to current times. It is no longer possible to think of an encyclopedic education that pretends to teach everything, because today that "everything" is not only unmanageable, but it is a goal that is moving away at an increasing speed. The question that then arises is, what do we teach? Again, Yuval Harari provides us with some clues when, in the same book cited above, he tells us that what we should do is "de-emphasize technical skills and emphasize general life skills. The most important thing of all will be the ability to deal with change, to learn new things, and to maintain mental balance in unfamiliar situations. To be up to the task of the world of 2050, we will not only need to invent new ideas and products, above all, we will need to reinvent ourselves again and again" [6]. If we had to synthesize this paragraph in a few words, we would say that the most important competence that future professionals should acquire is that of learning to learn, because, as is often said, what we can teach them today will probably become obsolete by the time they graduate, and what they need to know at that time may not have been invented yet. In reality, rather than asking what we should teach our students, the question we should ask ourselves is, what should they learn?

It is worth making a disclaimer here: when Harari talks about de-emphasizing technical skills, he is not referring to the fact that these skills are not important and necessary, but that those other skills that traditionally do not appear in study plans and that are now vital to achieve a professional performance in accordance with the needs of current society must be incorporated into the equation. The question that then arises is, what are these skills?

In a report published in January of this year by the World Economic Forum [7], based on a survey of 1,000 employers from 22 industrial sectors and 55 economies (which together employ more than 14 million people), the key competencies that workers currently need were identified. Analytical thinking turns out to be the main competence for employers, as seven out of ten companies consider it essential. This is

followed by resilience, flexibility, and agility, along with leadership and social influence, which underlines the fundamental role of adaptability and collaboration, along with cognitive skills. Creative thinking, motivation, and self-awareness rank fourth and fifth, respectively. This combination of cognitive, self-efficacy, and interpersonal skills among the top five emphasizes the importance that respondents attach to having an agile, innovative, and collaborative workforce, where both problem-solving ability and personal resilience are fundamental to success. In the next five positions appear technological literacy, empathy and active listening, curiosity and lifelong learning, talent management, and service orientation and customer service. In light of this evidence, there is no doubt that we need to carry out a reengineering process of engineering education. We engineers know about reengineering processes; why not apply that expertise to make the changes that society demands today? It is not by hiding our heads in the sand, like an ostrich, that we will solve the challenges of the here and now. As a frequently repeated but rarely fulfilled phrase says, if we do not do so, future graduates and society as a whole will demand it from us.

4 ENGINEERING AND ARTS

We have analyzed so far the relationship between engineering and education and how knowledge constitutes a constitutive link between them. But in the initial statement, we also mentioned art as the third element of the helix. Let's then analyze what role this component plays, what its relationship with the other two is, and how knowledge, also in this case, is the common denominator of the aforementioned triptych.

Throughout history, humanity's great advances were driven by movements that, in each circumstance, created new realities integrating the scientific and the artistic. The Egyptians, Greeks, and Romans created their marvelous works of engineering and, at the same time, achieved an ideal of beauty. Science and art share the idea of approaching truth, only through different paths and means of expression. During the Italian Renaissance, this idea took shape under the ideal of the universal man, and in this context, Leonardo Da Vinci emerged, who sublimely combined engineering and art. In Leonardo's biography, Walter Isaacson says that "the ability to make connections across disciplines—arts and sciences, humanities and technology—is the key to innovation, imagination, and genius. Skill without imagination is sterile" [8].

For their part, Ken and Kate Robinson, father and daughter, say in the book "Imagine if …" [9] that the common assumption is that science and art are opposing subjects in education. Science is supposed to deal only with truth, objectivity, and concrete facts; in contrast, the arts are only concerned with feelings, creativity, and subjectivity. In reality, arts and sciences have much in common. All the great discoveries that have driven the advance of science have depended on significant doses of imagination, combined with the practical ingenuity of experiments; furthermore, the arts are highly disciplined activities that require refined skills and critical judgment.

In several parts of this text, we mentioned innovation and creativity, concepts that are naturally associated with engineering and art, but also directly with education. It is not possible to think of modern education today without taking these elements into account. In this era of artificial intelligence, it is more essential than ever to develop and enhance the capacity to innovate and create at an institutional level, at a teaching level, and fundamentally, in students. But we will not achieve this by teaching the same topics for decades and, even less, by evaluating students' ability to

repeat what teachers have taught. Tony Wagner, an education specialist at Harvard University, cited by Andrés Oppenheimer in his book "Crear o morir" (Create or Die), says that "what you know is increasingly less important, and what you can do with what you know is increasingly more important. The ability to innovate, that is, the ability to creatively solve problems or turn new possibilities into reality, and skills such as critical thinking, the ability to communicate, and to collaborate with others, are much more important than academic knowledge." [10] Axel Rivas, an Argentine researcher and writer specializing in education, states that "innovating is altering the elements of a school order that stifle or limit students' desire to learn" [11]. We could add many more references to these, but it is clear that an education that does not integrate innovation and creativity will not be preparing students for the era we live in and for the challenges of the future.

From another point of view, it is pertinent to incorporate a more disruptive approach, if you will, like the one proposed by an Italian colleague known for being the designer of the first commercial microprocessor and touchscreens. We are talking about Federico Faggin, who in his latest book, "Irreducible" [12], argues that human consciousness is irreducible and distinct from mere information processing by technology. From this perspective, art is revealed as a fundamental expression of this subjective consciousness, possessing a unique human element that artificial intelligence cannot replicate. Education, therefore, must transcend the transmission of data, focusing on cultivating consciousness, critical thinking, and self-awareness, faculties that go beyond the current capabilities of artificial intelligence. While technology can be a valuable tool, it cannot replace the essential role of human consciousness in genuine creation, appreciation, and learning.

From another, surely more earthly point of view, David Goldberg, one of the ideologues of Olin College of Engineering, perhaps the most innovative and disruptive engineering school in the world, states in his book "A Whole New Engineer" [13] that the new type of engineer must develop and be able to apply multiple minds in their work; and thus he mentions the analytical, design, linguistic, social, bodily, and conscious minds. This idea somewhat reinforces everything we have been describing so far in the sense that purely technical training could limit students' ability to address complex problems holistically and generate truly innovative solutions. Along the same lines, almost 20 years ago, researcher and pedagogue Georgette Yakman [14] proposed the incorporation of the letter "A" for Art into the acronym STEM, for science, technology, engineering, and mathematics. This proposal, later supported by important institutions dedicated to the subject and now widely disseminated and used, responds to the need for a richer, more creative, comprehensive, and relevant education for the 21st century, recognizing the fundamental value of the arts in the development of essential skills for innovation and creativity.

5 CONCLUSIONS

It is for all that has been described so far that I propose the "triple helix of knowledge," since "knowledge" is the common denominator of engineering, art, and education: knowledge in its meaning of having the ability or capacity to do something. Both the engineer, the artist, and the educator all "know" how to do something, and also in all three activities, innovation and creativity must be fundamental ingredients to transform their practice into something more than the mere repetition of activities that can well be replaced by a machine or by artificial intelligence.

Thus, we will have professionals who integrate these elements into their know-how:

- Engineers who know how to teach, understanding the task of teaching as that which awakens in students the will and desire to learn.
- Engineers who enrich their professional practice by incorporating elements of art that favor innovation and creativity.
- Artists who, as Leonardo Da Vinci did more than 500 years ago, take elements of engineering to create works that express the richness of human imagination.
- Artists who teach us to see the world we live in a more human and sensitive way.
- Educators who, like us engineers, select and develop the best materials to motivate their students to learn and keep learning throughout life.
- Educators who draw from art the ability to be creative and innovative to ensure that educational practices are updated to meet the needs of this modern world in which we live.

To conclude, I want to recall something that the most influential Argentine of all time said, and in case it is necessary, I clarify that I am not referring to a soccer player. In a dialogue with university rectors from Latin America in September 2023, Pope Francis told the university authorities, "You have to train boys and girls in the three human languages: that of the head, that of the heart, and that of the hands. So that they learn to think what they feel and what they do, to feel what they do and what they think and to do what they feel and what they think, in the harmony of the three languages. If you only train their heads, you will not train professionals but macrocephalics, who are not human. The three languages together and in harmony" [15]. Allow me, with great humility, to associate the words of the Holy Father with what has been expressed here: these three human languages–that of the head, that of the heart, and that of the hands–are essential for the three activities we have been referring to: engineering, art, and education; none of them will be able to develop correctly without these three languages and without knowledge as an integrating and unifying axis.

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