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Research Article

Nanotechnology and its applications: an analytical study of selections from contemporary painting

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ABSTRACT

The present research aims to reach a set of new academic approaches emanating from the formal structure in the works of nano artists inspired by the general applications of nanotechnology through an analytical study of selections from contemporary painting and its role in the development of plastic performance, and considering it a new approach for enriching the field of painting and the educational process in general. The development of nanotechnology applications that the world witnessed in the twentieth century and the beginning of the twenty-first century has become characterized by the speed that made the global community pant behind the speed of change required to accommodate the requirements and effects of the outputs of that development. This research deals with the study of some applications of nanotechnology in terms of the formal structure of the works of nano artists, as it has become one of the important and basic influences that stimulate the artist's thought, his feeling, and his own subjectivity. An analysis of some of the works of contemporary nano artists, as an innovative approach to works in painting accompanied by technical analysis.

1. Introduction

The Science is the culture of the future, for the culture of inclusiveness is almost the science of the future, as the capacity of the various branches increases. Those branches multiply and vary, forming a comprehensive science [1]. This culture pluralism is not limited by certain limits, but rather it represents a concept of human culture that is comprehensive in all fields [2]. This is what the human being in general, and the artist in particular has to explore through what advanced technology has provided [3,4].

Despite the list of nanotechnology applications are numerous and varied in a wide range and are involved in many industrial, military, medical, agricultural and other fields, scientists today use extremely complex and highly efficient tools to implement multiple applications through the use of nanotechnology, where scientists and designers deal with a material at this scale on a very precise level with the creation of new substances with new technical design arrangements, innovative combinations and properties, and not found naturally, opening new horizons in science, art and technology [5].

Creativity is considered a refined form of human activities, as it is the main determinant of the features of human progress in various fields. The more complicated the aspects of life are, the more adaptation it requires, in order to keep pace with the movement of life and to compete with it. There is no doubt that the nature of life in the twenty-first century abounded and flourished with great achievements that indicated, in one way or another, that it was a mental product as a result of many efforts and the outcome of the scientific progress and its possibilities [6].

The research first deals with the study of some applications of nanotechnology in terms of the formal structure of the works of nano artists, as it has become one of the important and basic influences that stimulate the artist's thought, his feeling, and his own subjectivity. Hence, the idea of research on how to benefit from nanotechnology applications in terms of the formal structure through an analytical study of some of the works of contemporary nano artists, as an innovative approach to works in painting accompanied by technical analysis and color treatments. Secondly, the researcher carried out some practices based on inspiration from the forms of the formal structure of one of the applications of nanotechnology, especially electron flow, carbon nanotubes, to build works of art using digital art.

Art always relies on finding innovative intellectual starting points, in an attempt to form references with logical origins and access to non-traditional concepts and ideas, and to create special backgrounds and reference sources for the artist and art students, as a result of the scientific revolution brought about by nanotechnology and its applications, their works become characterized by a mental and intellectual methodology, whether in concept or formal intake.

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Research Problem: In addition to works in which some artists deliberately promoted nanotechnology and its applications, inspired by the formal structure of nanotechnology applications of nanotechnology artists and their simulation as a basis for artistic formulation, due to the interdependence of the relationship between "art, science and technology". Accordingly, the research problem is determined in the following question: What is the possibility of benefiting from the formal structure of the works of nano artists through an analytical study of selections of contemporary painting?

Research Hypotheses: The research assumes that the works of nano artists can enrich contemporary painting in light of the analysis of the formal structure of the works of nano artists related to the art of nanotechnology.

Research Objectives: 1- Benefiting from one of the formal structures through the works of nano artists by analyzing the works of some artists and determining their attitudes, fields, and the names of some of them, and then the destination of benefiting from them in the research. 2- Enriching the artistic vision in the field of painting by taking advantage of one of the applications of nanotechnology through an analytical study of the works of contemporary artists.

Research Importance: 1- Benefiting from the tremendous progress and development in the field of nanotechnology and modern scientific discoveries in enriching the artist's sources of vision, which confirms that there is no conflict between art and science, and enriches the building of a contemplative artist, researcher, innovator and creator at the same time. 2- Revealing the formal structure of one of the applications of nano artists' work to benefit it in enriching contemporary painting.

Research Limitations: This research is limited to: 1- an analytical study of some of the artists' works, which benefited from the scientific data for the applications of nanotechnology in constructing the artwork. 2- A researcher's self-experiment based on the use of Adobe photoshop program.

Research Terms: The concept of nanotechnology: Nanoscience is considered "the science that is concerned with the study of the infinitely small particles. It is the science of atoms and molecules. One nanometer is equivalent to one billionth of a meter (i.e. 10^{-9} m). If one of the particle dimensions is less than 100 nanometers in width, then it is considered one of the Nanoparticles, and the term nano means one billionth [7].

Contemporary Arts: The word "contemporary" in the comprehensive dictionary of meanings means living with the present with conscience and behavior and benefiting from all its scientific and intellectual achievements to serve man and his advancement. Contemporary plastic arts are not just an expression of aesthetics and a translation of the impacts of conscience only, as they are no longer a depiction of assets and events that convey reality and simulate nature. Rather, it is a fertile area to develop thinking skills and, asking questions, and delving into intellectual controversies provoked by the contemporary plastic language with its rich elements that are beyond the ordinary [8].

2. Materials and Methods

2.1. The present research follows the descriptive and analytical approach and reviews the works of some artists whose works were inspired by the formal structure of nanotechnology applications and the use of nanotechnology (interactive arts) to represent the following: Interactive Arts has been interested in employing nanotechnology in their work and has several pioneers, the most important of which are: Artist Eric Heller, Artist Scott Snibbe, Artist Victoria Vesna, Artist Shane Hope, and Artist Suzan A. E. Essa.

3. Results and Discussion

3.1. Artist Eric Heller

Eric Heller was born in Washington, USA, and then received his education in 1946, in the state of Minnesota. Then, he obtained a Ph.D. in chemical physics from the American Harvard University in 1973. Eric had administrative positions at the university until he worked in the Department of Atomic Theory and Molecular Physics at Harvard University and then he became a professor of Physics at Harvard. In the period 1998, Eric became interested in quantum mechanics, classical and scattering theory (Nano physics), condensed matter physics, and quantum chaos.

More than fifty articles were based on him, and a lot of scientific research published in scientific journals and conferences. He has made several art exhibitions based on the nano phenomenon. Eric is a Fellow of American Physics, the American Academy of Arts and Sciences, and the American Association for the Advancement of Science. He is also an elected member in the International Agency for Molecular, Quantitative and Molecular Sciences and the National Academy of Sciences; he was interested in nano sciences and its various developments and fields. Besides, he joined many work teams in separate regions working in the field of nanotechnology inside and outside the United States of America. So he participated in a number of experiments in 2006 with my colleague (Egiler), and Heiler Shedit, they are well-known physicists for painting some thumbnail snapshots and display them in a special sequence and format.

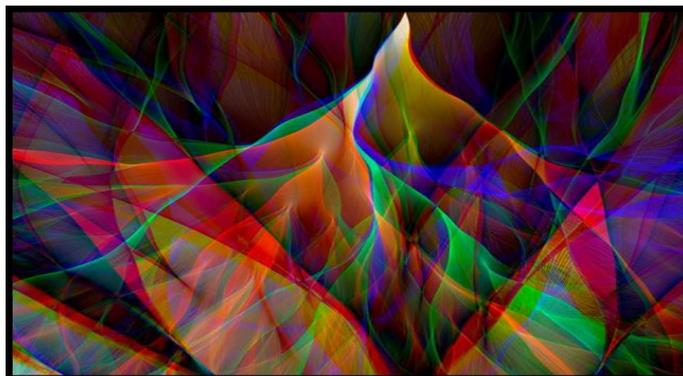


Figure 1. This figure shows an artwork inspired by one of the forms of electron flow paths. One of the applications of nanotechnology by the artist "Eric Heller", in 2006 [9].

Artist Name:

Eric Heller

Date of Work Production:

2006

Work Place:

Minnesota, United States

Work dimensions:

61 x 61 x 2.5 cm

3.1.1. The materials and media used

using large display screens presented in the exhibition halls to visitors who watched and interacted with them through the naked eye, by using stereoscopic vision glasses (3D), which are glasses with two lenses, one in red and the other in blue. Besides, it increases the contrast between color grades, deepening the sense of emptiness within the photographic space, and pushing the main elements forward as if they were pushed out of the frame.

3.1.2. Description and Analysis of the Artwork

Eric presented a set of corrugations and organic tones, which create a number of vibrations and delusional movement through the use of three-dimensional glasses, as if they were moving waterfalls or waves of colliding, rushing water. Moreover, the artist presents another group of nano experiments depending on benefiting from modern technological media in enriching his vision such as using computers to process these images and snapshots with a new vision [10].

In this work, the artist emphasized the elements of line and color that play an aesthetic role, as this appears clearly in the achievement of some aesthetic foundations, such as, balance is achieved through vertical spaces and runs in a bifurcation in an overlapping position, which gave a sense of stability, which worked on a sense of balance for the general form. Additionally, the juxtaposition of cold colors, such as blue and its shades, and hot colors, such as yellow and reddish-violet, achieved a kind of balance. Rhythm is achieved through the different directions of the intertwined lines and the different spaces between them, which led to the emergence of a diversity of rhythm, and the repetition of the blue color in different parts of the artwork led to the achievement of the varied rhythm. Unity was achieved through the repetition and diversity of vertical spaces. The color balance of hot and cold colors also worked to achieve unity and with the presence of interlocking lines, linkage and unity between its parts was achieved.

3.2. Artist Scott Snibbe

Artist Name:

Scott Snibbe

Date of Work Production:

2008

Work Place:

United States

3.2.1. Description and analysis of the artwork:

The work is based on a spherical circular formation, inspired by simulation with water in three scales using the full shadows of the human body or for visitors through interaction in each scale different physical forces can be observed, where gravity is the observed force. Visitors are showered with drops of water from a simulated shower. On a microscopic level, a thousand times smaller, as surface tension becomes more apparent, visitors play with a beach ball-sized drop of water. On the nanoscale, a billion times smaller and time slowed by a factor of one trillion, where electromagnetic forces can be observed, visitors play with simulated water molecules. This simulation gives visitors a chance to interact with water on different levels.

The sense of equilibrium is achieved through the gravitational diversity arising from the relationships between water molecules and the movement of shadows of the human body, as well as through the relationship between light and dark colors. The varied rhythm was achieved through the different directions of movement arising from gravity between the shadows of the human body and the water molecules. It also helped to feel the realization of movement, the repetition of water molecules according to the difference in width scales between the nanoscale and the micron. Unity was achieved through the presence of light-colored display spaces that work on eye comfort.

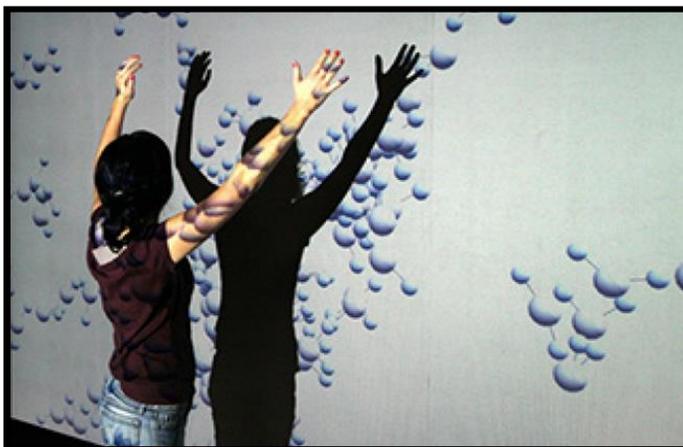


Figure 2. An interactive artwork showing the interaction of visitors with individual water molecules and the attraction of water molecules to the shadows of visitors. One of the applications of nanotechnology by artist (Scott Snibbe) [11].

Nano art is one of the important areas that the artist employed within his works, as it is a new branch of art that combines art, science and technology, and among the components of the nano landscape (the atomic and molecular landscapes that are natural structures at the atomic and molecular levels) and nano painting (which are the structures that were created by scientists and artists by manipulating the matter into atomic and

molecular tables using chemical and physical processes). These structures are painted by scientific research tools and scientific images are taken and processed using various artistic techniques, to turn them into works of art that are presented to the public. Nano art is a practical scientific art complex.

3.3. Artist Victoria Vesna

Artist Name:	Victoria Vesna
Date of Work Production:	2006
Work Place:	University of California, Los Angeles
The materials used:	sensors for the movement of the shadow of a person.

The work is based on inspiration from the shapes of buckyball balls, which are similar to football, one of the forms of nanometer crystals, subject to the science of physical chemistry. The particles of buckyball balls are used in the technological infrastructure of cell phone systems and are the main form of the structure of buckyballs, the molecule that helped launch nano science. This new science has the potential to change everything around us and push the limits of our rational minds, working at the level of atoms and molecules, using the nanometer scale.

A sense of balance is achieved through the diversity of the structural systems of the particles of the buckyball balls of different directions and the movement of manipulation through the movement of the person. Balance is also achieved through the relationship between light and dark colors. The varied rhythm was achieved through the different directions of movement arising from gravity between the shadows of the human body and the water molecules. It also helped to feel the realization of movement, the repetition of water molecules according to the difference in width scales between the nanoscale and the micron. Unity was achieved through the presence of light-colored display spaces that work on eye comfort.



Figure 3. Shows the possibility of manipulating the molecule and the response of the sensors to the movement of the shadow of the person (by the artist Victoria Vesna [12]).

3.4. Artist Shane Hope

Artist Name:	Shane Hope
Date of Work Production:	2013
Work Place:	Winkleman Gallery, Chelsea
Materials used:	3D pen.

The work draws inspiration from Hope's medium of choice, "nanofacture," a new term that describes design on a molecular level. He built his panels using a combined hardware and software toolkit, starting with a molecular modeling program called PyMol and ending with a RepRap 3D printer, RepRap. Both the line and texture elements played an aesthetic role, as it was clearly demonstrated in the achievement of some aesthetic foundations, such as balance, which is achieved through the distribution of areas that contain a variety of textures. Besides, the contrast between light and dark color tones also led to achieving a sense of equilibrium. Equilibrium is also achieved through the relationship between the straight and inclined lines at the top and the rough texture at the bottom of the artwork gave a sense of heaviness and equilibrium. The difference in their direction helped confirms this equilibrium.

The regular rhythm is achieved through the direction of the movement of the standing texture, and another type of irregular texture also appeared in some parts of the rough texture at the bottom and top of the artwork. The difference in movement arising from the various lines that make up the texture has achieved a kind of rhythm within the artwork. Unity is achieved through the color compatibility of the shades of yellow common in the two different areas that make up the texture within the artwork, which gives a sense of unity, coherence and harmony, and the compatibility of the existing parallel lines and their repetition at the top, it leads to unity.



Fig. 4. An artwork inspired by the shapes of nanometer materials, especially carbon nanotubes, subject to the science of physical chemistry, by the artist Shane Hope (Winkleman Gallery in Chelsea, 2011 [13]).

The Authors see that there are some graphic artists who were affected by the material shapes of the nanoparticle elements, which are characterized by artistic and aesthetic values and touches that raised an idea as in the form (Figure 5A, B, C) where it shows (a) carbon particles in their natural form, but the artists scientists were surprised by something else. It is that the carbon particles have turned to connect with each other, forming what looks like a tube, as shown in figure 5B, and it is called carbon nanotubes, including multi-walled ones, as shown in Figure 5C. There are nanotubes of different sizes, and they are multi-layered, meaning that they are a group of overlapping tubes. There are other forms of carbon particles, including spherical ones, and they are called "Buckyball balls". They are spherical particles of carbon, and they usually consist of 60 carbon atoms in the shape of a soccer ball.

As in Figure 6 A, B. (A) the element c60 is shown in the form of buckyball balls, (B) the element c60 is shown in the form of fullerene C60. Also, one of the different forms of carbon molecules is called fullerene, and it contains molecules with a different number of carbon atoms, including fullerene20, fullerene graph26, as shown in Figure 7(A:E) that showing the different positions of the fullerene molecule.

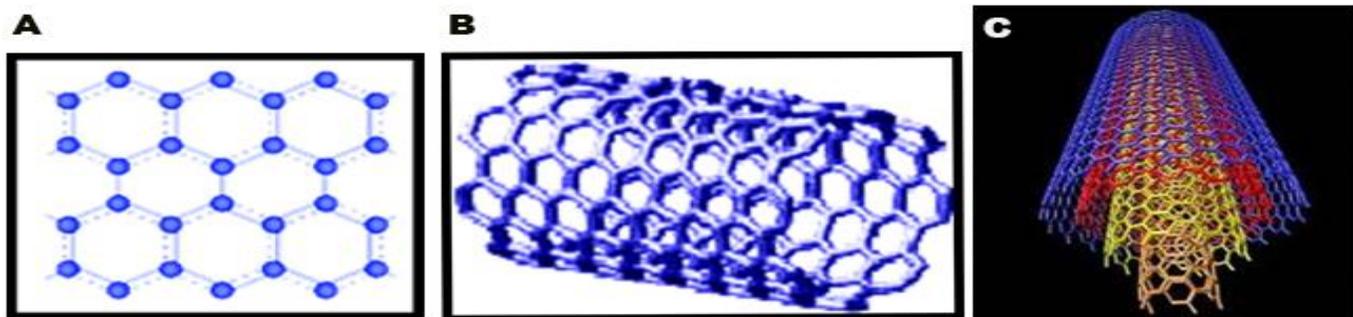


Fig. 5. shows a schematic diagram of the different positions of the carbon nanotube element . A. The figure shows the arrangement of carbon atoms. B. The figure shows carbon nanotubes. C. The figure shows multi-walled carbon nanotubes [14].

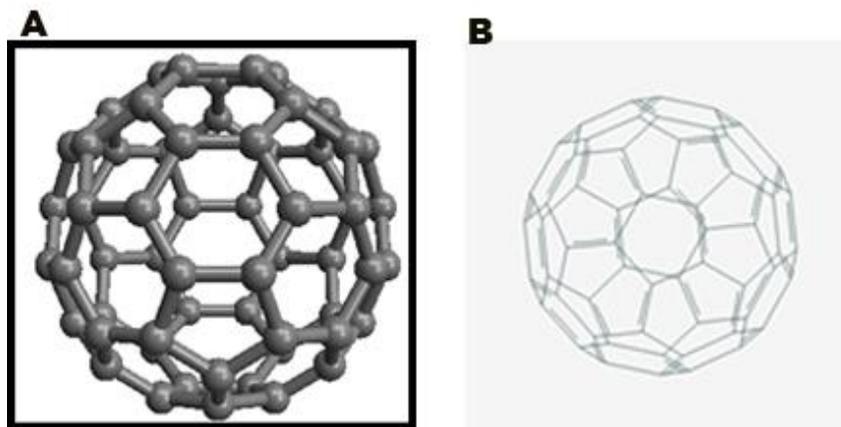


Fig. 6 A: A schematic diagram shows a C_{60} element in the form of a buckyball [15]. B: A schematic diagram shows a C_{60} element in the form of C_{60} fullerene spheres [16].

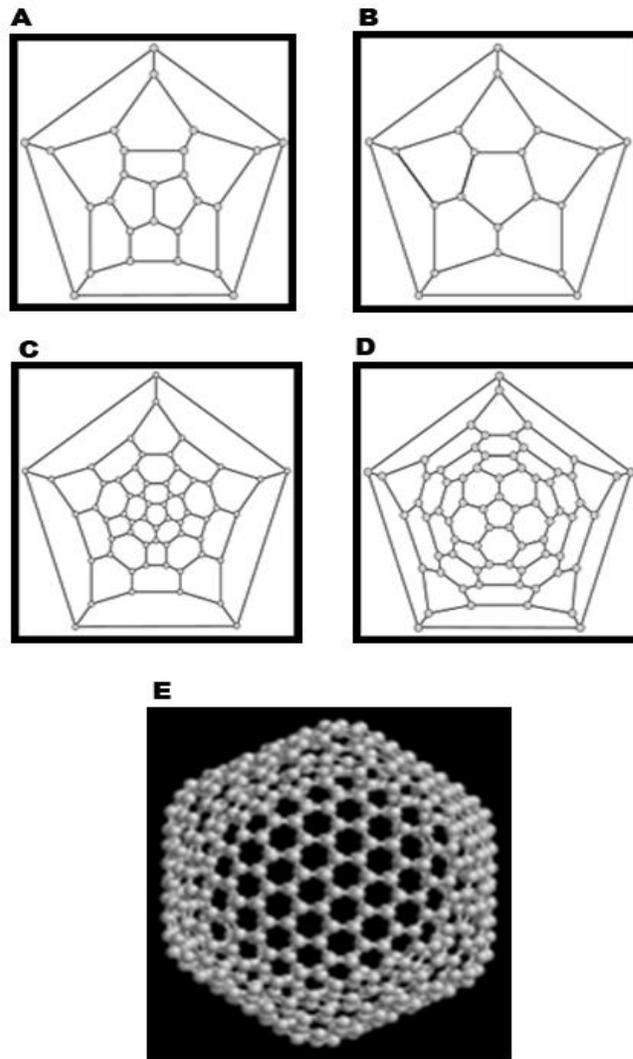


Figure 7. Shows a schematic diagram of the fullerene molecule [17]. A-fullerene graph. B-fullerene. C- fullerene graph. D-fullerene. E- Fullerene_C540.

The potential applications of carbon nanotubes are diverse, and carbon nanotubes can be used in many fields such as nanotechnology, electronics, optical applications, materials science and construction. Over the years, many discoveries have led to new applications, taking advantage of their unique electrical properties, their extraordinary strength and its efficiency in heat transfer. Structural applications of carbon nanotubes have many valuable advantages to be used as a structural material and the potential uses such as:

- Electromagnetic applications
- Chemical applications.
- Mechanical applications.
- transistors.

Technological development requires a change in the plastic cultural concepts in order for the modern man to adapt to the scientific and technological foundations of the era, as one of the functions of art in human society is that it helps to adapt to the environment in which we live and expresses the artist's point of view and his feelings. It is also a reflection and mirror of this human development. Scientific knowledge gives the artist the opportunity to innovate in a new way that copes and coexists with the new thought of this knowledge. This creator sees the world in the spirit of development and emphasizes the prevailing thought of his time, especially the era of nanotechnology.

3.5. Artist Suzan A. E. Esaa

Artist Name:	Suzan A. E. Esaa
Date of Work Production:	2021
Work Place:	Fayoum University
Materials used:	Cancun paper - paste - oil colors
Work dimensions:	40 x 60 cm

Artist Suzan (Author of the current research) was interested in using more than one of the forms of nanostructure, especially "kaolinite," under the scanning electron microscope (SEM), one of the sections of nanotechnology outputs subject to geology [18]. The Author reformulated the composition of a painting by breaking up more than one form and then choosing some wordings from the vocabulary. And transforming it into new and unusual

formative relationships, in addition to dimensions, expression and effect, using abstract geometric formulations for the word, simple lines with pale colors, with a harmony in the movement of the lines between the vertical and horizontal lines, with correlations with the wording of the other word, using formulations specific to the material in the style of the collage technique through Some of the scrap materials are made of paper and the use of paste material to create a diversity between rough and smooth textures. The tactile rhythm plays a strong aspect in the construction of this work, as the textures vary in their beauty between smoothness and roughness in the items and the ground through the use of pastes on the surface of the painting, where we notice the texture of the background being rough with its various effects in contrast to The woman's soft face makes it a focal point that drives the eye and leads its journey to the center of the picture. The rhythm is achieved through a system of achieving form construction. The work includes overlapping rhythms resulting from the repetition of curved lines and their intertwining with the longitudinal and horizontal lines in a gradual manner. The artistic work has a kind of rhythm through the use of plastic means with materials such as oil colours. The rhythm is achieved through two hot colors and a cold color in their shades. There is a kind of harmony between them. The work includes multiple linear rhythms that work to achieve rhythms within the work as a result of using oil paints in some color effects by using the broad brush as a tool in organizing the colors on the surface of the painting and mixing them with each other in a specific rhythm, as the tactile rhythm plays a strong aspect in constructing the work (Figure 8A-B).

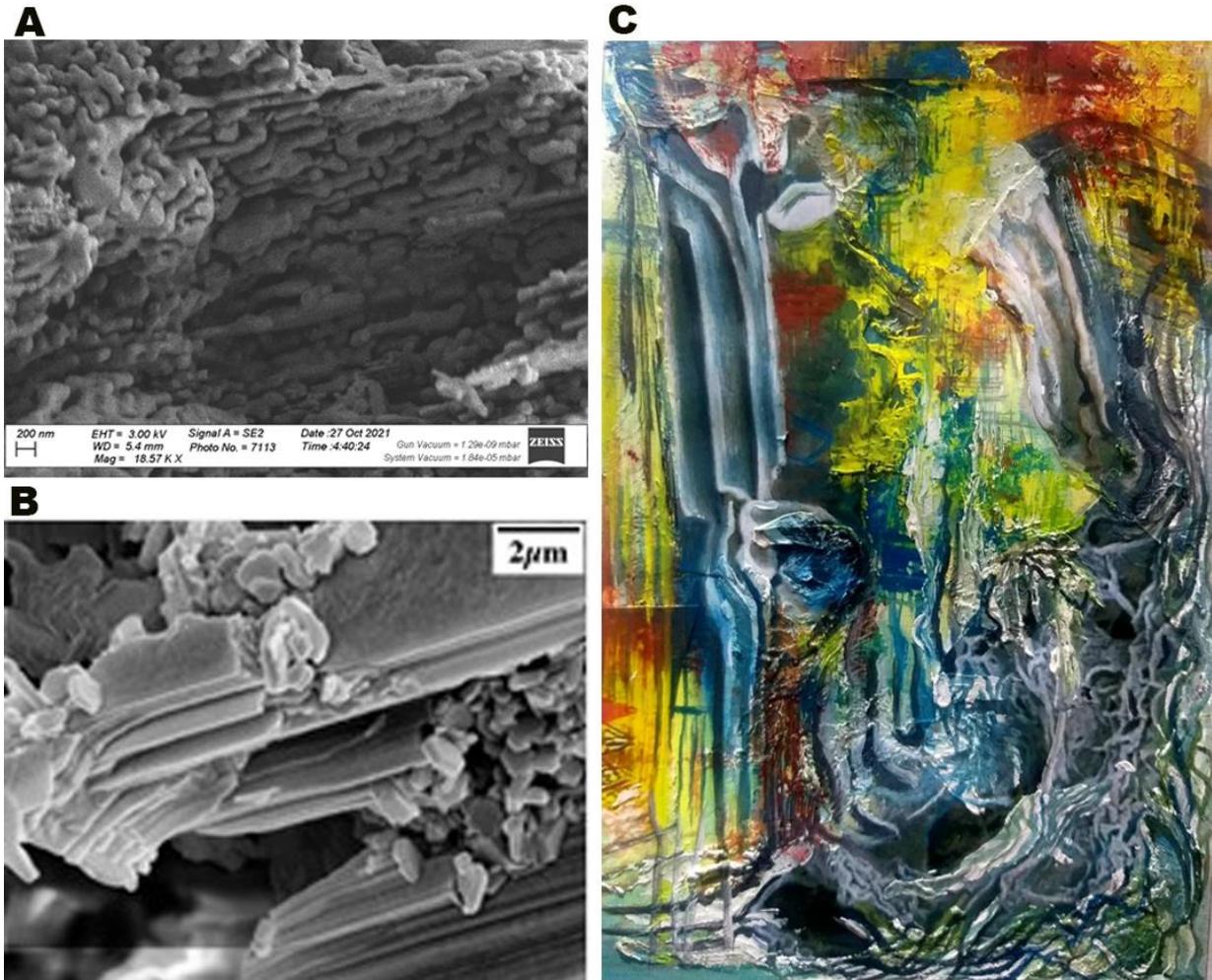


Figure 8. A; A microscopic snapshot of an examination of a sample mixed between Aswanli clay and kaolinite under a scanning electron microscope (SEM) showing one of the forms of nano-sized crystals of clay minerals, photographed by Auther Suzan A. E. Essa. B. One of the crystal shapes of clay minerals under an SEM electron microscope. C. Illustrating an innovative artwork prepared by Auther Suzan A. E. Esaa.

3.6. The author's painting artwork

Science has also provided the artist photographer with a newer creative thought based on the freedom of this artist to influence and interact with what has been confirmed by the theories and technological applications in the interpretations of nature phenomena and the contents of the invisible matter and its enormous energies. Therefore, modern art has appeared based on logic and scientific foundations, which provided different ingredients and fields for his creativity. She became interested in making a formative equivalent to it, which led to the emergence of new sources, themes, and elements for the artwork. Inspiration is from one of the forms of nanotechnology applications, which are tiny particles that include plastic elements present in them, which are lines, textures, formations, or their shapes, which are characterized by aesthetic values of "rhythm, repetition, and unity." All of this helps the artist to develop artistic and visual vision and apply an innovative artwork that takes distinct vitality and plays a role in creating the final form of the work. We find that the artist keeps trying, researching and adjusting from these conditions to the shapes of the infinitesimal particles

until he settles on an innovative vision of the artwork with its artistic value and comes out with its final appearance. From the researcher's practices (Figures 9 and 10).



Figure 9. Illustrates a "digital" artwork prepared by the author Suzan inspired by one of the forms of electron flow paths, one of the applications of nanotechnology, entitled "Water Vortexes".

3.6.1. Artistic and expressive values in the artwork for Figure 9:

The researcher was interested in using the term "representing the flow of electrons and taking the form of forked paths", where the researcher reconfigured the wording of the term to create an innovative digital work of art based on achieving the rhythm by repeating the extended and intermittent organic lines within the work of art. The work includes multiple linear rhythms, as this work relied on lines repetition and their formulation in a variety of forms, but in paths resembling swirls, which helped to highlight the value of rhythm, as the reverb appeared clearly in the work using the method of overlapping, overlaying and repetition through the different movement of the individual shape alternately, which resulted in an overlay. The artwork contains a color gradient of hot colors in addition to the presence of some influences from the color blue with the use of harmonious and compatible color combinations (Figure 9).

Unity in the artwork was achieved through the interconnection of lines and their rhythmic movements, which were collected in one direction, heading towards the ascent to the top.

3.6.2. Artistic and expressive values in the artwork for Figure 10:

The researcher was interested in using the origin of the single from one of the forms of multi-walled and single-walled carbon nanotubes, in terms of reshaping the formulation of the individual to build an innovative digital artwork based on achieving the color rhythm through a system that achieves the repetition of building the shape. The rhythm is evident through the diversity and overlapping of shapes, achieving a kind of diversity between zooming in and out, ascending in a spiral way, heading upwards, with the diversity of the size of the term, achieving a diversity in the movement of the line, which established a kind between clusters and fluidity in the middle of the artwork while maintaining the proportionality between the shapes and their balance within the work. Unity is evident in the relationship of the parts to each other and they are wrapped around each other ascending to the top achieve a kind of continuity, where a kind of balance is achieved through the presence of a sense of descending to the bottom of the painting with the presence of continuity to the top. This is done with an emphasis on the balance between these forms and unity through the relationship of the parts to each other and the relationship of the individual parts to the whole. The method of enlarging and minimizing the shapes of plastic item was used through the process of stretching, dragging and reducing some areas with the addition of some color effects and merging them with the background, which achieved a kind of fluidity in the movement of color. The background consists of a color gradient of blue and green drawn in yellow (Figure 10).

Therefore, we can summarize our results in the following sentences. the photographer has the ability to keep pace with development and technology innovations. The photographer benefits from the applications of nanotechnology with employment and results in interactive art. Nanotechnology, its tools and applications in the field of painting have entered a new phase, especially benefiting from all branches of science with all their specializations. The researcher employed textures, lines, colors and their color gradations in some of his artworks, influenced by the works of nano artists.

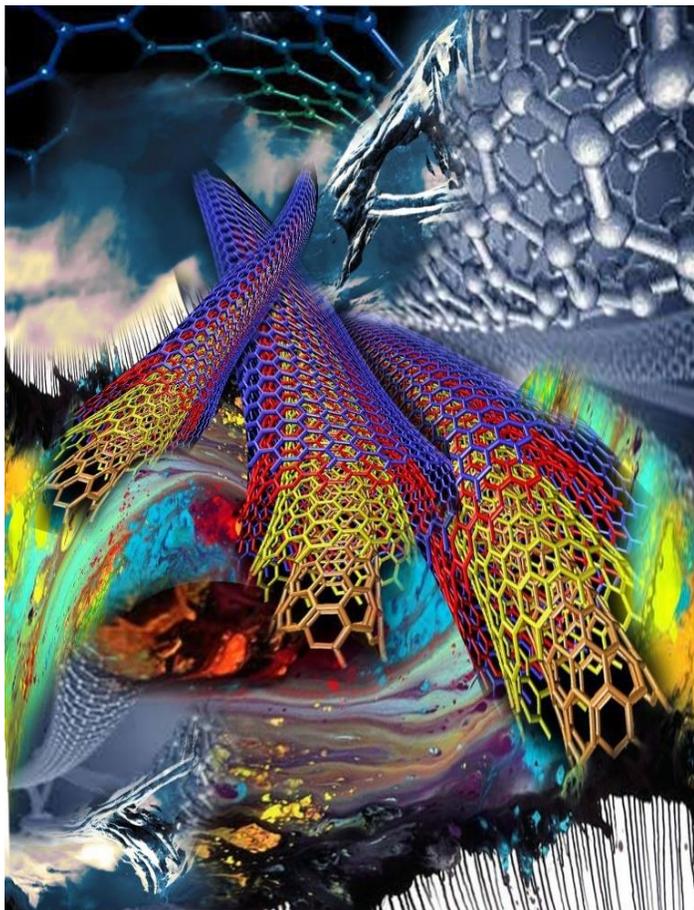


Figure 10. A "digital" artwork prepared by author Suzan inspired by one of the forms of multi-walled and single-walled carbon nanotubes, one of the applications of nanotechnology, entitled "Convergence".

4. Conclusions and Recommendations

Urging students to communicate with science laboratories, especially nanoscience, in order to learn about new outputs of nanoscience "nanotechnology" as one of the factors that develop students' thought, aesthetic and cognitive sense. Teaching plastic concepts and their artists within the curricula of art education as one of the branches of the newly developed arts that are based on scientific concepts. By teaching nanotechnology in schools and universities and training teachers on how to teach nanoscience and applications, because of the importance it represents in linking teachers to scientific development. Teaching nanotechnology is considered an urgent necessity in the 21st century, in light of the technical and scientific acceleration and the great competition between countries. Numerous conferences and seminars have indicated the need to introduce nanotechnology in the school curricula so that the student does not feel the gap between the school and the reality that he lives and sees through visual media.

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Author Contributions

Conceived and designed the paper: Suzan. Analyzed the data: Suzan and Hesham. Contributed Materials: Suzan. Wrote the paper: Hesham and Suzan. Revised the paper: Hesham and Suzan. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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