Nanotechnology in Kindergarten. Is there any Learning Gain using an ICT-based Approach?

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Abstract

This study focuses on the teaching/learning of nanotechnology-related concepts in kindergarten through an inquiry-based approach using digital scenarios in the Go-Lab platform. The change in children's views and level of understanding of the concepts, phenomena, tools, and applications of nanotechnology were investigated after their participation in an educational intervention. Using a variety of qualitative research methods, we collected data from interviews and student drawings. Our findings support the claim that students improved their understanding, but the topic was challenging and thus presented some difficulties. To overcome these difficulties, we suggest using more visual than textual types of information, as this has been shown to be more appropriate for students of this age.

1. Introduction

Many of the technological advances in the world today are related to Nanoscience and Nanotechnology (NST). Therefore, it seems more than relevant to include these topics in contemporary science curricula [1]

The inquiry-based approach is used by many teachers as it is claimed to achieve several goals, especially in science education. In this approach, students play an active role, acting as scientists and being involved in the practices and methods of science in order to construct knowledge themselves. At the same time, it is perceived as a process in which cause-effect relationships are discovered when students are asked to find solutions to real problems [2].

The design and use of appropriate educational materials, such as educational scenarios, contribute to the better performance of this approach. By creating scenarios, teachers are ultimately placed in the role of designer, planning and making decisions in advance, taking into account means, conditions, organisation, goals, objectives and evaluation.

Digital technology allows the creative use of technology in the educational process, with materials directly accessible to all, and the development of digital tools that support and promote learning and better integration of students. To design the scenarios in this work, the Go-Lab (Golabz.eu) platform was used, where teachers can create scenarios on a variety of topics in a user and creator-friendly way. This platform is specifically designed for inquiry learning, so students can also design and carry out experiments, formulate and test their hypotheses or draw conclusions, following the so-called "inquiry cycle" [3], presented in Table 1.

Table 1. General phases and sub-phases of the inquiry cycle*

General phases	Sub-phases
Orientation	Orientation
Conceptualization	Questioning / Hypothesis Generation
Investigation	Exploration / Experimentation / Data Interpretation
Conclusion	Conclusion

*Adopted from Pedaste et al., [3]

2. Body of knowledge

The field of nanotechnology integrates technology with science and engineering at the nanoscale dimensions of 1nm to 100nm. It is essentially the study of very small sizes in a wide range of scientific fields. It is argued that in order to be considered a master of nanoliteracy, one must master its big ideas, i.e., concepts such as size and scale, tools and instrumentation, size-dependent properties, and applications of NST [4]. Nanotechnology offers an opportunity to involve students in activities that are also important for them as students and as citizens of the future. These activities allow them to think critically and collaboratively and to participate in solving real-world problems [5]. Through nanoliteracy, students broaden their horizons and encounter new interdisciplinary scientific achievements and acquire the ability to judge the pros and cons of new applications, which is likely to increase their interest in this new branch of scientific discovery. It has been argued that the future workforce in science and technology should come from a 'nanoliterate' society [6].

With regard to the integration of NST topics in the curriculum, some obstacles have been reported, resulting on the one hand from teachers' views on the complexity of the relevant phenomena, and on the other hand, from students' views on the importance of these topics for their future lives [5].

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A review of the literature on teaching NST-related topics suggests that few studies have been conducted in K-12 education. For example, Lin et al. [7] found in their study of primary school students (11-12 years old) that there was a significant improvement in their understanding of NST-related concepts, while Saidi and Sigauke [8] found that their students (11-13 years old) were able to increase their knowledge and also increase their interest in NST.

This research aimed to investigate the outcomes of using digital scenarios in teaching/learning nanotechnology-related concepts in kindergarten through an inquiry-based approach using the Go-Lab platform.

3. Research methodology

This case study concerns preschool children (4-5.5 years old) in a provincial public kindergarten school in Greece with 20 students (as 2 of them missed some of the classes, we ended up with a sample size of 18 students). The researcher - a kindergarten teacher - approached the school premises after obtaining permission from the students' parents/guardians for their children to participate and for the collection/management of the children's data. At the same time, the children themselves were asked to give their consent to the research. It was emphasised to both the guardians and the children that their participation was not compulsory and that they could stop at any time during their participation if they felt uncomfortable without any repercussions. Thus, this was a 'convenience' sample, with the corresponding limitations on the generalisability of our research conclusions.

Figure 1. Students investigate objects using a variety of tools, like a magnifying glass (left) or a digital microscope (right)

For the study, multiple sources of data collection were chosen for qualitative analysis, resulting in a thorough examination of the teaching intervention from different perspectives and a more comprehensive coverage of the issue under investigation. Specifically, semi-structured interviews were used to answer the research questions, asking the children questions about the adhesive ability of the gecko lizard, the sizes of nano-objects, the tools used to visualise the nanoscale, and their understanding of the importance of nanotechnology. Drawings were also used to collect data, where students illustrated their understanding of related concepts in their own way. In addition, through the responses collected from the digital worksheets/scenarios, we were able to perceive the extent of the children's understanding, diagnose and capture their views on the subject under discussion. Finally, taking into account the percentage and time of completion of the activities, we also obtained information about their ability to interact successfully in the platform. In this direction, we also got complementary data from the teacher's personal diary, which provided a lot of information about the whole process and about the children's interactions with the digital material and with each other. This research is part of a broader study about NST teaching/learning in kindergarten, while in this paper, we will only focus on the results from the interviews and the children's drawings.

The research questions related to the study presented here are as follows: After involving kindergarten students in an inquiry-based approach using digital scenarios in the Go-Lab platform, (Q1) is there a change in their views regarding the adhesive property of the gecko lizard? (Q2) is there a change in their views regarding the use of appropriate tools to visualise objects at the nanoscale? (Q3) Is there any change in their views on the importance of nanotechnology?

In order to be able to manipulate and interpret the collected data, we followed a content analysis approach. Once all the data had been tabulated, we categorised the children's responses into four levels of success, from the lowest level (NST0) to the highest level (NST3), after evaluating the content of each response (as shown in Table 2). A similar content analysis approach of interviews [9] and drawings [10] has also been followed by other researchers in NST teaching /learning.

Table 2. Students' answers categorisation in levels of success

Level	Main feature in the answer
NST3	Scientific / almost scientific views
NST2	Partly scientific views
NST1	Alternative views
NST0	Vague / no answer

The evaluation and categorisation of the children's responses and drawings was carried out in three stages. First, 50% of the collected data was assessed independently by the teacher/researcher and two faculty members, experts in science education. After discussing and establishing common ground rules, the same data were re-assessed. Finally, the teacher/researcher completed the assessment of the remaining data.

3.1. Examples of analysis

In this section, some examples of the analysis of the drawings are presented.

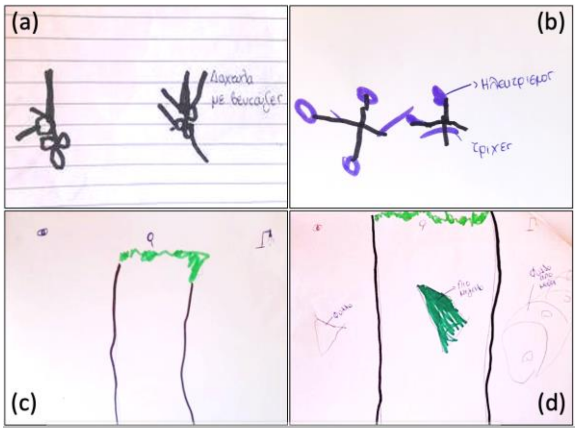

Figure 2. Students drawings representing the Gecko lizard foot (drawings a, b) and the way tree leaves are viewed when using different tools (drawings c, d)

As mentioned earlier, the drawings are evaluated and categorized in 4 levels of success, ranging from NST3 to NST0 (Table 2). The scientific views (NST3) category is assigned to drawings that have the most elements of scientific explanation of the phenomena under study. In the case of the Gecko lizard, the drawings should illustrate the abundance of the hair-like structures (called setae) that brunch into smaller tips (called spatulae), and also the large contact surface. In the case of the visualizing tools and how we see various objects through them, the amount of details is also crucial e.g. a tree leaf through the naked eye, a tree leaf through a magnifier lens where the nerves are shown and an even closer rendering of the leaf where the fibres and cells that make it up are shown when using a microscope.

For example the drawing in Figure 2d, presents exactly this scaling of views of a tree leaf and is categorized in NST3. In contrast, the same task presented in Figure 2c is categorized in NST0, as this is just an empty drawing.

The partly scientific views category (NST2) is assigned to drawings that are almost aligned with the scientific explanation: e.g. in the case of the Gecko lizard feet, the depiction of some setae and spatulae, and in the case of the visualization tools, the drawings should have the correct attribution of sizes for each tool.

For example, the drawing in Figure 2b depicts some setae and also some electrical charges explaining the adhesive property of the Gecko lizard feet and was categorised in NST2 (while other drawings more detailed depicting a large number of setae and spatulae were categorised in NST3).

On the other hand, the drawing in Figure 2a was categorised in the alternative ideas category (NST1), which is assigned to drawings in which alternative ideas are depicted. For example, in this drawing, the Gecko lizard feet are depicted as having little suction cups – a commonly found conception concerning the adhesive property of the Gecko [11].

In all previously mentioned drawings (Figure 2a-d), the handwriting is from the teachers' notes when students were asked to explain what they have drawn.

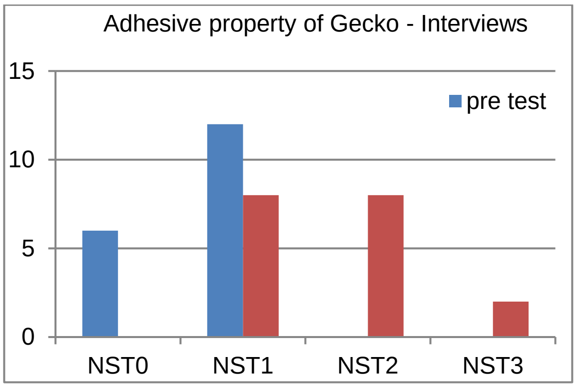

Figure 3. Pre-post comparison of Students' answers categorisation in levels of success concerning the adhesive property of the Gecko lizard
(higher level to the right)

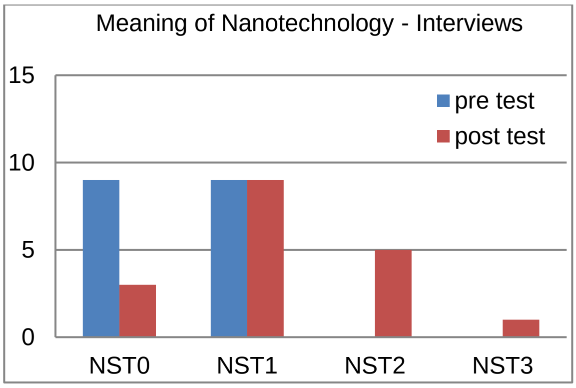

Figure 4. Pre-post comparison of Students' answers categorisation in levels of success concerning the meaning of Nanotechnology
(higher level to the right)

4. Results

In the following section we will present the results of the analysis of the responses collected during the interviews and the analysis of the students' drawings on three topics: the adhesive property of the gecko, the importance of nanotechnology and the tools we use to visualise objects at the nanoscale.

Figures 3-6, graphically represent the comparison between the pre- and post-intervention achievement levels, as previously defined (Table 2), from NST0 (left) to NST3 (right).

On the other hand, we can observe that in most cases, some of the answers and drawings after the intervention were still categorised at the lowest level of success (NST0), while at the same time, only a few students reached the highest level (NST3).

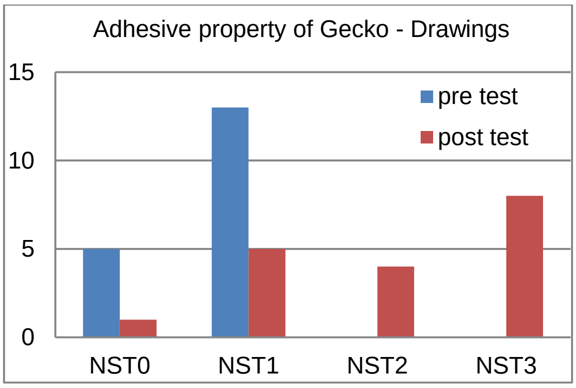

Figure 5. Pre-post comparison of Students' drawings categorisation in levels of success concerning the adhesive property of the Gecko lizard (higher level to the right)

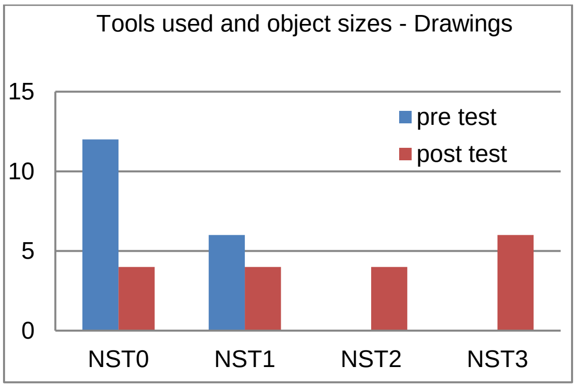

Figure 6. Pre-post comparison of Students' drawings categorisation in levels of success concerning the size of the objects in the nano-scale and the tools used to visualize them (higher level to the right)

We also calculated the Hake gain for all the previously mentioned datasets. The normalized gain, introduced by Hake (1998), "as a rough measure of the effectiveness of a course in promoting conceptual understanding. Hake defined the average normalized gain as: g= (post– pre) / (max-pre), where "pre" and "post" are respectively the average scores of the students and "max" the potential maximum score.

Table 3 presents the Hake gain for the above pre-post datasets.

Table 3. Hake gain for the pre-post datasets

Dataset	Hake gain
Adhesive property of Gecko - Interviews	0,43
Meaning of Nanotechnology - Interviews	0,29
Adhesive property of Gecko - Drawings	0,59
Tools used and object sizes - Drawings	0,50

Hake gain is a common tool for measuring the effect size within the Science Education community. Typically is divided in three ranges: small (<0.3), medium (0.3 - 0.6), and large (>0.7).

Our data fall into the medium range of the learning gain, with a clear head of the drawings datasets against the interviews datasets (where one of them is marginal to the medium range) – an observation already obvious from Figures 3-6.

5. Conclusions

In this research, we investigated the outcomes of implementing nanotechnology-related digital scenarios in kindergarten, with data collected from semi-structured interviews and drawings made by the children. Given that our results show a clear improvement in children's achievement, and thus allow us to argue - within the limitations of our case study - that nanoscience and nanotechnology (NST) could and should be included in the kindergarten curriculum, as has also been suggested elsewhere [13].

On the other hand, this topic proved to be quite challenging for children of this age, as only a few of them were able to reach the highest level of success in most of the topics that were studied.

At the same time, their levels of success were higher when they were asked to represent their knowledge than in the interviews, where they were asked to describe it verbally (Figures 3-6 and Table 3).

In our view, this is a clear indication of the right way to approach such a difficult topic in kindergarten. By encouraging pupils to use less textual information and more visual information, such as a drawing, we can not only improve their understanding but also facilitate the communication of their views to their classmates [14].

Digital scenarios provide added value to the previous remark, as visual information can be easily integrated and presented to students.

In conclusion, given that nanoscience and nanotechnology (NST) are rapidly penetrating all aspects of our daily lives, their inclusion in the curriculum seems more than obvious. NST can provide students with opportunities for authentic experiences in solving real-world problems that are interesting and important to them, not only as students but also as future citizens [5]. This was also noted in the teacher's log, which described the pupils' great enthusiasm when asked to carry out investigations using physical or digital objects and manipulatives, leading to a deeper engagement with the subject.

5. References

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