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Interdisciplinary dialogues: Combining science and art in contemporary cultural production

Abstract. The aim of the study was to examine the collaboration between artists and scientists. The research methodology involved an interdisciplinary approach, which allowed for a detailed analysis of the processes occurring at the intersection of scientific and artistic practices and the identification of new forms of cultural production. The main results emphasised the importance of interaction between scientists and artists for the creation of new forms of self-expression. It was found that science and art are closely related spheres of human activity. Historically, for example, music was long regarded as a mathematical science; thus, the division between art and science is rather blurred. The study found that interdisciplinary collaboration between scientists and artists contributes to the emergence of innovative forms of cultural expression that go beyond traditional models of both science and art. An analysis of specific projects, namely "Arts at CERN" and "Beyond Quantum Music", showed that such projects often stimulate new approaches to solving socially important problems, stimulate interest in scientific topics among a wider audience, and create a platform for creative experimentation. It was found that the key factors for the success of such projects are open dialogue between participants, mutual enrichment of knowledge, and a willingness to experiment. Therefore, interdisciplinary dialogues have significant potential for strengthening cultural capital and developing creative industries, especially in the context of the contemporary challenges of globalisation and digitalisation. The results of the study provided new perspectives for understanding contemporary cultural processes, emphasising the importance of dialogue between different fields of knowledge for the development of innovation in cultural production

Keywords: project; collaboration; artist; self-expression; creativity; culture; space

INTRODUCTION

Interdisciplinarity is one of the key elements of cultural production in the 21st century, marked by the integration of various fields of science and art. The interaction between science and creativity contributes to the creation of new forms of cultural expression and the discovery of new horizons for innovative ways of self-realisation. This phenomenon is particularly noticeable in the context of globalisation and digitalisation, when traditional boundaries between disciplines are blurred and new approaches become necessary for the correct use of modern technologies. The study by L. Cheng *et al.* (2022) examined how such integration of elements of science, technology, engineering, art, and mathematics can promote the development of innovative thinking in students. The authors emphasised the importance of practical learning, which allows students to actively apply their knowledge in practice and develop interdisciplinary skills. O.I. Higuera Martínez *et al.* (2021) investigated trends in promoting creativity in science and engineering. The researchers focused on how creativity can be integrated into curricula and research

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practices to improve the innovative abilities of students and professionals.

Scientific and creative collaboration inspires discoveries in science, which is why many researchers have emphasised the importance of art in interdisciplinary projects and the creative process when working on important scientific issues. Author F. Lysen (2023) analysed creative-scientific collaboration within the Maastricht Brain Stimulation and Cognition Laboratory, exploring how such interdisciplinary projects can influence the scientific and artistic environment. The author emphasised the importance of supporting and developing creative-scientific collaborations to stimulate innovation and expand the boundaries of scientific and artistic research. Researcher R. Crowell (2023) examined the challenges and opportunities of collaboration in interdisciplinary projects in the fields of mathematics and art. The article emphasised the importance of diversity of experience and skills within a team to achieve innovative results. Scientists K.-Y. Ku and L.-K. Yu (2022) discussed how art, science and ecology interact and enrich each other, creating new approaches to understanding nature and society.

Creativity, compared to science, is an important aspect of human activity. The influence of creativity on leading scientific discoveries and, conversely, the influence of science on important artistic achievements can be traced. Therefore, scientists are considering the creation of a single space where art and science will be equally important and equally used as means for creating new forms of self-expression and cognition of the surrounding world. D. Doyle *et al.* (2023) explored the concept of a third space in the context of creative-scientific projects, focusing in particular on successful methodologies of STARTS (Science, Technology, and the Arts) projects. The authors analysed how the integration of art and science can create new spaces for innovation and the development of creativity. The researchers emphasised the importance of creating a third space where art and science can interact and develop together.

Art, particularly visual art, is often used to disseminate important scientific data and concepts. Specifically, S. Paoletti and P. Paolucci (2019) investigated the use of art as a means of presenting scientific concepts within the framework of an educational project for a high school. The main findings showed that art can be an effective tool for increasing student interest in scientific disciplines, promoting a better understanding of complex ideas through visual and creative approaches. M.K. Halpern and H.S. Rogers (2021) explored the complexities and challenges that arise in collaborations between science and art. The authors focused on various aspects of interdisciplinary projects, in particular how such collaborations can create new forms of knowledge and influence public understanding of science.

G. Inchingolo *et al.* (2023) studied the transformation of space data into visual art, emphasising the importance of interdisciplinary collaboration. The authors stressed that such integration can make astronomical data more accessible and understandable to a wider audience. Thus, the use of art to popularise scientific concepts contributes to raising public awareness.

The aspects of interaction between artists and scientists and the process of their joint activity aimed at developing new forms of self-expression are understudied. The aim of this study was to examine in detail the interaction between representatives of science and art and to analyse the results of their collaboration. The research methodology involved several complementary methods that made it possible to explore both the scientific and artistic aspects of interdisciplinary collaboration between artists and scientists. Content analysis was used to identify the main trends and ideas that are discussed and actively implemented in the academic scientific and artistic spheres. The study of the interaction between science and art in different cultural contexts was based on a comparative analysis of several interdisciplinary projects. Musicological analysis was used to study musical compositions created through collaboration between scientists and musicians. The selection of projects for analysis was based on the innovativeness of the concept and the relevance of the idea, i.e. whether the project is currently active, since a huge number of projects that are important from both a scientific and artistic point of view have ceased their activities due to a lack of funding.

THE HISTORICAL CONTEXT OF THE DEVELOPMENT OF INTERDISCIPLINARY PROJECTS

The interaction between art and science is an important process in the context of human development as *Homo sapiens*. It is arguably the ability to express oneself through creativity that distinguishes humans from other living creatures (Morin, 2022). Science, in turn, contributes to the creation of completely unexpected forms of art and the realisation of creative concepts. The development of interdisciplinary projects has deep roots leading back to antiquity, when science and art were inseparable components of human cognition. In the Middle Ages, science and art often intertwined, particularly in the context of religious art, where artists combined knowledge of theology, astronomy, and physics to create their works. However, with the onset of the Renaissance, science and art began to separate, leading to the formation of distinct disciplines. Nevertheless, it was during this period that active collaboration between artists and scientists took place. A striking example is Leonardo da Vinci, who merged art, anatomy, mathematics, and more. The genius of Leonardo da Vinci, for example, in his artistic works, lay in the fact that the scientist meticulously studied human anatomy, notably conducting 30 dissections, which led to the most realistic depiction of the human being (Martins e Silva, 2008). For the Renaissance, such a feature in paintings was innovative, and Leonardo da Vinci's work gained immense popularity.

The following centuries introduced new challenges related to industrialisation and urbanisation. Numerous scientific discoveries in various fields led to the emergence of new technologies that changed the life of society. Interdisciplinary projects began to be viewed as essential for progress and new discoveries, as the limitations of individual disciplines in explaining complex phenomena were recognised. The 20th century became a key stage for the development of interdisciplinarity due to the growth of social and environmental issues that demanded new approaches for their resolution. Specifically, following World War II, there was active cooperation between various scientific disciplines, which manifested in the creation of new fields of knowledge, such as neurobiology and biosecurity. Research by S. Han *et al.* (2023) established that the

effective development of biosecurity requires the integration of knowledge from biology, medicine, computer science, law, and social sciences. Consequently, disciplines that require expertise not just in one specific field, but in several scientific spheres, became widespread. Universities began to implement interdisciplinary programmes, which fostered the formation of new academic communities engaged in joint research, yielding conclusions that could not be reached using only a single science.

The development of technology, particularly information technology, has fundamentally changed the nature of scientific research. Computerisation and process automation have significantly accelerated data collection and processing, tasks which previously required substantial time and resources. Moreover, scientists and the public now have access to a large volume of contemporary research, which promotes the more active realisation of certain scientific ideas. Access to vast amounts of data and its shared use by researchers globally has led to the growth of global research networks, where data from different regions can be integrated and analysed in real-time. Alongside technological progress, new methods and approaches to research have become widespread, allowing scientists a deeper understanding of complex systems. One such method is machine learning, which enables the analysis of enormous datasets to reveal patterns that are not always obvious to humans. The use of machine learning algorithms is increasingly popular across various fields of science, from physics to economics.

In bioinformatics, machine learning is used to predict the functions of proteins based on their structure, and to identify potential drug candidates. In economics, such methods allow for the modelling of market behaviour and the forecasting of economic crises. Consequently, machine learning is effective and useful across multiple domains. With the development of technology and new research methods, scientific projects are becoming increasingly interdisciplinary. To address certain scientific questions and confirm hypotheses, it is necessary to combine knowledge from diverse spheres of art and science. Interdisciplinarity allows scientists to view problems from different angles and find solutions that would be unavailable within the confines of a single discipline. Despite all the advantages of technologies and new research methods, collaboration between representatives of different disciplines is not without its problems, especially when considering joint projects between scientists and artists, who often have varying worldviews and perspectives. Even setting aside the personal qualities of creative individuals and scientists, interdisciplinarity still presents certain limitations. It requires not only technical resources but also a paradigm shift within the scientific community. For instance, scientists and artists specialising in a particular field may find it difficult to collaborate with representatives of other disciplines due to differences in terminology, methodology, and problem-solving approaches.

Another challenge is the need for new skills. To work on joint projects, scientists must possess knowledge not only in their own field but also at least a basic understanding of allied disciplines. These challenges create a demand for new forms of education in universities, which would incorporate interdisciplinary methods of professional training and allow future researchers to work effectively in interdisciplinary teams. However, a certain limitation arises here as well: the world is currently overloaded with information. On one hand, this is beneficial, as any scientist, or merely an interested individual, has access to a large volume of research, data, facts, and so on. Yet, the vast amount of information simultaneously brings certain complications, as it is impossible to process all the information from a given scientific field, considering the average human lifespan. Considering the growing trend towards interdisciplinary faculties and the training of interdisciplinary specialists, it becomes virtually impossible to possess a perfect command of several scientific domains simultaneously. Despite these challenges, scientists and artists working within the sphere of interdisciplinary research serve as mediators and generators of ideas, helping to approach problems from radically new perspectives. Technologies continue to evolve, and new research methods open up ever greater opportunities for collaboration across diverse scientific disciplines.

INTERDISCIPLINARY PROJECTS: SCIENCE AND ART

The importance of interdisciplinary projects that combine science and art is growing significantly in the 21st century. This form of collaboration opens up new horizons for creativity and innovation, as it combines different approaches, methods and concepts. It allows scientists and artists to work together, exchange ideas and create new formats that cannot be achieved within a single discipline. Art is a complex and multifaceted concept that encompasses various forms of expression of human thoughts, feelings and experiences. Art is an important element of cultural heritage and national identity, as well as one of the most significant tools of communication in society. The value of art lies in the fact that, through various forms of conveying images and emotions, it offers an alternative experience that can be relived. Thus, through art, people have the opportunity to feel emotions and capture non-physical transmissions of feelings simply by looking at a painting or listening to music.

The concept of art has changed throughout history. In ancient cultures, art often had a religious or ritual character. During the reign of theocentrism, it was believed that art was created for religious needs, for example, music was written mainly for worship, painting was concentrated on church walls, etc. The concept of art as an independent category began to spread during the Renaissance, when artists began to gain recognition as individual creative personalities. Aesthetics, as a philosophical discipline, studies the nature of art, its essence and meaning. According to aesthetic theories, art should evoke emotions, stimulate thoughts and encourage reflection. One of the most famous philosophers, I. Kant, defined art as a product of "subjective perception," emphasising that the value of art can change depending on individual perception. This is very important because each person can perceive a particular work of art in their own way, based on their life experience and their own emotions.

Science is a system of knowledge that arises from the study of phenomena in the surrounding world using certain methods. Science is not a static structure; it is a dynamic system that constantly adapts to new challenges

and changes in society (Hjørland, 2022). The main goal of science is to understand the surrounding world and the rules that govern nature and society. Science uses a systematic approach known as the scientific method, which includes formulating hypotheses, experimenting, observing, and analysing the data obtained. The history of science spans millennia and is closely linked to the development of human civilisation. The origins of science and the first known experiments can be traced back to the civilisations of Ancient Egypt and Mesopotamia, where the elements of astronomy, mathematics and medicine were born. Science in antiquity was not only a practical activity but also a profound philosophical quest that laid the foundations for the further development of science in Europe (Lawson, 2021). Modern scientific research is increasingly becoming interdisciplinary, bringing together knowledge and professionals from different fields, which allows not only to expand the scope of projects, but also to solve complex problems such as climate change, epidemics, globalisation and other challenges facing humanity (Stadnik, 2024).

The combination of science and art is appropriate because these two fields share a common goal: to promote the search for truth and knowledge about the environment and ourselves. Science, through a methodical approach and experimental verification, seeks to find objective truth about the physical world. It is based on research that allows to understand the laws of nature, the mechanisms of functioning of systems, and the properties of material objects. Art, on the other hand, uses subjective and emotional approaches to express human experiences and perceptions of the world. It offers new perspectives and visualisations that help to reflect the deeper aspects of human existence. In addition, the combination of science and art is an important aspect of contemporary cultural production, presenting the synergistic potential between two seemingly different fields of activity. Contemporary society faces numerous challenges that require an interdisciplinary approach, where science and art can complement each other, creating new forms of cultural expression. This combination promotes not only innovation but also new approaches to solving complex issues that arise in various fields.

The combination of science and art also has a significant impact on the psychological and cultural development of society. Art based on scientific ideas can help expand the boundaries of human perception by stimulating creativity and critical thinking. For example, interactive installations that combine science and art can engage viewers in active exploration and interaction, providing new experiences and a deeper understanding of scientific, often abstract concepts. From a cultural perspective, the synthesis of science and the arts promotes interdisciplinary dialogue and the development of cultural innovation. This process allows artists and scientists to work together, exchange ideas, and develop new forms of expression and knowledge. In turn, such collaboration leads to the creation of new cultural forms and practices that contribute to progress in both fields. The combination of science and art is necessary for the expansion of human understanding and experience. Through the integration of scientific and artistic approaches, a comprehensive understanding of the world can be achieved, which in turn contributes to the development of both science and art.

Innovations arising at the intersection of science and art play an important role in the development of cultural production. This process reflects the desire to experiment and search for new forms of expression that meet the challenges of today. The combination of science, technology and art opens up new opportunities for the creation of cultural products that go beyond traditional genres. In contemporary cultural production, there is a tendency to expand the boundaries of traditional forms, manifested in the emergence of new genres and styles that combine elements from different disciplines. For example, digital art is a striking example of how technology allows the creation of new forms of expression that go beyond traditional painting or sculpture. New forms of expression open up new horizons for artists and scientists, allowing to experiment with new materials, techniques and ideas. Such projects often require a high level of technical competence, which emphasises the importance of collaboration between artists and scientists. An interdisciplinary approach allows scientists and artists to collaborate to create unique cultural products that respond to contemporary challenges. Science and art are two equal and closely related fields, so collaboration between artists and scientists is successful despite numerous difficulties and challenges.

One of the key aspects of contemporary cultural production is inclusiveness. It allows different social groups that previously did not have such an opportunity to be included in the cultural dialogue. This process is particularly important in the context of globalisation, when cultural products become accessible to a wide audience, regardless of their social status, nationality or place of residence. Accordingly, interdisciplinary projects help to attract new audiences and new participants who may not have been involved in traditional forms of cultural production before. This happens because interdisciplinary projects allow different forms of expression to be combined, making them more accessible and interesting to a wider audience.

"ARTS AT CERN" PROJECT (2012 – PRESENT)

The artist residency at the Large Hadron Collider was launched in 2012 by the European Organisation for Nuclear Research (CERN). The "Arts at CERN" project brings together artists and scientists, providing them with a platform for collaboration at the intersection of science, art and technology. The programme aims to create new cultural products that integrate scientific knowledge and artistic expression, promoting innovation and new approaches to world perception in general. "Arts at CERN" was created to promote interdisciplinary collaboration between artists and scientists working at CERN. The programme's goal is to explore new ways of expressing complex scientific concepts through art in order to popularise science among a wider audience. Scientific experiments and research at CERN, such as particle physics and space exploration, are a source of inspiration for artists, who in turn broaden the understanding of these concepts through their artworks. Since the establishment of the artist residency at CERN, more than 250 artists from around the world have taken advantage of this opportunity. The artists had the opportunity to freely communicate with about 1,000 scientists and observe their activities. Science inspires art, and art inspires new discoveries - this is the message conveyed by the "Arts at CERN" project.

The "Arts at CERN" project programme was based on creating an inclusive space for artists and scientists, but this interdisciplinary collaboration has gained widespread publicity and grown significantly. The "Arts at CERN" project includes numerous art exhibitions at leading global art events, as well as a large number of online exhibitions. The main goal of the "Arts at CERN" programme was to create an environment where scientists and artists can communicate, exchange ideas and work on joint projects. Scientists working in fields such as physics or cosmology provide artists with access to the latest scientific achievements and concepts. Scientists share complex concepts and abstract ideas related to physics or space exploration. Such knowledge inspires artists to create new creative compositions, often using unconventional approaches. For example, physical experiments studying elementary particles or the structure of the universe can be transformed into art installations that show the complexity and beauty of scientific processes.

On the other hand, artists involved in the programme bring new approaches to understanding and explaining phenomena to the world of science. Artistic interpretations of scientific concepts can help scientists look at their research in a different way, revealing new aspects or approaches to their work. Artists and scientists, as representatives of different fields, often think and perceive the world in slightly different ways. This difference inspires artists to take unconventional approaches to creativity in the context of scientific concepts, and inspires scientists to undertake new and extraordinary research that would not have been obvious to them without communication with artists. This exchange of ideas stimulates innovation in both science and art, creating conditions for the emergence of new cultural products. Participants in the "Arts at CERN" programme go beyond their specialisations, trying to find common ground that can form the basis for joint projects. This approach allows to create works that combine elements of science, art and technology, creating new forms of cultural expression (Fig. 1).

Figure 1. Swiss artists Andrea Anner and Thibault Brevet (AATB) with scientist Laura Lambert at the MEDICIS facility during their residency with "Arts at CERN"
Source: Arts at Cern (n.d.)

The interaction between scientists and artists within the framework of "Arts at CERN" has a significant impact on the development of contemporary culture and society by promoting new forms of art that combine science and technology and creating unique cultural products that reflect the current state of knowledge and technology. In addition, such cooperation contributes to the dissemination of scientific knowledge and technological achievements among a wide audience, making them more accessible and understandable.

Ch. Warakaulle, Director of International Relations at CERN, noted that art and science are important pillars of society, and that artists and scientists share common core values: curiosity and a passion for understanding the world at a deeper level. At CERN, it has always been believed that these two fields can develop together through creative interaction, and this is the basis of art at CERN (CERN, n.d.). The "Arts at CERN" project is a source of inspiration for scientists and artists who seek to create new forms of cultural expression and contribute to the development of modern society. One of the latest "Arts at CERN" projects was created by J. von Bismarck and B. Maus in 2023, entitled "Round About Four Dimensions" (Fig. 2).

Figure 2. "Round About Four Dimensions"
Source: Arts at CERN... (2024)

Understanding four-dimensional space is a challenge for the average person. For this reason, J. von Bismarck and B. Maus created the sculpture "Round About Four Dimensions" to help people understand the essence of four-dimensional space. In mathematical and physical concepts, such a sculpture is called a "hypercube". The sculpture shows a rotational movement in three-dimensional space, which is a projection of four-dimensional space. Four-dimensional concepts are important in understanding physics (Rahaman, 2022). However, the phenomenon of four-dimensional space is currently beyond human spatial perception, so the work of J. von Bismarck and B. Maus attempts to show a trend that will eventually lead to a correct understanding of the characteristics of four-dimensional space.

The main idea behind the sculpture "Round About Four Dimensions" is to expand the perception and understanding of space and time through art. The project shows that even abstract mathematical and physical concepts can be visualised, allowing viewers not only to broaden their understanding of scientific theories, but also to enjoy the beauty and complexity of four-dimensional forms. The art presented in "Round About Four Dimensions" acts as a

bridge between science and culture, prompting reflection on the nature of reality and the concept of the structure of the universe as a whole. The work of J. von Bismarck and B. Maus shows how complex concepts can be transformed into exciting visual experiences that raise awareness and interest in science and art. Another interesting project within the framework of "Arts at CERN" is the work of artist and composer Y. Kim entitled "Chroma VII" (Fig. 3).

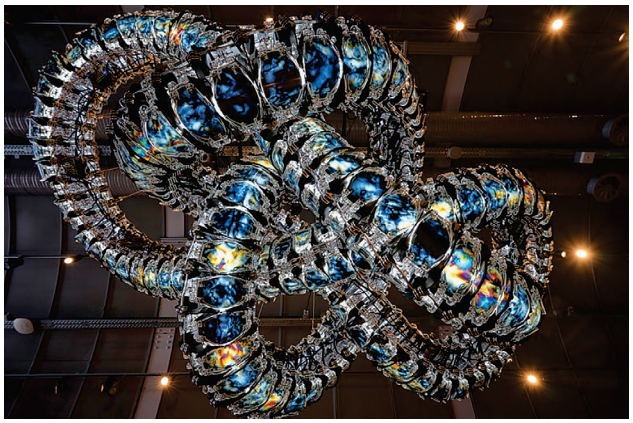

Figure 3. "Chroma VII"
Source: Arts at CERN… (2024)

"Chroma VII" is a sculpture that represents a unique synthesis of science and art, using CERN's scientific achievements as the basis for its concept. The sculpture reflects the connections between space, energy and matter through its structure. "Chroma VII" consists of 324 separate parts made of transparent polymers. The composition of the parts allows to change their colour and pattern (Nemoto *et al.*, 2019) as a result of any kinetic movement, friction and pressure changes. The idea behind the sculpture is to reflect the variability of the universe and focus attention on its complexity and unexplored nature. The main idea of the "Chroma VII" sculpture is to attempt to visualise the complexity and grandeur of science through art. It is designed to open up new perspectives for viewers on scientific concepts that are usually complex and abstract. "Chroma VII" invites viewers to immerse themselves in reflections on the nature of matter and the forces that shape universe. This work is not only an expression of a creative approach to science, but also an inspiration for further exploration of the limits of what is possible in art and science.

Another work of art, "Broken Spectre", was created as part of the "Arts at CERN" project by R. Mosse with the support of J. Shainman and C. Gebauer. In the video, R. Mosse raises an important issue concerning the ecological disaster near the Trans-Amazonian Highway. The uniqueness of the work lies in the fact that environmental problems are shown through the prism of different views on the situation, namely through cultural, historical, socio-political and anthropological perceptions of the situation. The video shows the problem in its various manifestations, which helps to broaden awareness of the possible consequences of environmental problems. R. Mosse shows the process of deforestation and its negative impact on people's lives. Through rapid changes in scale in the video, the work highlights the negative aspects of human intervention, namely: deforestation in the Amazon, mass burning, colonisation of virgin lands, etc. (Fig. 4).

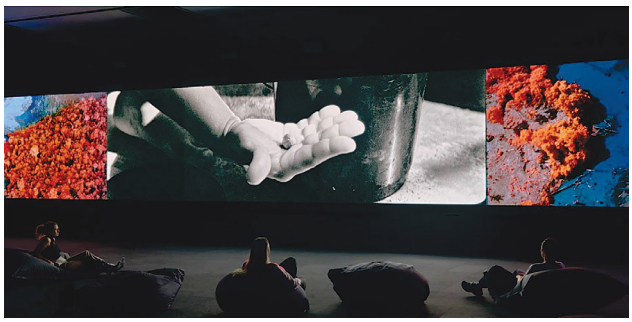

Figure 4. R. Mosse, "Broken Spectre"
Source: Arts at CERN… (2024)

To understand the extent of the environmental problem of deforestation in the Amazon, scientists have long used remote sensing images. R. Mosse's video work "Broken Spectre" goes even deeper, using three separate filming techniques. A special camera was created to capture images of the burning Amazon rainforest, with the support of a company specialising in spectroscopy. Ultraviolet light was used to capture certain scenes in close-up, making it possible to show the forest's biomass. In order to present man's crimes against nature, scenes were shot using infrared film.

R. Mosse worked on the "Broken Spectre" project for a long time, conducting research in the field of ecology and the latest visualisation technologies. The title of the project, "Broken Spectre", refers to the atmospheric phenomenon of the Brocken spectre, which reflects the artist's conceptual approach to exploring the relationship between the visible and the invisible, reality and its reflection, actions and consequences. In the case of R. Mosse's project, the "spectre" represents the ecological crisis, which remains unnoticed or ignored by the general public, despite its catastrophic consequences. For video work, R. Mosse used an approach that allows to capture images beyond the visible spectrum, thus enabling the artist to show the processes of forest destruction in a new, more dramatic context. R. Mosse used these images to highlight the scale of environmental destruction and show it in conditions that are not normally visible to the human eye.

The thermal images created as part of the project are a powerful visual tool that conveys the seriousness of the environmental crisis in the Amazon. The images, saturated with shades of red, orange and yellow, evoke associations with fire, heat and destruction, thus drawing attention to the anthropogenic impact on nature. The "Broken Spectre" project is an important part of the discourse on global environmental issues, particularly deforestation and biodiversity loss. The Trans-Amazonian Highway, near which the project is unfolding, is one of Brazil's main transport arteries, serving both as a factor in the region's economic development and a serious threat to the environment. Large-scale deforestation for agriculture, mineral extraction and other anthropogenic purposes leads to irreversible changes in the ecosystem, which in turn affects the planet's climate balance. The "Arts at CERN" project, which involves collaboration between scientists at the Large

Hadron Collider and invited artists, has made and continues to make a significant contribution to the popularisation of science and the rethinking of certain approaches to the study of the universe and particle physics. Thanks to the communication between representatives of different, yet related fields – science and art – a large number of valuable artistic ideas have been realised, which in turn bring science to the masses and help even more people get involved in research.

"BEYOND QUANTUM MUSIC" PROJECT (2015 TO PRESENT)

The "Beyond Quantum Music" project combines two diverse fields: music and quantum physics. The project resulted in a tour by the team with a large-scale show consisting of music based on scientific concepts of quantum physics, visual imagery, lectures by leading 21st-century physicists, and numerous roundtable discussions. The tour as part of the "Quantum Music" project took place in 2016, and in 2019-2022 an updated show called "Beyond Quantum Music" was developed. The foundations of quantum music lie in the principles of quantum mechanics, which describes the behaviour of particles at the subatomic level. One of the key concepts is superposition, which allows particles to exist in several states at the same time. An approach to musical composition based on quantum theory allows for the simultaneous existence of several harmonic states. In the musical sphere, this phenomenon can be interpreted as the ability to create sounds that exist in several musical states at the same time. Thus, quantum physics provides composers with a tool for constructing more complex and varied musical textures. Quantum data and calculations have been used by musicians to create and analyse music, opening up new horizons in musical composition and sound design (Miranda, 2022).

Quantum music finds its embodiment in various experiments with electronic music, where composers use quantum algorithms to generate sounds. For example, the creation of complex soundscapes that change in real time based on the principles of quantum superposition. This process opens up the possibility of creating music that never repeats itself, as it is constantly changing. In general, the integration of concepts, data, calculations, etc. from quantum physics into music, particularly in the field of composition, significantly changes the concepts of harmony and music theory in its classical sense. Quantum data can be applied to musical composition and analysis, offering new opportunities for creativity and process optimisation (Chuharski, 2022).

Quantum music, as a new direction, influences contemporary culture, stimulating the development of new forms of musical expression and interaction with the audience. With the advent of quantum technologies in music production, there is a need to rethink traditional concepts of music theory and composition, which may lead to the emergence of new genres and styles of music that will be different from anything that has existed before. Quantum music can become an important tool in educational programmes aimed at popularising quantum physics. Thanks to music, complex scientific concepts can be explained in a more accessible and understandable way to a wide audience, which will contribute to the development of scientific interest among young people. This is the idea behind the "Quantum Music" project.

Quantum music offers an innovative approach to teaching, allowing teachers to explain complex quantum concepts through musical analogies, making abstract concepts more accessible and understandable to a wider audience. One of the biggest challenges in teaching quantum physics is that many concepts in this science have no direct analogues in everyday human experience. Therefore, for the average person, understanding and comprehending certain concepts is a difficult task. The principles of quantum mechanics, such as superposition or quantum entanglement, are difficult to comprehend without special training. However, through quantum music, these concepts can be presented in a form that appeals to auditory sensations and emotions, promoting deeper understanding and memorisation. Quantum music can reproduce quantum phenomena such as oscillation between several states (analogous to superposition) or the simultaneous influence of two parts of a musical piece on each other (analogous to quantum entanglement). Such examples allow students not only to read or hear about these phenomena, but also to experience them on an intuitive level through musical interpretations.

Music, as a universal language, can help lower the barrier to entry into complex scientific topics, including quantum physics. In educational programmes, quantum music can be used as a teaching tool in both traditional lectures and interactive workshops. For example, during a lesson, students can be asked to listen to musical works based on quantum principles and then discuss how these works reflect specific physical phenomena. In addition, the integration of quantum music into educational programmes may include the creation of musical installations where visitors can interact with musical elements that correspond to quantum processes. This approach makes learning more interactive, which is especially important for engaging young people in science.

The concert "Beyond Quantum Music" was based on the idea of transforming traditional musical structures using quantum principles. Using the achievements of quantum mechanics, composers sought to create soundscapes that represent complex and dynamic interactions between different musical elements. The main concept was to engage listeners in an interactive musical experience where sound and musical structure constantly changed according to the principles of quantum superposition and entanglement. The approach chosen for this project was based on the use of the latest technologies in combination with traditional instruments. Composers and performers used quantum computers and algorithms to create and process sounds, which made it possible to achieve greater variability and unpredictability in musical compositions (Fig. 5).

The technical implementation of the "Beyond Quantum Music" project involved the use of both hardware and software. The main tool for creating quantum music was quantum computers capable of performing complex calculations and generating sound forms based on quantum algorithms. The use of quantum computers made it possible to create unique musical textures and soundscapes that would have been impossible to achieve using traditional methods. Another important aspect was the use of specially designed musical instruments that allowed interaction with quantum algorithms. These instruments were equipped

with sensors and interfaces that allowed musicians to control quantum processes by playing the instrument. This process not only expanded the musicians' capabilities in creating sound, but also allowed to actively participate in the creation of quantum compositions.

Figure 5. European capital of culture
Source: Beyond quantum music (2022)

The "Beyond Quantum Music" concert had a significant impact on listeners, offering them a unique audiovisual experience. Concertgoers noted that the music created using quantum principles had an unusual, almost meditative sound that differed from traditional musical performances. The meditative nature of quantum music is explained by the smoothness and simultaneous sounding of several harmonic structures, thanks to which listeners are immersed in a state of calm and relaxation. Quantum music uses concepts from quantum physics, such as superposition and entanglement, to create sound structures that are not common in traditional music. This phenomenon involves parallel melodies, dynamically changing harmonies, and complex rhythmic structures that overlap each other. Listeners experience a sense of uncertainty when listening to quantum music, as the sound elements are constantly changing and interacting, which affects the perception of music as a dynamic and unstable environment.

Quantum music often uses dissonance and non-standard electronic timbres to create an emotionally rich experience, which is generally the main purpose of writing music. Therefore, the value of music lies in the fact that it offers an alternative emotional experience. During a quantum music concert, listeners can experience a wide range of emotions, from anxiety and tension to excitement and calm. Complex sound textures and the unpredictability of compositions can make listeners feel like they are entering a new sound world, prompting deeper emotional engagement. Music based on quantum principles can create increased cognitive load due to its complexity and unpredictability. Listeners need to constantly adapt to changing sound and rhythmic patterns, which can activate various cognitive processes, including attention, memory, and spatial thinking. This property of quantum music can contribute to the development of auditory perception and analysis, as well as stimulate intellectual interest.

Quantum music, as the main part of the "Beyond Quantum Music" project, presents opportunities for innovation in music, expanding listeners' perceptions of what music is. The application of quantum physics concepts has prompted listeners to rethink musical forms and genres, as well as encouraging experimentation in their own musical practice. The integration of quantum concepts into music opens up new aesthetic possibilities and cultural perspectives. Listeners have the opportunity to experience a new type of musical experience that combines elements of science and art, contributing to cultural development and innovation in the field of music (Fig. 6).

Figure 6. Concert "Beyond Quantum Music"
Source: Beyond quantum music (2022)

Quantum music, as an interdisciplinary field, combines the principles of quantum mechanics and musical composition. Using fundamental concepts of quantum physics such as superposition, entanglement, and the uncertainty principle, this field challenges traditional notions of sound and harmony, introducing new ways of understanding and perceiving music. The potential of quantum physics as a tool for expanding possibilities in music theory is extremely important (Arya *et al.*, 2022). The integration of quantum theory into music not only expands the boundaries of musical creativity, but also opens up new opportunities for technological innovation in sound production and composition. At the same time, the use of quantum principles in music may remain difficult for a wide audience to understand, especially those with no experience in quantum physics. Despite this, the "Beyond Quantum Music" project has become an important milestone in the development of quantum music as a new form of musical art that combines science and art.

CONCLUSIONS

Interdisciplinary projects represent collaboration between different fields of knowledge, which is critical for the progress of society. The study found that interdisciplinarity has always been a driving force behind the development of science and art, opening up new horizons for innovation and creativity. The evolution of science in the 21st century is the result of the development of technologies and new research methods that have made more complex and integrated projects possible. The study found that interdisciplinarity is accompanied by new challenges, such as the

need to integrate knowledge and skills from different disciplines, but at the same time opens up new perspectives for scientific research.

As the study showed, interdisciplinary projects combining science and art are extremely important because they open up new opportunities for creativity and innovation. Such projects allow scientists and artists to work together, exchange ideas and obtain new data that cannot be achieved within a single discipline. The "Arts at CERN" project promotes the importance of the scientific basis of artistic works and initiates collaboration between creative people and various scientific and research spaces. The study emphasised that within the "Arts at CERN" project, communication between scientists and artists takes on a unique character that goes beyond traditional interdisciplinary interactions. This initiative is an example of how creative and scientific approaches can be combined to create new forms of cultural expression and innovative approaches to knowledge. The collaboration between scientists and artists at CERN demonstrates how different methods and perspectives can enrich each other, contributing to the development of new ideas and approaches.

The "Beyond Quantum Music" project highlighted the enormous potential of quantum concepts in creating new forms of music. The results of the study showed that the use of quantum algorithms, superposition, entanglement and the uncertainty principle enabled composers within the "Beyond Quantum Music" project to create unique soundscapes and interactive compositions that go beyond traditional music and have a meditative effect on listeners. In the future, it would be worth expanding the range of projects studied, drawing on more examples from different fields of science and art to gain a more complete understanding of the role and significance of interdisciplinary dialogue in contemporary cultural production.

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Міждисциплінарні діалоги: поєднання науки та мистецтва в сучасному культурному виробництві

Анотація. Метою дослідження було вивчення співпраці між митцями та науковцями. Методологія дослідження передбачала міждисциплінарний підхід, який дозволив детально проаналізувати процеси, що відбуваються на межі наукових та художніх практик, і виявити нові форми культурного виробництва. Основні результати підкреслили важливість взаємодії науковців та митців для створення нових форм самовираження. Виявлено, що наука і мистецтво є тісно пов'язаними сферами реалізації людини. Якщо звернутися до історії, то до прикладу, музика довго вважалася математичною наукою, отже розподіл мистецтва та науки є доволі не чітким. У результаті проведеного дослідження було встановлено, що міждисциплінарна співпраця між науковцями та митцями сприяє виникненню інноваційних форм культурного вираження, які виходять за межі традиційних моделей як науки, так і мистецтва. Аналіз конкретних проєктів, а саме «Arts at CERN» та «Beyond Quantum Music» показав, що такі проєкти часто стимулюють нові підходи до розв'язання суспільно важливих проблем, активізують інтерес до наукових тем у ширшої аудиторії та створюють платформу для креативних експериментів. Було виявлено, що ключовими факторами успіху таких проєктів є відкритий діалог між учасниками, взаємне збагачення знаннями та готовність до експериментів. Відтак, міждисциплінарні діалоги мають значний потенціал для зміцнення культурного капіталу та розвитку креативних індустрій, особливо в контексті сучасних викликів глобалізації та цифровізації. Результати дослідження надали нові перспективи для розуміння сучасних культурних процесів, підкреслюючи важливість діалогу між різними сферами знання для розвитку інновацій у культурному виробництві

Ключові слова: проєкт; співпраця; митець; самовираження; творчість; культура; космос