

The Role of Physics in Science Integration

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Abstract. Special and General theories of relativity may be considered as the most significant examples of integrative thinking. From these works we see that Albert Einstein attached great importance to how we understand geometry and dimensions. It is shown that physics powered by the new multidimensional elastic geometry is a reliable basis for science integration. Instead of searching for braneworlds (elastic membranes - EM) in higher dimensions we will start by searching them in our 3+1 dimensional world. The cornerstone of the new philosophy is an idea that lower dimensional EMs are an essential component of the living matter, they are responsible for our perceptions, intellect, pattern recognition and high speed signal propagation. According to this theory each EM has both physical and perceptive (psychological) meanings: it exists as our Universe-like physical reality for its inner objects and at the same time it plays perceptive (psychological) role in the external bulk space-time. This philosophy may help us to build up a science which explains not only inanimate, unconscious phenomena, but consciousness as well.

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INTRODUCTION

The impulse to integrate knowledge is born out of need of a unified vision of the reality. Physics traditionally accepts the "experimental method" introduced by Rene Descartes: science has to be relied on experiments and proofs. Only the strict language of mathematical logic may be applied for checking whether a scientific hypothesis is true or false. The great physicists of the 20th century demonstrated in their works that use of rich and complex mathematical methods is a reliable way to create a qualitatively new physics. This is how on the basis of Riemannian curved geometry and tensor calculus Albert Einstein created his General Relativity. And, in turn, physics often gives an impulse to the origin of new mathematical theories.

Other natural sciences, like biology and neuroscience, which describe living organisms, are less mathematized and hence lack scientific exactness and strictness. All experimental data, on which the results here are based, are obtained by means of modern technologies and equipment developed owing to discoveries made by physics (lasers, semiconductors, superconductors, fiber optics, and nanotechnology). Even modern computers became available only because of the achievements in physics.

Richard Feynman writes in his lectures on physics [1], "Physics is the most fundamental and all-inclusive of the sciences, and has had a profound effect on all scientific development. In fact, physics is the present day equivalent of what used to be called *natural philosophy*, from which most of our modern sciences arose. Students of many fields find themselves studying physics because of the basic role it plays in all phenomena. "He also notes that if "we, for some convenience, divide this universe, into parts—physics, biology, geology, astronomy, psychology and so on, nature does not know it!" A picture of the reality must be entire.

All scientific efforts of Albert Einstein were concentrated on investigating of general features of the nature. Even in a letter of April 14, 1901, to his school friend Marcel Grossmann, Einstein had revealed his generalizing approach to physics: "It is a wonderful feeling to recognize the unity of a complex of appearances which, to direct sense experiences, appear to be quite separate things." His theories on Brownian motion, quantum property of light and relativity form the foundation of modern physics and other natural sciences.

And, finally, Einstein started the most grandiose scientific project in the history of human civilization - a grand unification of quantum physics and gravity: search for a unified field theory. This project set the stage for the ambition of some of today's best scientists. As a result of their efforts, two theories of quantum gravity: loop quantum gravity [2, 3] and string theory [4, 5] have been created. The theories seem to be, in a sense, complementary and give us two brilliant examples of integrative thinking. But in spite of the indubitable successes, neither of these theories could be called the final theory.

In this work the tendencies of knowledge integration in our contemporary world are discussed. The current period of time may be marked as crucial regarding upcoming changes in our understanding of the reality. According to Gerard 't Hooft [6], "It is obvious that drastic modifications in our ways of thinking are required to solve some very persistent problems in our attempts to reconcile the theory of General Relativity and Quantum Mechanics. "

INTEGRATIVE THINKING PARADIGM

During more than 25 centuries western thinking was dominated by the dualistic paradigm described by Aristotle's syllogism. A statement is true or false, exclusively one of both and all of intellectual activity consists of evaluating, arguing or refuting the statement.

Many approaches recommend a less dualistic, mutually exclusive way of thinking. But up to now a central paradigm was not clearly defined. Integration is proposed as such a paradigm.

Integration can be defined as [7, 8]: "a process of combination of elements that, at first approach, seem to be incompatible or even conflicting, but, after a bit of analysis and re-synthesis (leading to reformulation or re-orientation), prove to be rather complementary."

The historically most significant example of integrative thinking is Newton's theory, improved by Einstein. This example is particularly striking because during centuries the theories of Newton were quoted as the illustration *par excellence* of scientific, Aristotelic-cartesian thinking.

Neils Bohr, the patriarch of quantum mechanics, was the most prominent articulator of the principle of complementarity. Bohr believed that complementarity was a major new category of thought with ramifications way beyond physics [9, 10], "The opposites are complementary."

There are three levels of conceptual integration:

1. Just bringing several approaches together. This approach is synonymous with *multidisciplinarity*.
2. Synthesizing one "unified" theory out of several theories. This often results into something much simpler and more comprehensive than the original theories.
3. Integration as a scientific tool.

But one should be very careful while declaring two elements, approaches, theories or even sciences as complementary, because more plausibility may be achieved at a cost of transcending exact scientific reliability which is determinative for fields where exact measures and experiments can be performed --the physical sciences.

In two cases it appears easier to decide whether two elements or theories may be integrated or not:

1. "Duality": it is just like particle-wave duality in quantum mechanics - "in reality everything comes from the description by waves, which are then quantized to give particles [4]." Two theories are "dual" to each other if they can be shown to be equivalent under a certain interchange. The simplest example of duality is reversing the role of electricity and magnetism in the equations discovered by James Clerk Maxwell. Another example of using dualities is M-theory [5]. It has as limiting cases the five string theories studied in the last generation.
2. "Unity": if elements A and B may be unified into a third qualitatively new and more informative element C. Just like Albert Einstein unified categories of space and time in his Special Relativity [11].

As we know, the understanding that two categories or theories are complementary may lead to outstanding scientific discoveries. This work shows that there are complementary elements and categories even within the scope of such exact science as mathematics (particularly, in a part of it – geometry).

MAIN STRATEGIES OF KNOWLEDGE INTEGRATION

In the Western philosophical tradition, the tendency to integrate knowledge has had two main expressions, which for historical reasons are called "reductionism" and "emergentism." The main conceptual problem associated with reductionism is epitomized in the phrase "the one and the many." The main conceptual problem associated with emergentism is epitomized in the phrase "the part and the whole." According to Fuller [12], "The sets of questions suggested by these two metaphysical strategies imply two radically different conceptions of inquiry. According to the reductionist strategy, inquiry is an intensive, perhaps even microscopic, search for the essential properties into

which an individual can be analyzed without remainder and which together can be used to synthesize the individual without cost. By contrast, the emergence strategy works by differentiating a whole into its proper parts -- but at a cost, since it is not clear that the process can be reversed, so as to allow the parts to be reintegrated into the original whole."

There are three main versions of reductionism:

1. "Scientific reductionism": this version is simply the idea that all of nature can eventually be described scientifically; that there are no inherently unknowable facts [13].
2. "Greedy reductionism": the idea that every explanation in every field of science should be reduced all the way down to particle physics or string theory.
3. "Hierarchical reductionism": organisms can be described in terms of DNA, DNA in terms of atoms, atoms in terms of sub-atomic particles; but there is no need to deal with details of sub-atomic particles to explain animal behavior if one can make adequate explanations and predictions at a higher level.

Emergentism also involves a layered view of nature, with the layers arranged in terms of increasing complexity and each corresponding to its own special science. Some philosophers hold that emergent properties causally interact with more fundamental levels, while others maintain that higher-order properties simply supervene over lower levels without direct causal interaction.

Some scientists of the 19th century believed that various chemical reactions (poorly understood in their time) could provide examples of emergent properties, although modern chemistry has shown that these reactions can be given satisfactory reductionist explanations. This raises the possibility that the emergentist position is more a matter of epistemology than metaphysics.

On the example of solid state physics we see that in certain cases a holistic description of complex systems is more effective than a reductionist one. Many phenomena in solids became clear when holistic approach in terms of quasi-particles (phonons, excitons, magnons) was applied.

That said, emergentist methods are not generally at odds with the classical scientific method. Where holistic scientists come from a standard science background, holistic work in science tends to be a union of the two approaches.

Richard Feynman was convinced that every phenomenon in the living world could be explained in terms of moving and oscillating atoms. But he stressed that a real understanding comes only through cooperation of physicists with other scientists: chemists, biologists, physiologists and psychologists. Only after being consulted by specialists in the corresponding field of science, a physicist can make decision how to apply a physical theory in order to solve concrete problems. Feynman considered physics to be equal to old natural philosophy, which gave an impetus to the development of other sciences [1].

Let's show in more detail how integrative ideas and principles manifest themselves in Albert Einstein's works.

THE WORLD PICTURE ACCORDING TO EINSTEIN

In 1912 thirty-four prominent German scientists signed the general manifesto appealing to researchers in all fields of science to combine their efforts in order to "bring forth a comprehensive Weltanschauung (a world picture)." Among the signatories were Ernst Mach, Sigmund Freud, David Hilbert and then still little-known Albert Einstein.

From Einstein's works, one can see his inspiration to create that world picture, that universal conception, which would explain every empirical fact – not only of physical science, but also of life.

Throughout his scientific career Albert Einstein demonstrates virtuous use of two powerful tools:

1. Universalism: the postulation of universal formal principles.
2. Generalization: the discovery among phenomena of a unity through generalization of the basic theory.

In a letter to Max von Laue of January 17, 1952, Einstein writes that his early concern with the physics of fluctuation phenomena was the common root of his three great papers of 1905, on the quantum property of light, Brownian movement, and relativity.

The first of the three papers that Einstein published in 1905 came up with an explanation of Brownian motion. Einstein showed that the jiggling of the pollen grains seen in Brownian motion was due to molecules of water hitting the tiny pollen grains. He not only proved that everything around us is made up of atoms and molecules but also made predictions about the properties of atoms that could be tested. It was soon realized that the laws of Brownian motion do not exclusively pertain to the realm of physics but likewise to chemistry, biology and even economics.

Einstein first realized that light can act as though it consists of discrete, independent particles of energy, in some ways like the particles of a gas. His revolutionary proposal seemed to contradict the universally accepted theory that

light consists of smoothly oscillating electromagnetic waves. But Einstein showed that light quanta, as he called the particles of energy, could help to explain phenomena being studied by experimental physicists. He used this interpretation to explain the photoelectric effect. Einstein's theory, and his subsequent elaboration of it, formed the foundation for much of Quantum Mechanics. Now Quantum Mechanics is the basis of modern developments in chemistry, molecular biology, and electronics, and the foundation for the technology that has transformed the world in the last fifty years.

The third of Einstein's 1905 papers proposed what is today called the special theory of relativity. He based his new kinematics on a reinterpretation of the classical principle of relativity. Einstein was not the first to propose all the elements that went into the special theory of relativity; his contribution lies in having unified important parts of classical mechanics and Maxwell's electrodynamics. Later in 1905, Einstein elaborated how, in a certain manner of speaking, mass and energy are equivalent. Clifford Will [14] assures us that: "Special relativity is so much a part not only of physics but of everyday life, that it is no longer appropriate to view it as the special "theory" of relativity. *It is a fact . . .*".

We see that Einstein lived under the compulsion to unify – not only in his science but also in his politics, in his social activity, even in his everyday life. His discoveries changed the face of modern physics and influenced the development of other natural sciences.

In Einstein's works the reductionist methods co-exist in harmony with the holistic ones; if the quantum theory of light and the theory of Brownian motion explain the nature from the reductionist point of view, the concept of space-time in special relativity and Bose-Einstein statistics have holistic features.

Albert Einstein was the first to notice that the laws of nature become simpler in higher dimensions. By introducing a fourth dimension he unified mechanics and electromagnetism. And this is how string theorists use higher dimensions trying to unify gravity with other forces.

He also was among the first scientists who realized the role of the novel geometrical methods in physics. His interpretation of Riemannian curved geometry led to creation of General Relativity which still remains the most reliable theory of gravitation. Remarkably, General Relativity can be extended easily to higher or lower space dimensions.

From these considerations we see that Albert Einstein attached great importance to how we understand geometry and dimensions. The better we know the laws of multidimensional geometry, the better we can explain the physics of the entire world.

DUAL METRIC MODEL OF MULTIDIMENSIONAL GEOMETRY

The concept of multidimensional geometry itself has a dualistic meaning: each surface may be embedded into a higher dimensional bulk and at the same time it may contain lower dimensional surfaces embedded in it. Multidimensional geometry is tightly connected with the basic rules of human perception and depends on how we explain the terms "dimension", "embeddance" and "space".

Traditionally, under the term "space" we imply a set of zero-size points on which a metric can be defined. Under the term "dimensionality" we understand a minimal number of real numbers needed to describe this set unequally. An elementary geometrical object "point" itself has no dimensionality and is the same for all dimensions. This understanding of dimensions tells nothing about their true nature. Why do compositions of points have different number of dimensions?

In this work a new approach to multidimensional geometry based on smooth infinitesimal analysis (SIA) is proposed. An embedded surface must be considered from two sighting points, namely, for internal and external observers. For the internal observer we have a picture we are used to (for example, the space-time we are living in), but for the external observer the picture is quite different (when we try to imagine a 2-dimensional surface we act like external observers).

According to this approach n-dimensional spaces and surfaces are composed of n-dimensional elementary objects "point-connections." The number of dimensions of a manifold depends on how its points are connected. So, an n-dimensional object "point-connection" has a dual nature: in addition to being a point of a manifold, it plays a role of connection within a certain set of points of a manifold. In other words, an n-dimensional "point-connection" has two elements: first – a "point" to be connected, and second – a "connection" which connects the "points."

Smooth infinitesimal analysis is a mathematically rigorous reformulation of the calculus in terms of infinitesimals. It views all functions as being continuous and incapable of being expressed in terms of discrete entities [4]. The *nilsquare* or *nilpotent* infinitesimals are numbers ε where $\varepsilon^2 = 0$ is true, but $\varepsilon = 0$ need not be true at the same time. In SIA every function whose domain is \mathbb{R} , the real numbers extended by infinitesimals, is continuous

and infinitely differentiable. Intuitively, smooth infinitesimal analysis can be interpreted as describing a world in which lines are made out of infinitesimally small segments, not out of points. These segments can be thought of as being long enough to have a definite direction, but not long enough to be curved.

The standard point of view postulates that lines are made of points. This point of view and SIA are complementary and give us a basis for a new multidimensional geometry: each manifold in this geometry will look different from the points of view of external and internal observers. From the point of view of an external observer it will be a set of infinitesimal segments and from the inside – a set of points equipped by a metric.

Another interesting feature of SIA is its **elasticity**: different segments make different contributions into the length of a curve, depending on the angle between a segment and the OX axis. The curve ADB may be considered as a result of stretching of the curve ACB. Infinitesimal segments have no length but they may be stretched.

An infinitesimal segment cannot be considered as a separate entity, it can exist only as a part of the line: we'll call it a **connection**. One and only one point of the manifold will correspond to each infinitesimal segment. But there may be an infinite number of connections passing through the selected point. From the point of view of the external observer each manifold may be represented as a set of connections which connect the points of the manifold. A holistic manifold (our Universe-like) will be composed from holistic elements – “point-connections”. Proceeding from general considerations, we will use closed connections, because they are suitable for both finite and infinite manifolds. In the case of isotropic and continuous manifolds connections will have spherical form.

We see that each connection itself may have an internal structure: it is also to decompose into subconnections. The process of decomposition of a manifold into subconnections will stop when all subconnections will consist only of 1-dimensional connections - circles.

Let's consider a simple case: a two-dimensional plane imbedded into Euclidean space R^3 . We can apply to this plane two different transformations which don't differ from the traditional point of view:

1. Expansion: increases k times the distance between every two points on the plane, but radii of the connections stay the same;
2. Stretching: proportionally increases both the distance and radii of the connections (from the sighting point of the external observer).

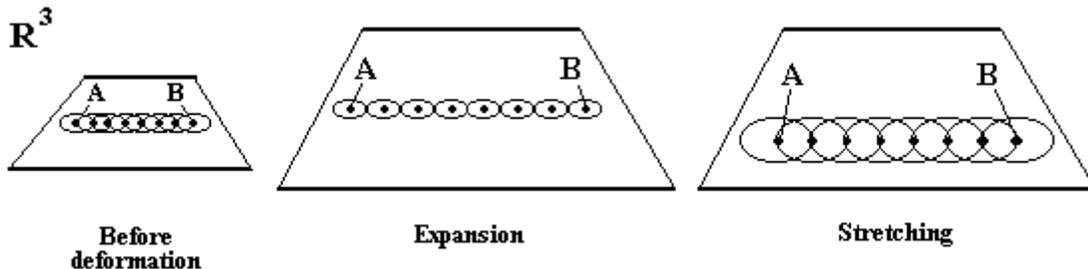


FIGURE 1. Expansion and stretching of a two-dimensional plane.

We can see that the points connected before deformation stay connected after stretching, but they may become unconnected after expansion (See Fig. 1). An example of an expansion is what happens in our Universe after the Big Bang. The standard Big Bang cosmology assumes that the Universe began expanding from the state that was very hot, very small, and very highly curved. This inflationary model agrees very well with observations. Stretching is not observable for the internal observer because it doesn't change the structure of the embedded surface. Clearly any multiple of an infinitesimal is also an infinitesimal. For set Δ of infinitesimals and any positive real number k we can define a function $f: \Delta \rightarrow \Delta$ as $f(x) = k \cdot x$. This function translates Δ into Δ , but $f(x) \neq x$ if $x \neq 0$ and $k \neq 1$. We'll call this function stretching of Δ with parameter k .

The embedded surface may be treated in two ways: as a subset of the points of the bulk or as a set of lower dimensional connections added to the bulk. During expansion and stretching points of the embedded manifold change their positions the same way, but the connections don't.

As was shown, n -dimensional connections ($n > 1$) are composed of 1-dimensional connections – circles. These circles according to SIA are made of infinitesimally small straight lines. Stretching of such a circle may be understood as stretching of these infinitesimal segments (1-dimensional connections introduced earlier are the analogs of those segments). The internal observer doesn't feel the deformations if they act like stretching or compressing because any set Δ of infinitesimals the infinitesimal segments are associated with will be translated into itself. But stretching of Δ changes its relative position in respect to the bulk.

The proposed model shows that the classical approach based on the notion of a limit and smooth infinitesimal analysis are rather complementary than conflicting: if the former describes the world from the sighting point of the internal observer, the latter is more suitable when investigating an embedded surfaces from the sighting point of the external observer.

Obviously we will have two different metrics for the embedded surface - internal and external. In the context of the proposed geometrical model an embedded surface may change its form in the bulk, undergo vibrations, but its internal structure stays unaware of these changes if they act as stretching or compressing. In other words, such geometry is an elastic one. It is just like inflating a balloon with a pattern on it: during the inflation process everything grows bigger and bigger, but when the air is out everything is restored.

The proposed geometry has three features, which distinguish it from the existing geometries:

1. It is holistic. Space is represented as interweaving of connections; each point exists only in the context of the background space, which may be understood as undivided wholeness.
2. It is really multidimensional. Point-connections of different dimensionality have different topology.
3. It is elastic. Embedded surfaces possess dual metric: internal and external. They can change their form in the bulk without changing the internal metric.

DISCUSSION

Einstein's full theory of space-time, called General Relativity can be extended easily to higher space dimensions. This fact is a good argument in favour of the multi-dimensional world concept. In the recent years a few interesting theoretical models of the braneworld scenario have been proposed [16-18]. These models explore the D-brane concept [19] and are not truly multi-dimensional.

According to the new geometry we can introduce new objects – elastic membranes (EM), which must be considered from two sighting points: for internal and external observers. For the internal observer we have a picture we are used to (space-time we are living in), but for the external observer, interacting with the embedded EM from higher dimensional bulk space-time, the picture is quite different.

By analogy with D-branes from the position of the external observer we will accept that EMs are extended, stable, physical objects (just like D-branes are). The embedded EM may be considered as a set of connections between the points of the external space-time. But unlike D-branes all the matter of the EM is inside its structure and may be understood as its internal defects. These defects will produce the internal elastic deformation of the membrane that we call gravity.

According to the present model, when interacting with the elementary particles from the higher dimensional bulk space-time an embedded EM can change its form in the bulk EM, it may be stretched or contracted, but the internal observer will stay unaware of these changes because the matter and space are bounded to each another.

Heisenberg's uncertainty principle will work in this physics only from the point of view of the internal observer. For the external observer each embedded elastic membrane may be stretched and even a very small region will become observable. The theory postulates that these elastic deformations (stretching) will not be observable from the point of view of the internal observer [20].

In other words, reality may be considered as the process of time evolution of holistic energetically very weak macro objects - elastic membranes with the geometry based on smooth infinitesimal analysis. An embedded membrane in this multidimensional world will look different for the external and internal observers: from the outside it will look like a material object with smooth infinitesimal geometry, while from the inside our Universe-like space-time fabric. For example, living organisms play the role of internal observers of the Universe, and at the same time they serve as external observers for 2D membranes embedded into our Universe.

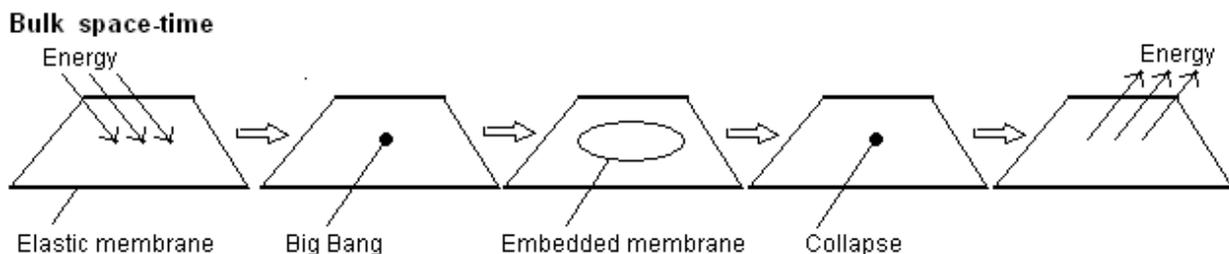


FIGURE 2. Birth and decay of an embedded elastic membrane.

When interacting with elementary particles and other membranes, a membrane will transform their energy into its elastic energy (a new form of energy) - the energy of stretching of the infinitesimal segments. Under certain conditions these interactions may cause Big Bang like event inside the membrane and birth of a new EM embedded in it (See Fig. 2). After collapse of the new EM the Big Bang energy will return to the bulk it came from.

The new multidimensional physics may be useful for explaining our perception. It is supposed that our perception may be considered as the result of elastic oscillations of two dimensional (2D) elastic membranes with closed topology embedded in our bodies. Only one elastic membrane responsible for its perceptions will correspond to the selected organism, but there may be other membranes, even at the cell level. We can observe our 2D self-membranes through our perceptions, which are encoded in elastic oscillations of the elastic membrane.

The model explains some features of our perception which cannot be explained using other models:

1. quasi two dimensional character of our perceptive experience;
2. feeling of self awareness as being one whole;
3. active character of our perception: in our brains physics of perception is separated from the information processing physics. But at the same time both mechanisms are tightly connected and under certain conditions can affect each other.

According to the new approach the reality is made of the one kind of stuff – elastic membranes, which have both physical and perceptive properties, but in addition they have also internal physical properties – the internal physical world. This internal world is our Universe like space-time structure with elementary particles and embedded lower dimensional elastic membranes.

Membranes may be organized in two ways:

1. infinitely embedded - when each elastic membrane has a parent elastic membrane;
2. finitely embedded - when there exists the last elastic membrane which is embedded into the infinite dimensional absolute space-time - a new physical structure with new physics and physical laws.

The second scenario seems to be more viable because it presupposes further development of physics and another argument is that M-theory has a finite number of dimensions - 11.

Philosophically the proposed theory may be classified as multidimensional integration theory where two dimensional holistic objects – elastic membranes are responsible for our perception.

CONCLUSION

This work deals with main tendencies of knowledge integration and the role of physics in this process. Albert Einstein's great contribution in the creation of a universal picture of the entire world is discussed. After a detailed analysis of the situation in modern science a few conclusions can be made:

- We need knowledge integration in order to create a unified vision of reality.
- Physics is the only natural science, which gives us mathematically strict description of the reality. Physics also provides us with technologies and equipment to be applied in other natural sciences.
- Every phenomenon in the living world can be explained in terms of moving and oscillating physical entities. But a real understanding comes only through cooperation of physicists with other scientists.
- On the example of solid state physics we see that in certain cases a holistic description of the complex systems is more effective than a reductionist one. Where holistic scientists come from a standard science background, holistic work in science tends to be a union of two approaches.
- Einstein lived under the compulsion to unify – not only in his science but also in his politics, in his social activity, even in his everyday life. His main scientific tools were universalism and generalization.
- His three great papers of 1905 had a fundamental character and changed our understanding of the entire world. We see from these works that Albert Einstein attached great importance to how we explain geometry and dimensions.
- Introducing of the unity "point-connection" and the duality "zero-infinitesimal" allows us to create a new model of multidimensional geometry and explain the nature of such terms as "dimensionality" and "embeddance." This geometry may be useful for predicting and explaining our perception and consciousness.
- Reality may be considered as the process of time evolution of holistic energetically very weak macro objects - elastic membranes with the geometry based on smooth infinitesimal analysis.
- It is supposed that our perception may be considered as the result of elastic oscillations of two dimensional (2D) elastic membranes with closed topology embedded in our bodies.

Keeping in mind all the above said, we can claim that physics powered by its rich theoretical and experimental technologies is a reliable basis for knowledge integration. Albert Einstein, undoubtedly, made the most important

contribution into modern science and is one of the greatest scientists of all times. In tight collaboration with other natural sciences, physics is expected to provide us with mathematically strict descriptions of the entire world and new experimental technologies for our practical needs.

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