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The Contribution of the Health Crisis to Young Children's Nano-Literacy through STEAM Education

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Abstract

Nano-Science and nano-Technology (NST) is a new interdisciplinary field that promises to provide solutions to timeless global challenges. Given that NST deals with elements that cannot be observed with the naked eye, their understanding by young children undoubtedly requires appropriate teaching methods. These distinct aspects of NST align well with the capabilities of smart mobile devices, the critical feature of which is their ability to display interactive simulations and playful visualizations. This article aims to emphasize the feasibility of empirical research of how digital technologies support NST teaching to young children in the wake of the sudden pandemic outbreak based on a comprehensive literature review. With the virus as the central entity of nanoscale, following the current demands of the unprecedented health crisis, and developing appropriate educational applications in digital games, young children can be introduced to the fundamental concepts of NST. NST is an interdisciplinary field that can enhance children's perceptions of the interconnectedness of nature with different fields of knowledge, such as Science, Technology, Engineering, Art, and Mathematics (STEAM).

Keywords

STEAM education, digital technologies, mobile applications, nano-technology, early childhood, size and scale, virus

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Introduction

We live in an era where technological developments permeate all areas of human life. Following the demands of the unprecedented health crisis we are going through, modern technologies during distance education change the teacher's role and the student's role in the educational process. The teacher becomes the mediator of the learning process as technology acquires a prominent position in the educational process (Kalogiannakis, 2010; Vojteková et al., 2021). Children discover new knowledge and develop skills with the support of their family environment (Ampartzaki, Kalogiannakis & Papadakis, 2021. However, integrating new technologies into young children's education is not easy.

The first section of the paper discusses the current health crisis and digital technologies in the education of young children with a focus on the capabilities of mobile devices and their applications in young children's learning process. The second section focuses on 21st-century skills and STEAM education. The third section emphasizes Nano-Science and nano-Technology (NST) as the pre-eminent interdisciplinary field of knowledge and then stresses nano-literacy due to understanding the "Big Ideas" of NST. The following are the conclusions and a discussion on the role of the pandemic in initiating young children's nano-literacy based on an interdisciplinary approach to teaching and learning. Finally, the work is completed with our suggestions for further research.

The health crisis and digital technologies in the education of young children

Coronavirus has infected more than 174 million people in just a few months and has killed more than 3.5 million patients worldwide. This pandemic outbreak has severe consequences for the health sector, depleting the health care system and the economy, leading to suffocating situations for many companies (World Health Organization, 2021). This crisis, of course, could not but significantly affect our education system. After the suppression of the canonical operation of institutions and other educational structures appears to be the emergence of remote alternatives. The learning process occurs from home through specific educational platforms and applications, online meetings, and collaborations. This era examines the integration of technology in both live and online learning. Children are encouraged to adapt and benefit from the current situation. Both children and teachers are encouraged to understand digital technology, explore it, and channel their creativity through innovations in specific tasks (Darma et al., 2020).

At the same time, many studies have already examined the effectiveness of digital technologies in the learning process compared with the learning opportunities provided to young children by traditional teaching methods (Aladé et al. 2016; Dorouka et al., 2020a; Kalogiannakis & Papadakis, 2020). Due to radical changes in the domain of technology, many researchers have proceeded to construct a specific nominal separation, introducing the notion of old (for

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example, desktops) and new technologies (for example, tablets) (Kucirkova, 2018). For instance, Mercer, Hennessy and Warwick (2010) describe how interactive whiteboards (new technologies) relate to flipcharts and dry-wipe boards (old technologies) but fulfil the same aim of collaborative learning.

The assets of mobile devices and their applications for young children

The educational use of digital technologies offers new opportunities for early childhood children to effectively engage with mathematical concepts (Papadakis et al., 2021; Schacter & Jo, 2017). In their research, Rogowsky et al. (2018) used tablets to test how they affect the development of preschool children's arithmetic ability due to their ease of use, unlike the mouse and keyboard we use in classic computers, which pose hand-eye coordination challenges to young children. Also, Papadakis et al. (2016) investigated the impact of new and traditional technologies on mathematics teaching. They discovered the unique features that render new digital devices, like tablets, more developmentally appropriate with increased effectiveness in learning for young children than computers.

The elements that make smart mobile devices, such as tablets, potentially ideal educational tools for young children are their flexibility in the learning process and instant multi-sensory feedback (Kalogiannakis & Papadakis, 2020). These characteristics are essential through the current health crisis-˙ the speed and ease of use without prerequisite knowledge-elements useful for a smooth adaptation and integration of children from other countries during the critical migration period we are going through-, and the possibility of representing the visible, but also the invisible to the "naked eye" world, an advantage crucial for understanding the global battle with the "invisible enemy," the new coronavirus.

Consequently, following the outbreak of COVID-19 and the subsequent spectacular advancement of the digital age, digital technologies need to be deeply integrated into young children's teaching and learning to play their expected role indeed. It is also undeniable that digital educational activities must be based on concepts of scientific education or, in other words, on correct didactic concepts. Exigent by the matter is the recurring question:

Will a traditional educational approach relating to a single subject area be sufficient for our children's learning process and future?

Skills 21st century & STEAM education

The constant transformations of the digital world have determined that the labor market requires new skills and professional profiles. In particular, the industry's future will value individuals who can understand, employ and integrate interdisciplinary knowledge and methodologies, capable of working in diverse (in terms of sector, industry, and culture) teams. The constant transformations of the digital world have determined that the labor market requires new skills and professional profiles. In particular, the industry's future will value individuals who can understand, employ and integrate interdisciplinary knowledge and methodologies, capable of working in diverse (in terms of sector, industry, and culture) teams (Kähkönen et al., 2016).

Industrial, political and educational leaders unite behind initiatives that support the development of children's skills, such as promoting "deeper" learning through skills such as critical thinking, curiosity, communication, creativity, problem-solving, innovation, teamwork, and collaboration (Jackman et al., 2020; Papadakis et al., 2018; Allina, 2018; Jacobs, 2014).

Furthermore, in the global research community, interdisciplinary learning in schools is becoming an increasingly popular area of interest. There is much discussion about the educational approach around Science, Technology, Engineering, Arts, and Mathematics (STEAM) (Psycharis & Kallia, 2017; Kähkönen et al., 2016). STEM and STEAM teachers agree that STEAM initiatives allow children to transfer their knowledge to different disciplines and solve creative problems in a different context, both inside and outside school (Gess, 2017; Liao, 2016). Children need the skills with which they can build knowledge (see **Figure 1**). STEAM education cultivates children's critical thinking and problem-solving, collaboration and communication, creativity and innovation (Liao et al., 2016), skills that can be transferred and used in an extracurricular setting.

Figure 1. 21st century skills

STEAM education is necessary for the job market and is present in most of our daily products and services. Therefore, it is imperative to prepare individuals of the 21st century for a STEM workforce. However, the purpose of STEM training is far greater than meeting financial or technological goals. Students develop an understanding of what is happening globally, how scientific phenomena affect their lives, and their ability to participate as global citizens in a rapidly changing world (Adams et al., 2018).

The integration of STEAM education in the learning process

The integration of STEAM fields in an educational approach to a topic is achieved in various ways: It can involve different STEM disciplines, highlight one discipline more than another, present in a formal or informal setting, and include various pedagogical strategies. The characteristics of integrated STEM education for Primary and Secondary education classes offer substantial opportunities for children to actively participate in their learning, to develop new concepts, practices, and skills; to recognize the interrelationship between Science, Technology, Engineering, and Mathematics (Bryan & Guzey, 2010), and the contribution of the Arts to develop a comprehensive learning procedure (Allina, 2018).

Each industry has its own culture, its practices, knowledge, and ways of exchanging knowledge. These crucial differences between disciplines can shape how teachers teach the content of a subject and its related practices. However, understanding the culture, practices, and ways of knowing and sharing knowledge about STEM industries is only a milestone on the path to integration. One of the main challenges in integrated STEM teaching and learning is basic content knowledge and procedures in all disciplines (Psycharis, 2018; English, 2016). Children should be allowed to participate in specific practices of the various subjects and at the same time to recognize and understand how in each subject the skills and practices are mutually supportive and interact. Consequently, in a comprehensive STEAM teaching and learning (see **Figure 2**), children work collaboratively, use multiple tools, collect and analyze various data sources to solve a problem or challenge.

Figure 2. A depiction of STEAM education

NST as the pre-eminent interdisciplinary field of knowledge

The focus of attention of various scholars, such as Jones et al. (2013), in the STEAM interdisciplinary educational approach, leads to discussions related to the integration of NST in Primary school curricula. NST is a new scientific field of research and development that has shown rapid development worldwide over the last two decades (Dorouka et al., 2021; Höst et al., 2020). NST is not a distinct, independent scientific object. On the contrary, as it pervades all scientific disciplines, it forms a predominantly interdisciplinary field. NST draws its main axes from many sciences, such as physics, chemistry, biology, materials science, and contributes to the interconnection (Mandrikas et al., 2021). For this reason, many researchers, such as Lin et al. (2015), focus on understanding NST as a genuinely interdisciplinary field that can enhance children's perceptions of the interconnectedness of nature with different areas of knowledge, such as Science, Technology, Engineering, Art and Mathematics (STEAM). Furthermore, it is an essential field of development (Mandrikas et al., 2020), as matter in this size scale (see **Figure 3**) exhibits properties with great potential that can revolutionize various fields such as energy, environment, and medicine (Delgado-Ramos, 2014).

Range		Scale World Name (description)	Objects (interactions)	Forces (gravity, electrical, nuclear)	Instruments
10^{2} m	100 m	human scale	**football field** (interact sequentially)	gravity dominates	eyes and feet
10^{1} m	10 m				
10^{0} m	1 m		**you** (can see & interact easily)		eyes, hands, arms
10^{-1} m	dm				
10^{-2} m	cm	small	**things handled daily**	gravity begins to lose dominance less than this scale	eyes, hands, & fingertips
10^{-3} m	mm				
10^{-4} m	100 μm	(barely visible)	**hair thickness**		magnifiers, tweezers
10^{-5} m	10 μm	microscale (many atoms)	**cells, "germs"**	electrical forces dominate in an atomic-bulk fashion	
10^{-6} m	1 μm		**bacteria** **visible light wavelengths**		optical microscopes
10^{-7} m	100 nm	nanoscale (few atoms)	**viruses**	electrical forces dominate in a precise, discrete fashion: van der Waals, coulombic, & hydro-phobic/philic **(intermolecular bonding)**	atomic force microscope
10^{-8} m	10 nm		**carbon nanotubes, proteins**		scanning tunneling &
10^{-9} m	1 nm		(transition to quantum effects)		electron microscopes
10^{-10} m	1 Å	atom scale	**small molecules** (e.g. H_2O) **single atoms**	electrical forces hold atom together nuclear forces hold nucleus together **(chemical or intramolecular bonding)**	scanning tunneling & electron microscopes

Figure 3. The worlds of scale and their fundamental role in NST (Adapted from Tretter, 2020)

The concept of being interdisciplinary has raised expectations and is suggested to be an essential property that may decisively contribute to the progress of Nano-Science. Stevens et al. (2009) recognize a promise that may significantly impact society to a greater degree than previous leaps in scientific knowledge. Interdisciplinarity is perhaps the only thing that gives Nano-Science a name. After all, chemists, physicists, biochemists, and cell biologists have been studying nanoscale phenomena-the dimension of viruses, atoms, and molecules- for centuries (Kähkönen et al., 2016).

There can be varying degrees of interdisciplinarity in scientific research. Nano-Science refers to the reductiveness, or rather reductionism, of the natural sciences (Kähkönen et al., 2016). Scientific ambition is the connection of quantum mechanics, solid-state physics, inorganic chemistry, and molecular biology and their integration, at least in part- at the nanoscale (Jackman et al., 2020). Some scholars have suggested that Nano-Science paves the way for greater convergence of sciences, the so-called nano-bio-information-cognitive-sciences, or sciences related to nano-Technology, biotechnology, information technology, and cognitive technology (Jamali et al., 2018; Finardi, 2018).

The sustainable development of NST for the critical areas of human evolution requires the nano-literacy of a new team of scholars, engineers, entrepreneurs, and policymakers to create the necessary workforce. Although NST education targets multiple population groups, it is particularly crucial to young children, as they are expected to be most affected by the uncontrolled pace of its development (Peikos et al., 2020). Thus, it will be the generation of NST reforms that will be called upon to make public policy decisions. In addition, the didactic transformation of NST concepts is vital for children, as the interdisciplinary nature of NST can be subversive to the existing fragmentation of cognitive subjects under distinct course titles and also for teachers as it relieves them from the perils of having to get involved with topics that transgress the boundaries of their field of specialization. Also, NST is a cutting-edge technology that maximizes its potential to contribute to the development of an interdisciplinary learning environment with meaning and significance for children, encouraging them to pursue an NST-related direction at the level of their professional orientation (Dorouka et al., 2021).

Nano-literacy and the "Big Ideas" of NST

What kind of understanding of NST makes a person nano-literate? Nano-literacy is associated with understanding several basic concepts/ideas of nano-Technology (see **Figure 4**). In particular, the widely accepted list of the nine Big Ideas of Nanoscale Science and Engineering results from extensive discussions among experts in various fields (Blonder & Yonai, 2020; Gilbert & Lin, 2013). It is important to emphasize that all nine Big Ideas are interdisciplinary and are the following: size & scale, size-Dependent Properties, Tools & Instrumentation/Characterization, Models & Simulations, Surface-Dominated Behavior, Societal Impact/Public Education, Self-Assembly, Surface-to-Volume Ratio, Quantum Mechanics (Stevens et al., 2009). Suppose functional nano-literacy implies the ability to use and discuss these ideas. In that case, it is also necessary to raise awareness of the variety of research methods and the reasons for employing each of these methods, given that different approaches lead to different knowledge (nature of knowledge) (Kähkönen et al., 2016). The central role of technology in Nano-Science is emphasized in the Big Ideas of Nano-Science since it is associated with the cognitive-scientific skills that are important for general education in NST.

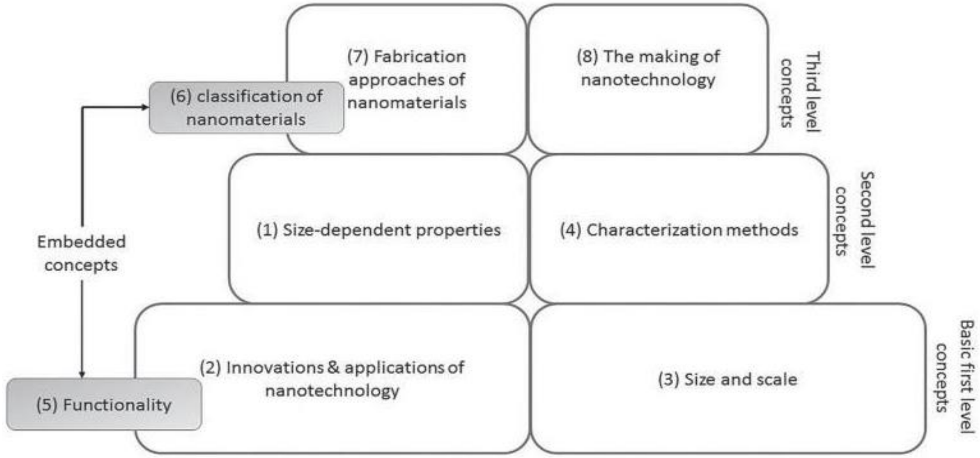

Figure 4. The construct of NST concepts (Adapted from Blonder & Yonai, 2020)

One obstacle to the beginning of children's understanding of NST is the lack of sensory experience of the invisible world. For example, electrons, atoms, molecules, and viruses are too small to see, while matter interactions and abstract phenomena evolving at this level are often against common intuition (Mandrikas et al., 2020; Magana et al., 2012). So, considering that NST concerns elements that cannot be observed with the naked eye, their understanding by young children undoubtedly requires appropriate teaching methods. Although there are practical solutions, regarding the way NST teaching process would be embraced within schools directly or indirectly through STEM approach, they are extremely limited (Dorouka et al., 2022a; 2022b).

Discussion

The distinct aspects of NST are well aligned with the capabilities of smart mobile devices, the critical feature of which is their ability to display interactive and three-dimensional simulations (Papadakis et al., 2021; Zydney & Warner, 2016). Through visualization, children can easily perceive the relative difference of objects that vary in size (Swarat et al., 2011). Unfortunately, although mobile applications effectively encourage young children to participate in interdisciplinary activities, no educational application has been found to adequately support young children's connection to NST, a cutting-edge technology. Nonetheless, children are already strong allies in the unprecedented fight against the new virus. So, having already taken on the role of helper worldwide in this challenging struggle, who could deny that they can understand nanoscale entities, such as the virus?

Approaching the viral state on a macro-scale (virus symptoms), micro-scale (cells), and nanoscale (virus) is substantial for NST education and particularly beneficial to young children even on a post-pandemic stage. Utilizing the powerful capabilities of digital technologies, young children familiarize themselves with the first Big Idea of NST, namely size and scale, allowing themselves a deeper and more meaningful understanding of the "invisible enemy" that enables them to effectively guard against it and actively contribute to limiting its spread (Dorouka et al., 2022a; 2022b).

In particular, through properly designed educational applications of the playful form (Kalogiannakis et al., 2021), children can recognize the different behavior in the entities of the macroworld, the microworld, and the nano-world, as well as the difference in their size with qualitative criteria (Delgado et al., 2015; Magana et al., 2012). Evaluating, that is, how nanoscale entities, such as the virus, affect micro-scale entities, such as the red cells that infect a lung virus entering our body. Afterward, these affect macro-scale; the person who becomes ill with symptoms of the virus, such as fever and cough, can lead even young children to a qualitative understanding of size and scale and, consequently, to the beginning of their nano-literacy (Dorouka et al., 2022a; 2022b).

Consequently, in conjunction with the current virus situation we are experiencing worldwide, what could nano-literacy be, if not a golden opportunity, to introduce children to nanoscale concepts early in school?

Conclusion

The spread of the COVID-19 pandemic triggered the most severe financial crisis since the great catastrophe of the 1930s. In the emerging and ever-changing context of COVID-19, a series of measures are being implemented to slow the spread of the virus. The educational reality and the learning processes are modified with the adaptation of teachers and children to a virtual environment. The children's health, safety, and information about the sudden situation they are experiencing is undoubtedly a priority. Education amid the pandemic is becoming a technology-dependent asset (Burgess & Sievertsen, 2020). Members of the academic and educational community are called upon to "embrace" technology and pay particular attention to children's experiences to make learning rich and influential (Sahu, 2020). Teachers, in particular, play a crucial role, as they must realize that they can actively promote didactic transformation programs in the interdisciplinary field of Nanotechnology for health promotion (Wang et al., 2020) by incorporating nanoscale entities, such as the virus, into the school curriculum.

The future social and financial impact of NST is increasing the demand for a nano-literate set of people and a nano-capable workforce. This directly indicates the urgent need for nano-teaching interventions in schools and educational programs for young children (İpek et al., 2020). In other words, the revolutionary progress of the NST presents comprehensive and essential social and educational challenges. This requires teaching initiatives that include the convergence between Science, Technology, Engineering, Art, and Mathematics (STEAM) resulting from the nanoscale-focused scientific effort that leverages mobile devices' powerful capabilities and applications. Therefore, it is crucial to reinforce the educational process with the tools necessary to enable NST literacy.

Suggestions for future research

Recovery from the economic "strangulation" can be achieved by taking action in the health and education sectors. As a consequence of the current health crisis, education, economy, and society, in general, may greatly benefit from a nano-literacy tool for young children that focuses on size and scale that is one of the vital concepts in the NST interdisciplinary field -- or one of the nine Big Ideas for Science and Engineering of nanoscale (Stevens et al., 2009). The expediency of focusing this nano-literacy tool for young children on the first great idea of nano-technology illustrates the need to start creating a single digital nano-literacy tool that can be extended to other Big Ideas of nano-Technology (Dorouka et al., 2020b).

It seems necessary to increase the attractiveness of the STEAM professions and improve the employability, not only of modern citizens with distance education due to the pandemic and the simultaneous migrant wave but also of future people, as nano-literate members of society. Therefore, there is an urgent need for further research in this direction; the future workforce understands the importance of NST and its impact on education, society, and the economy through the educational possibilities of digital technologies. After all, how else could the socio-scientific issues of Responsible Research and Innovation (RRI) be understood to bridge the gap between the scientific community and the general public? How else could the future become sustainable for our planet?

Conflict of interest

The authors declare that they have no conflict of interest.

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