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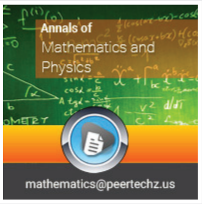

Opinion

The amazing systemic structure of Mathematics

Ramon Blanco Sanchez*

Department of Mathematics, University of Camaguey Ignacio Agramonte Loynaz, Camaguey C.P. 70100, Cuba

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***Corresponding author:** Dr. Ramon Blanco Sanchez, Department of Mathematics, University of Camaguey Ignacio Agramonte Loynaz, Camaguey C.P. 70100, Cuba, Email: ramon.blanco@reduc.edu.cu

Starting with the works of Ludwig von Bertalanffy, the general systems theory went from being applied to biological systems to identifying systemic structures in different natural, technological and social phenomena, even systemic structures are appreciated in different branches of science.

The analysis of any phenomenon from its systemic structure allows a better understanding of the characteristics and functioning of the phenomenon under study, which is why the general system theory is considered a useful tool for the study of any phenomenon, whether social, technological, or scientific.

For example: in analyzing content with a systemic approach, the integral can be understood as the mathematical tool to study the phenomena that result from the sum of infinite infinitesimals, which leads to the application of double integrals to calculate areas, surface integrals to calculate the area of a non-flat surface, the calculation of the mass of different bodies and in general all the phenomena that for their study are broken down into infinite infinitesimals.

Indeed, systemic structures can be found in any science, For example, the human organism is a system composed of several subsystems, in physics Newton's laws of mechanics form a system, and the periodic table in chemistry results from the interrelationships between chemical elements. But the systemic structure that Mathematics presents is really amazing, each new mathematical concept or a new branch of Mathematics is articulated to the existing structure, for example, when non-Euclidean geometries were developed, the new results were obtained by obeying existing laws, the spline method for the approximation of functions is executed using matrix properties that allow speeding up the solution of the resulting system of linear equations, a relatively recent result the finite element method, its application obeys the principles and laws established in Mathematics [1-4].

The trigonometric functions were determined in the beginning to study the metric relationships in the triangles and later they were understood as functions, which allowed the analysis of different phenomena, but these functions fulfilled the concept of an existing function and, moreover, they are periodic with periods that are multiples of π, as you know π results from the times that the diameter fits in the length of the circumference, which illustrates the systemic structure of Mathematics since it is reasonable to think that the relationship of the diameter with the circumference has nothing to do with the period of a function.

The trigonometric functions, despite their modest origin, continued to appear in Mathematics, for example in Euler's formulas: $e^{ix} = \cos(x) + isen(x)$, $e^{-ix} = \cos(x) - isen(x)$, from which one of the most notable examples of the systemic interrelation between mathematical objects is obtained, expressed in the equation: $e^{\pi i} = -1$, since the constants e, π and I (imaginary unit) appeared in Mathematics at different times and in different contexts and it turns out that they are related in a relatively simple equation. Furthermore π also appears in other relations that have nothing to do with its origin, for example, $1 + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \frac{1}{5^2} + \cdots = \frac{\pi^2}{6}$ this is the sum of the series: $\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}$ which is the result of the Fourier series expansion of the function f(x) = x^2 on the interval $[-\pi, \pi]$.

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Another manifestation of systemic relationships, also notable, is found in the golden ratio: the relationship between the side of a regular pentagon and its diagonal: 1.6180339887…., which appears unexpectedly in the Fibonacci sequence (Leonardo de Pisa): 1,1,2,3,5,8,11,... where each term is the sum of the previous two: $F_n = F_{n-1} + F_{n-2}$, which apparently has nothing to do with a pentagon and its diagonal, notwithstanding the ratios of consecutive terms have the golden ratio as a limit. But also the positive root of the equation: $x^2 - x - 1 = 0$ is the golden ratio: $\frac{\left(1+\sqrt{5}\right)}{2} = 1.6180339887$

Another example of a function that transcends its origin is the logarithm function, initially intended to facilitate the multiplication of very large numbers, but given the systemic structure of Mathematics, it reappears in the equation $ix = \ln(\cos(x) + isen(x))$ from which is obtained $i\pi = \ln(-1)$.

It is also notable that the functions e^x, cos(x), and sin(x) can be expressed as infinite sums $e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!}$, $\cos(x) = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n}}{(2n)!}$ $sen(x) = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{(2n+1)!}$ which allows the constant **e** to be expressed as $\sum_{n=0}^{\infty} \frac{1}{n!}$ which is a sum of fractional numbers despite **e** being an irrational number.

Thus effectively each element that is incorporated into Mathematics has to satisfy the existing structure, as it is the case that 0! = 1.

The examples indicated show how the mathematical objects interrelate with each other forming a systemic structure, that is, they show an interdependence that in many cases was unforeseen a priori, but as the examples cited show, structural relationships are manifested that illustrate its functioning as a system.

The systemic structure of Mathematics is one of the aspects that characterize it, from the point of view of its ontology.

Conclusion

The systemic structure of Mathematics can be used to apply a systemic orientation in the study, application, and development of this science, taking advantage of all the interrelationships that its objects manifest among them, in a similar way to the example cited for the application of the integrals the derivative It can be seen as the mathematical tool that allows studying all the phenomena of instantaneous variation. Even its systemic structure can also be used in an analysis of the epistemology of this science.

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