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Engaging Preschoolers in STEAM Education: An Adaptation of a Nano-Literacy Program in Distance Education

Hellen Vretudaki[1*] and Evangelia Klada[2]

[1] Department of Preschool Education, University of Crete, Greece
[2] Directorate of Primary and Secondary Education, Crete, Greece
* **Corresponding Author E-mail Address:** hellenvretudaki@gmail.com, evretoudaki@uoc.gr

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ABSTRACT
The aim of this paper is to present a program in nanoscience and nanotechnology (NST) to pre-school children through distance education. The activities followed the teaching learning sequence (TLS) methodology and dealt with: a) the nano scale and size, b) exposing children to appropriate instruments/tools through which they investigated elements of the nanoworld and c) raising pre-school children's awareness of applications of nanotechnology, based on the interdisciplinary STEAM approach. For this reason, a series of organized activities which had been implemented at an earlier time in a kindergarten setting were redesigned to meet the current needs of the children in the context of distance learning during the pandemic lockdown. The results from the implementation of the learning sequence were very encouraging in terms of the perceptual and exploratory abilities of the preschool children. By the end of the program, the children were able to identify "nano" size materials. In addition, they seemed to be able to reflect on the application of nanotechnology in their daily lives.
keywords: "nano" size, preschool, distance education, nanoscience, nanotechnology

1. Introduction

Science education is a very interesting and challenging field for young students because of its experimental nature. Quality science teaching is highly interactive and characterized by a participatory learning environment. Thus, quality science teaching promotes children's innate curiosity, as the approach to concepts and phenomena utilizes exploratory, reflective processes, as opposed to the frontal, traditional ones that make students passive recipients. In a broader context, in areas of science and technology such as medicine, physics, biology, etc., rapid developments are taking place, most of which affect the daily life of young students as final recipients of their achievements (Dorouka, Papadakis, and Kalogiannakis, 2019). Nevertheless, there is a large gap between the subjects that modern science deals with and those that students are taught in school in science (Stavrou and Asimopoulos, 2011). To fill this gap, recent research in science education has begun to turn to teaching subjects beyond traditional ones (Manou and Spirtou, 2013). The integration of nanoscience and nanotechnology (N-S&T) into teaching has come to emphasize the relationship between science education and technology with contemporary everyday social life.

In recent years NST has attracted intense research interest as its widespread application in industry and technology has made it necessary to educate students on a number of its elements and products (e.g., mobile phones, textiles, sports equipment, etc.) which are increasingly penetrating their modern everyday life. Nanotechnology has been hailed as the next "industrial revolution" of our modern era. To carry out successful research in this field, educational research is necessary to develop standards that will properly prepare the future workforce employed in these fields, tomorrow's 21st century citizens (Jones et al., 2013).

Due to its interdisciplinary nature, NST can be explored through a range of disciplines such as science, technology, engineering, mathematics (STEM) in primary and secondary education and the arts to develop a comprehensive learning procedure (Allina, 2018). Nanotechnology is already being used in innovations that affect the quality of people's lives. Therefore, there is a strong interest in integrating NST into science education in secondary and primary education, mainly with older students, as younger children may have difficulties in comprehending the size of matter at a nano scale. The reason lies in the fact that nano scale is not sensorially perceptible due to its very small size and to the lack of developmentally appropriate teaching materials (Ghattas and Carver, 2012). Young learners perceive all objects that are not visible to the naked eye as objects of the same order of magnitude (Magana et al., 2012). Teaching such innovative content may seem like a difficult task, but in pre-school education the arguments put forward by researchers in favor of introducing NST in compulsory education are a strong motivation for teachers to dare to develop and utilize appropriate teaching materials (Tzioli, 2019).

1.1. Approaching Nanoscience with Younger Children

Nanoscience contains some basic concepts and principles that students should gradually master to deepen their conceptual approach (Bryan et al., 2015). In the USA such efforts were made and after many revisions the 9 Big Ideas of nanoscale science and engineering were articulated (Stevens et al., 2007). In summary they are: 1) Size and scale, 2) Structure of matter, 3) Size-dependent properties, 4) Forces and interactions, 5) Self-organization, 6) Instruments and measurements, 7) Models and simulations, 8) Social, ethical, and legal implications and 9) Quantum phenomena. At the younger ages, the following can be approached with relative success: a) Size and scale, b) Size-dependent properties, and c) Instruments and measurements (Manou et al., 2018).

In particular: a) size and scale help to describe matter and predict its behavior. Stevens and colleagues (2009) proposed dividing this wide variety of sizes into scales or "worlds" (e.g., macroworld, microworld, nanoworld, atomic world). b) The size-dependent properties of matter can change with respect to scale. For example, during the transition of a material from the macroscale to the nanoscale, its properties change unexpectedly, as the material may interact with other objects or acquire new functionality. At this size matter exhibits properties with great potential to revolutionize various fields such as energy and medicine (Kremmida, 2019; Mandrikas et al., 2019). c) Instrumentation and measurements involve the development of specialized tools such as microscopes and electron microscopes which assist in observing and understanding concepts and measuring nano-sized elements.

As for students at all levels of education, it has been documented that they have misconceptions about the three worlds, as well as an inability to understand them (Mandrikas et al., 2019). In a study investigating students' perceptions of the smallest extant object, the vast majority referred to micro-objects of the macrocosm (fly, grain, etc.). Even elementary school students mentioned ants as the smallest thing they knew, while in older classes students mentioned atoms and bacteria. It seems that younger students think that the smallest items in existence are those in the macrocosm or microcosm, while older students, although they report atoms as the smallest, are unable to classify microcosm and nanoworld objects by size. (Peikos et al., 2015). This is because they lack sensory experience of the non-visible world and due to the fact that NST focuses on studying specific properties of matter at scales ranging from 1 to 100 nm

(Dorouka et al., 2019). Moreover, studies indicate that microscopes are the most well-known instrument for observing the "smallest" things, while students believe that the term "Nanoscience" is associated with something small (without realizing the actual order of magnitude) possibly influenced by related narratives (Peikos et al., 2015).

Some additional issues associated with introducing nanoscience to preschool classrooms are: a) teachers' inability to efficiently process science content and organize a supportive learning environment b) the absence of specific evaluation scales for science assignments compared to other lessons (Gerde et al., 2018; Greenfield, 2015).

For preschoolers, some researchers suggested more play-centered activities and tools to capture children's attention and ensure their involvement. Specifically, Ahlcrona (2012) and Simon et al. (2008) selected puppets as a means of expression to facilitate preschool children's comprehension and to reflect on children's misunderstandings when they deal with nanotechnology concepts. It seems that puppets operate as mediators so that children can absorb difficult concepts as they can activate and encourage children's creative thinking and play.

Overall, when a problem is relevant to students' everyday lives and it can be approached and solved by NST through tools such as the electron microscope, it can stimulate students' imagination and motivate them to engage more systematically with science (Harmer and Columba, 2010). Furthermore, it is important to introduce NST in early childhood education because of the importance of enhancing young children's "nano-literacy" (Lin et al., 2015). "Nano-literacy" can be developed in children when they have acquired knowledge and the skills that allow them to manage everyday issues related to nano-technology products. In addition, using smart mobile devices (tablets) enhances young children's nano-literacy because they help them understand the elements that cannot be observed with the naked eye, since the devices display these elements through interactive and 3D simulations (Dorouka et al., 2020).

In recent years, there seems to be a strong interest in Teaching Learning Sequence (TLS) in the science and nanoscience teachers' academic community. These are small-scale curricula that last a few weeks and are products of developmental research. Learning sequence is applied to a specific science content and follows a cyclical evolutionary path. TLS is characterized by four principles: a) Transforming the content of new knowledge to meet the needs of students, b) Students creating alternative ideas on the topic being taught, c) Selecting the field of application of the new knowledge, and d) Combining appropriate teaching methods to implement and evaluate the teaching intervention (MéHeut, 2018; Psillos and Kariotoglou, 2015).). Evaluation is usually carried out by administering a questionnaire before and after implementation.

1.2. Nanoscience and New Technologies: The Case of Distance Education

Research has pointed out that when children are provided with interactive learning experiences using desktop computers or smart mobile devices, their cognitive skills improve as do the digital skills required for future success in demanding work environments. Using digital technology as an instructional tool can motivate children to learn when it encourages open-ended exploration, promotes interactive processes and provides systematic and specialized support (scaffolding) by the teacher to all participating students (Kalogiannakis and Papadakis, 2020).

With regard to scale and nano size in particular, because digital technology can help portray objects students are more easily able to understand the continuity of scale in nature through analogy as opposed to absolute comparison. Young learners' developing perception enhances their ability to appreciate and categorize objects in the micro-nano world more accurately (Dorouka et al., 2019). However, digital technology alone cannot dramatically increase young learners' perceptual abilities and enable them engage in higher-level cognitive functions (hypotheses, comparisons, reasoning, inferences) and metacognitive processes such as checking and revising. It is the pedagogical interactive atmosphere created by the teacher in the classroom that achieves this, especially when conditions involve distance education.

The unprecedented socio-economic conditions dictated by COVID-19 imposed changes in traditional teaching and learning processes. Integrating and using new technologies effectively has become necessary in the educational sector as teaching has been functionally transformed to support the daily educational needs of students through distance learning (Adedoyin and Soykan, 2020). Consequently, the need to create more interactive experiences has emerged, using new technologies which can provide a plethora of audio-visual stimuli that in the long run seem to positively affect the daily life of children (Tsiavos et al., 2021).

Distance education is an integrated educational methodology that requires careful planning with clear teaching and learning objectives and well-organized support and training processes. Distance education uses various digital tools such as interactive videoconferencing in which participants build knowledge through active participation in an interactive environment (Anastasiadis, 2020). When experimenting and interacting with objects is a necessary condition to learning scientific concepts, school-family collaboration takes on another dimension, especially when distance learning is involved. Parents become co-educators of their child in a collaborative context where the teacher mediates, supports, guides and models every new concept and process to activate young children physically, verbally and cognitively (Stites et al., 2021).

1.3. Necessity of the Present Study

In general, attending preschool is important because of the positive association between attendance and the development of children’s cognitive, emotional, and executive skills (Stites et al., 2021). During the pandemic young children faced many difficulties in participating in school lessons. In this prolonged health crisis, distance education seemed to be the only way to engage in schooling. For efficient preschool teaching and learning in this situation, the course materials had to be prepared in advance and uploaded to the database. It was also considered best if preschoolers’ parents assisted in their children’s efforts. Parents can facilitate their children’s learning e.g., getting the link for online classes or downloading the course materials (Zhou, 2022). Preschoolers’ parents’ involvement seemed crucial for the children, since data from various countries (Canada, USA, Hong Kong, Turkey, Greece) showed that generally there was a lack of teacher training in distance education, problems with home access to technology and many problems when parents could not or were not available to help their children (Nikolopoulou, 2022). All of these difficulties impacted the quality of the learning process, creating large gaps in children’s comprehension, a significant delay in learning subject flow and centralization in the basics in each learning area. Data reveals that the most common activities in distance education were language, psychomotor, kinesthetic activities and mathematics (Steed and Leech, 2021; Yıldırım, 2021).

Considering the above, in preschool settings learning and teaching modes require additional specialized educational materials, network resources, and highly qualified teachers (Bequette and Bequette, 2012). It is essential to determine the methods for promoting effective teaching methods in preschool education. Although there is a growing literature on distance education especially for young children these days, we deal with a limited number of didactic approaches aimed at effective learning of contemporary issues such as nanoscience and nanotechnology.

Digital technologies and nanoscience can provide reliable answers to children's concerns related to the specific morphological and behavioral characteristics of the coronavirus, based on scientific and exploratory ways of learning. Approaching viruses on a macro-scale (virus symptoms), micro-scale (cells), and nanoscale (virus) is crucial for NST education and particularly beneficial to young children even in a post-pandemic stage.

Nowadays, preschool children need to learn more about concepts of nanoscience and nanotechnology concepts so that in the future they can act as informed citizens. Although initial efforts have been made at preschool level to identify the central concepts of NST education, we need to know more about the developmental course that takes place for meaningful understanding. Considering the literature mentioned above, we found a limited number of studies that provide a core NST content for the preschool level. Additionally, there was only a very limited number of instructional approaches and evaluations for learning outcomes for preschool students' understanding of NST content. Therefore, theoretical frameworks for interpreting preschool children's learning are still an open issue in the nano-science research field.

Taking into account the previously mentioned considerations, the authors of this article participated in an interdisciplinary research project undertaken by the Laboratory of the Department of Primary Education and the Laboratory of Informatics in Education and Science Teaching of the Department of Preschool Education of the University of Crete. Fifteen pre-school and primary school teachers participated in this project aiming to develop STEAM teaching materials focused on the fundamental concepts of nanoscience and nanotechnology. The program described in the present study was carried out in the following school year, building on a previous face-to-face implementation, in an attempt transfer it to distance education situations due to the COVID-19 pandemic.

2. Methodology

2.1. Purpose of the Research

The purpose of this study was to investigate preschool children's ability to perceive nano scale and size. A secondary purpose was to raise awareness among preschool children about the applications of nanotechnology in their daily lives.

A sub objective was also set:

To investigate the effectiveness of the specific educational intervention in distance learning.

2.2. Research Questions

1. What are preschool children's perceptions of the smallest object visible to the naked eye? (Does it exist or not exist?).
2. What are preschool children's perceptions of the smallest objects that are not visible to the naked eye? (Do they belong to macro-micro or nanoworld?)
3. What do preschool children believe about tools that aid in perceiving objects that are not visible to the naked eye?
4. Was the specific intervention program in distance education effective for preschool children?
5. Are preschool children able to reflect on the applications of nanotechnology in their daily lives?

2.3. Sample

Two classes were selected following convenience sample procedures. The sample consisted of 40 preschool children aged 4-6 years (M=62.65 months). Eighteen of the sample children were boys (45%) whereas 22 were girls (55%). The sample population was all kindergarten classes in Crete, Greece. All sample children were native Greek speakers, and came from middle-class families. According to the teachers' judgments and the verbal ability pre-tests, all children had typical development, without language problems. The parents' occupations were unrelated to the main subject of the program. All of the parents had secondary school diplomas or degrees from a college or university. None were employed in teaching the natural sciences or chemistry or worked as a doctor. In addition, they did not face any serious problem in home access to networks because the majority of the children's houses were very close to school. Teachers had university degrees and worked as full-time educators in Greek kindergartens.

2.4. Materials

2.4.1. Software

We used the Kidspiration an open-type software - concept mapping software - where students connected images and words related to the concept of nano; Tux Paint - art software - where children drew tools that help explore nanoparticles; and closed-type software (educational game on the Wordwall digital platform) where children grouped images from the macro-micro-nanoworld.

2.5. Research Design

This program was developed through the Teaching Learning Sequence (TLS) and aimed to engage children in inquiry-type processes based on (a) Plan, (b) Develop, (c) Apply and (d) Evaluate. During the development of the Teaching Learning Sequence (TLS), the researchers sought to organize developmentally appropriate activities suited to distance education that would help the preschoolers understand the concept of nano by remediating the possible misconceptions they had around the topic.

To achieve this, a protocol of actions was developed to inform parents about the program and the need to support their children in the exploration, implementation, and evaluation phase. With the completion of each session, which lasted for one and a half hour, parents were informed of the procedures for implementing and completing the next session. That is, when teachers saw children's initial representations of very small objects/materials and evidence that they were deliberately reflecting on the concept of size through the interdisciplinary activities, parents were asked to support the children's exploratory efforts in identifying very small objects. Also, in teleconferences, parents were informed about the software and interactive games uploaded on the asynchronous tele-education platform *e*-me aiming to help children consolidate the newly acquired concepts.

Specifically, in the first phase of the learning sequence, "Plan", together with the preschoolers a mind map was formed which included their initial possible misconceptions, needs and desires. The mind map included the children's views on the key questions posed to them, as well as the teachers' interpolations that aimed to have them further explore elements from the macro-micro-nano world.

The second phase of the learning sequence, "Develop" began with purposeful readings of fairy tales that focused on a first perception of size, such as "Snow White and the 7 Dwarfs", etc. The preschoolers' prior knowledge about the topic was elicited through questions such as a) what is the most elementary object you know, b) what do you think the word "dwarf" represents, c) do you think there are things that are not visible to the naked eye?, etc. All the children's responses were recorded and they were asked to explore the topic further with the help of their family. Over the next week the preschoolers showed pictures (comparing the length of materials from macro-micro-nano world-e.g., fly, one hair, an eyelash, a grain of sand, a cell, a virus…), told stories, etc. from home about the topic and they were then asked to express their views again about the most elementary/small object they discovered in their home. They presented their findings (stone, gravel, crumb, soil, etc.) via videoconferencing.

In the third phase of the learning sequence "Apply", organized activities were carried out by the teachers with supporting audiovisual material (videos and images with applications of nanotechnology in space, medicine, and everyday life) in an attempt to approach the size and the concept of "Nano" (Morientes, 2021).

The organized activities lasted for a month during which the children's perceptions gradually began to change as they came to understand through exploratory processes that there are objects that are not visible to the naked eye e.g., viruses and bacteria. They were then puzzled about possible ways of observing and investigating these elementary objects and a preschooler suggested visiting a place (laboratory) where they could see very small objects with the help of a special instrument. With the help of the teachers, the class decided to organize a remote visit to a microbiology laboratory.

The visit was carried out via Webex in the following days and after the children had spoken to the microbiologist, they were given the opportunity, through a simulation, to observe from home, viruses and other microbes that "make our bodies sick". Impressive images were also presented online that highlighted the value of the digital/electronic microscope as a tool for imaging particles that are not visible to the "naked eye". They were also fascinated by the images of the molecular structure of these particles. Most of the children reflected and then accepted that there are probably objects smaller than the macrocosm but also smaller than the microcosm which belong to the nanoworld. They then engaged in classification and distinguishing games with the software Kidspiration*,* Tux Paint and Wordwall software. The total duration of the program was 2 months. The introductory phase of providing children with background knowledge and informing the parents of aspects of the program such as tools, platforms, shared activities with their children lasted two weeks. The implementation of the program's central activities lasted four weeks (one month), and the extension and evaluation program lasted two weeks (See Table 1).

In the last phase of the learning sequence "Evaluation", although approaching the concept of 'nano' scale with preschool children was extremely difficult, it seems their interest was strongly aroused by involving their family in the search for and presentation of relevant information. They also showed a strong interest in the activities involving systematic observations with the simple microscope and magnifying glass because, as they said, they felt like "little scientists". Finally, they understood that there are materials so small that we cannot detect them with the naked eye.

The consolidation activities were carried out using new technologies and also through interactive worksheets on the Liveworksheets platform. With these activities, the children were able to draw their conclusions, group objects from the macrocosm, microcosm and nanoworld and distinguish objects that are visible to the naked eye with a magnifying glass or with a simple microscope or electron microscope.

Table 1.
Program's central activities

Duration	Content of TLS	Parents contribution
1^{st} session	Creation of a protocol of actions concerning the unfolding program	Informing and discussions with parents (aim, scope of the program, operation of the *e* me platform, duration of the sessions…)
2^{nd} session	1^{st} questionnaire delivery concerning children's initial representations about the smallest materials in the world and specifically nano material	Parents were asked to support children's exploratory efforts in identifying very small objects/materials
3^{rd} session. 1^{st} phase of the TLS (Plan)	Creation of a mind map with children's initial representations and teachers' insertions for further explorations	Parents assist children's efforts
4^{th} session (Develop ideas)	Purposeful readings of fairy tales relevant to the size of subjects e.g., "Snow White and the 7 Dwarfs", "shortchickpeaman" e.tc. Picture presented to the children depicted very small things. children make assumptions for the smallest	After each reading questions were delivered to the children with parents' assistance (repeated the questions, refrain children's behaviour and ideas)
5^{th} session	2^{nd} initial questionary delivery about the smallest subjects in the world	Parents assist their children's selections of the smallest things from their surroundings
6^{th}, 7^{th} sessions. 2^{nd} phase of the TLS (Apply)	Organized activities were carried out with supporting audiovisual material (applications of nanotechnology in everyday life and in space…)	Children's perceptions gradually began to reshape about the smallest material in the world
8^{th} session	Visualizing a visit to a microbiological laboratory. Looking through a digital microscope particle that are not visible to the "naked eye" e.g., the corona virus	Parents assist children's understanding
9^{th} session	Children engaging in a series of classification and distinguishing games with the software Kidspiration, Tux Paint and Wordall software	Parents helped their children download the software games and fill in the organized digital activities the teachers' uploaded to the e me platform
10^{th} session. last phase of the TLS (Evaluation)	Children fill in the interactive worksheets on the Liveworksheets platform. Children answer the questionnaire concerning the smallest thing in the world e.g., nano-size material for 3^{rd} time,	Parents helped their children with the digital interactive activities. Parents read the questions to and quided their children to fill in the appropriate section in the questionary

3. Results

The main purpose of the present study was to investigate, through the distance learning process, the perceptual abilities of preschool children regarding the nano size and scale and their further reflection on the applications of nanotechnology in everyday life. The statistical data analysis found that the sample children's gender did not affect their perceptions and performances $t(40) = -.62$, $p > .05$, but children's age contributed significantly to these results $t(40) = 2.53$, $p = .013$.

Due to the young age of the sample children, the teachers could not follow a typical evaluation procedure, so they developed a scale, using descriptive statistics (percentages) which assessed the degree to which the children comprehended the program concepts.

Data analysis showed that the children encountered many difficulties understanding the existence of materials that they cannot see by naked eye. The most common misunderstandings concerned their belief that the smallest objects/materials were ones in the macrocosm (n=38, 95%). By the end of the program, these beliefs were overturned, since at the end of the study a significant percentage (n=33, 82.5%) revised their initial views and understood that the smallest objects do not belong to the macrocosm or microcosm, but to another space, the nanoworld, where the smallest objects are not visible to the naked eye.

With regard to the second question, whether children believed that objects existed that are not visible to the naked eye, in the initial phase of the program the majority of children answered in the negative (n=39, 97.5%). However, the same was not true at the end of the program, when an overwhelming percentage (n=34, 85%) of children perceived that they existed and stated that nano-size elements were the smallest objects.

The third question, which concerned children's knowledge of the existence of tools used by scientists to observe very small objects, even objects of the nano size, while children were initially unaware of the existence of scientific observation tools, in the course of the learning sequence (n=39, 97.5%), they learned that there were such tools and as a result, at the end of the learning sequence, a significant percentage (n=36, 90%) had reversed their opinions.

Table 2.
Children's answers about objects that are not visible to the naked eye

Questions	Before	After
Are there objects we cannot, see?	No (95%)	Yes (82.5%)
What is the smallest object?	Macroworld materials (97.5%)	Nanoworld materials (85%)
How can we see a nano particle?	With our eyes (97.5%)	Through a microscope (90%)

With regard to conveying the whole investigative process through distance learning, it appeared from the results that the interest of a large percentage of the children remained unchanged. The researchers observed that the younger preschoolers found it difficult to follow the process, but this was also the case when the same topic was taught in class. However, parental mediation compensated to some extent for the lack of face-to-face activities, as it played an important role as in all distance teaching approaches designed during the COVID 19 pandemic. Under these circumstances, the modern WeBex and asynchronous e me education digital platforms played a pivotal role by conveying the whole process through the interactive digital classroom and a variety of digital applications. Therefore, the answer to the question of whether distance education affected the learning process of preschool children was positive. To counterbalance the lack of face-to-face interactions and the additional learning problems involved in distance education (children's indifference, tiredness, difficulty in understanding the subject), teachers should purposefully schedule activities which engage preschool children in various ways (physically, linguistically, cognitively).

The procedures for evaluating, consolidating and extending this program were as follows: The majority of the preschoolers showed great enthusiasm and participated actively throughout the program. With their parents they also frequently searched for information on the Internet about the nano scale and looked for objects in their everyday life that were not visible to the naked eye for some time afterwards, extending the newly acquired knowledge to new situations and contexts. In addition, to a great extent, they became aware of our sensory weaknesses and understood that they are largely remediated by the use of smart technology such as microscopes, and in particular digital/electronic/microscopes. As you can see on Table 3, we followed thematic analysis on the quantitative data.

Table 3.
Children's responses after the implementation of the program

Evaluation sheet	No	A bit	Quite a lot	A lot
Did you find anything new in the activities we did?	n=2, 5%		N=18 45%	N=20, 50%
Can you identify objects in the macrocosm, microcosm, and nanoworld?	15%		27%	58%
Can you convey what you learned to others?		38%	32%	30%

Responsible Research and Innovation (RRI) teaching practices were proposed to extend the program. Specifically, after completing the learning sequence where the children perceived the existence of nano-sized particles, the discussion was extended to the application of nanotechnology in everyday life, where further reflections were discussed about the positive and negative impacts, the man-made and natural environment, the use of nanomaterials. Then, images of the application of nanotechnology in various areas of life such as medicine, space, information technology and in the field of cosmetics were presented, as well as the products of these applications (mobile phones, water filters, sunscreens, etc.).

To consolidate the knowledge an on-line survey was created using a double entry table and was uploaded to the *e* me platform and administered with the parents' assistance where the children's choices about the individual applications of nanotechnology were recorded in response to the question: "What in your opinion was the most interesting application and why". Then, through a fictional scenario "Let's go to the beach!!", children were asked to make reasoned decisions, in deliberate dilemmas, based on their recently formed views on the topic. All children's answers and open-ended comments were recorded and uploaded by parents to the platform.

Table 4.
Extension of the program. Questionnaire about Nanotechnology applications

Individual applications of nanotechnology	No / I don't know	A bit	Quite interesting	Very Interesting
After all that you've seen do you think using nanotechnology in Medicine is interesting?	3%	8%	47%	42%
Do you think using nanotechnology in cosmetics is interesting?	2%	12%	67%	19%
Do you think using nanotechnology in exploring space is interesting?		1%	12%	87%

4. Discussion-Conclusions

As we can see from the results of the present study, a number of the preschoolers had formed their initial impressions of the smallest object visible to the naked eye, influenced by their sensory perception and understanding of the world around them visually, as well as their personal experience. In exploring their initial impressions, most children could provide some kind of explanation, but this was inadequate as far as scientific thinking was concerned. Because of this difficulty, they perceived, as Magana, Brophy and Bryan, (2012) also reported, all objects that are not visible to the naked eye as objects that are of the same order of magnitude, i.e., small.

With regard to the first research question as to what the children thought was the smallest thing visible to the naked eye, it appeared that, while at the beginning they named small objects from the macrocosm, at the end of the program a large proportion of them realized that there are objects that are not visible. This finding as to the preschoolers' initial misperceptions of the smallest object present in their space is consistent with the findings of Mandrika, Michailidi and Stavrou (2019) and Manou and Spirtou (2018) in which it appears that students' perceptions of the smallest objects were micro-objects from the macrocosm in the vast majority. Furthermore, the shift in the preschoolers' initial views is believed to be due to the digital technology where the children literally discovered new worlds (Dorouka et al., 2019). At first the older preschoolers and then the younger ones became aware, to the extent possible, that there are indeed objects that we cannot see with the naked eye.

Regarding the second research question about the preschoolers' perceptions about the existence of objects that are not visible to the naked eye, while their initial representations were far from the concept of nano, they managed to revise their initial views and perceive that in the nanoworld there are smaller objects that are not visible to the naked eye. As mentioned above, digital applications played a key role which made the non-visible worlds visible and helped the preschoolers expand their knowledge on a cognitive and digital level (Tsiavos et al., 2020). Moreover, they were excited to discover a new world identifying nanoparticles as the most elementary material. Thus, the introduction of the concepts of nanoscience/technology in preschool education can be a realistic goal if we move along the axes proposed by the STEAM approach (engagement, exploration, explanation, processing, evaluation), (Karapanou and Tzirou, 2018). Furthermore, the visualization of the nano scale through digital technology helped the children form new representations and classify objects and elements of the micro/nano world more effectively (Dorouka et al., 2019).

The interdisciplinary nature of nanoscience/technology should be noted here and the possibility of using teaching approaches using a variety of interdisciplinary activities in the context of Science (observation, experimentation), Technology (use of tools, digital applications), Engineering (construction), Mathematics (serialization, classification, problem solving procedures, etc. etc.), as well as all the fields taught in the current curriculum, makes it possible to include nanoscience in the daily preschool classroom (Dorouka et al., 2019).

Regarding the third research question, the preschoolers identified the microscope (simple or electronic) as a tool for observing the microcosm and the nanoworld respectively. The young learners perceived the nano size as something very small, influenced initially by the interdisciplinary approaches to the program (reading texts, dramatization, classification, etc.), but mainly through cognitive dilemmas that were intentionally posed to them after they were introduced to digital/electronic microscopes and during their fruitful interaction afterwards. (Harmer and Columba, 2010). These results are in line with the findings of the study by Peikos, Manou and Spirtou (2015) which reported that young students associate nanotechnology with something very small through exploratory processes and reflective situations.

In recent years, research has highlighted the benefits of using new digital tools in the education of preschool children so that young learners can solve problems, collaborate and create (Stone-MacDonald et al., 2012). Thus, in the present study, the software used to consolidate new knowledge and concepts was functional, effective and enjoyable for the children. Although studies dealing with the implementation of nanoscience/technology through the STEAM methodology in primary education are in their early stages, there seems to be a gradually growing interest and increasing support for the necessity of introducing the subject in compulsory education (Hingant and Able, 2010; Jones et al., 2013; Laherto, 2011; Lin et al., 2015). The necessity is based on the multiple benefits that preschool and school-age children gain when participating in such exploratory processes, in that both their individual and social skills are developed (Stone-MacDonald, 2012; Torres-Crespo et al., 2014). It is no coincidence that there is growing interest in finding and utilizing developmentally appropriate digital devices and applications that will facilitate the exploratory efforts of young students because they visually portray information on the properties of nanomaterials and the application of materials in nanotechnology ((Dorouka, et al., 2020).

It was clear that using an interactive classroom in distance education and a range of digital applications enhanced the children's interest, engaged them and facilitated their understanding to a significant extent. Parents’ support for the preschoolers’ exploratory efforts at home (materials, internet, books) and their involvement as co-teachers during the distance learning sessions were crucial (Stites et al., 2021). The distance teaching interventions required very good preparation of materials adapted to the capabilities and needs of the children (Anastasiadis, 2020), the participation of parents both in the use of the digital applications uploaded on the digital platforms (Dong et al., 2020) and in the exploration of materials and books, and in the creation of alternative methods when the children could not cope with the demands of the lesson.

A prerequisite for mobilizing the interest of the preschoolers was involving them in various exploratory processes and exposing them to new information related to their everyday life. The emerging need of the children to get to know the viruses that make their bodies sick, to observe elements that are not visible to the naked eye (grains, bacteria, microparticles in the air or materials, etc.), to learn about the benefits and adverse effects of nanotechnology on humans and the environment, helped them acquire a different attitude towards knowledge (Harmer and Columba, 2010; Jones et al., 2013; Spirtou et al., 2018).

Teachers’ assistance (scaffolding) was undoubtedly of great help to all participating preschoolers (Kalogiannakis and Papadakis, 2020). Given that the present program was through distance education, parents were asked to perform various roles and were the main facilitators and educators of their children. Teachers supported and prepared parents to understand the “how”, “what” and “why” of the whole educational process (Adedoyin and Soykan, 2020). This, we believe, was one of the important parallel benefits of the implementation of this program in that educational processes found new functional forms and brought parents, teachers and students closer together to empower the children on many levels.

Overall, it could be said that the present study is in line with others which argue that it is feasible in primary education to teach at least 3 of the 9 Big Ideas of nanoscience/technology, namely: “Size and scale”, “Size-based properties of materials”, and “Measurement instruments”, (Blonder and Sakhnini, 2012; Huang et al., 2011). However, there is a great need to produce educational materials to teach the concepts of nanoscience/technology and digital devices and applications that will enhance young learners’ understanding and act as a compensation for our sensory deficits. It is also considered necessary to train primary school teachers in modern science and technology issues and how to use them in education. Informing young pupils and involving them in critical dilemmas concerning the applications of nanotechnology in modern everyday life seems to be a one-way street. The didactic approach to the subject will probably add to the work of teachers, but it may serve as a springboard for the creation of modern, attractive, dynamic learning environments in line with the needs and capabilities of young citizens of the 21st century (Dorouka and Kalogiannakis, 2020; Harmer and Columba, 2010; Jones et al., 2013; Kalogiannakis and Papadakis, 2020; Lin et al., 2015).

5. Limitations and Future Directions

The major limitation of the present study was the small and specific sample (parents, children,) as well as the specific materials created to meet our study needs. The classroom teachers did not have had any background knowledge in distance education, but were sufficiently informed about digital applications and tools. In addition, the extent of parents’ involvement at home in keeping their children aware of each topic is unclear. Despite parents' communications before each session, and teachers' admonitions to operate in concert, teachers only had an online view of the situation during lessons in which the parents (mainly the mothers) were present. The time of the distance lessons (2:10 - 4:20 p.m.) was another limitation on its own because the majority of parents regarded it as unsuitable. The platforms and networks released students and educators (in primary and secondary education) at around 1 p.m. and then given over by the Ministry of Education to preschool educators after 2 p.m. Now, teachers are more aware about distance education through their experience and additional studies conducted during the two years of the pandemic. Keeping in mind the above-mentioned program, perhaps preschool teachers would feel more comfortable applying it to reappraise its results when they have to deal with distance learning activities. The learning procedures in this paper can be extended or revised to appropriately assist preschool children's needs and kindergartens' special characteristics. We share our experience for further exploration and applications.

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