Primary School Students' Preconceptions about the Term Nanotechnology and the Water Nano-filters

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Abstract

Nanoscale Science and Technology (NST) concerns the understanding and the manipulation of matter at the nanoscale (1 to 100 nm), where unique properties of materials enable novel applications. Since a lot of NST products are available, e.g. water nano-filters, it is argued that students need to develop their nanoliteracy to come up with everyday issues arising from NST applications. However, research related to students' preconceptions about NST topics in primary school is limited. This paper aims to answer two research questions (RQs): What are the students' preconceptions about (1) the term nanotechnology and (2) the mechanism of the water nano-filters? The participants were 250 (for the RQ1) and 132 (for the RQ2): 5th and 6th-grade primary school students from Greece. A written questionnaire with open-ended questions was used for the data collection. A deductive as well as an inductive qualitative content analysis approach revealed theory-driven and data-driven categories, respectively. In particular, the categories revealed for the RQ1 formulated on the Big Ideas of NST and the data, while categories for the RQ2 formulated on the relational and linear reasoning models in combination with the accuracy of the specific information that students mentioned. The study showed that most of the students conceptualize NST in the context of size in a vague manner, e.g. "a technology for small things". Moreover, a substantial number of participants provided anthropomorphism-related terms ("nano" in Greek means dwarf) while only a few students referred to NST applications as well as to observation tools. Concerning water nano-filters, the majority of students provided linear explanations including vague information about the filtering mechanism, e.g. "the filter consists of small pores". Explanations based on the observable pattern (the use of the filter), were also evident. The findings of this research could enhance our knowledge for designing educational interventions about the NST content through the lens of the constructivist approach.

Keywords: *Primary school students, preconceptions, nanotechnology, water nano-filters*

1. Introduction

Nanoscale Science and Technology (NST) concerns the understanding and the manipulation of matter at the nanoscale (1-100 nm), where unique properties *of materials* enable novel applications. The literature review revealed specific "Big Ideas" of NST (i.e. core concepts) that are proposed for inclusion in compulsory education, such as the size and scale, the tools and instrumentation, the size-dependent properties as well as the applications of NST [1]. Since a lot of NST products are already available in the market, it is argued that students need to develop their nanoliteracy to come up with everyday issues arising from NST applications [2]. For instance, we can find portable water bottles that purify the water taken directly from lakes or rivers [3]. More specifically, nanoporous membranes have been developed in order to separate the unwanted particles that can be contained in the water (e.g. viruses) [4]. However, research on primary school students' preconceptions about NST content is in its infancy, indicating that only a few students relate nanotechnology to small size [5]. Secondary school students and adults, in contrast, tend to relate nanotechnology to science and technology in general or applications such as computers [6].

In this paper, we aim to answer two Research Questions (RQs):

- RQ1. What are primary school students' preconceptions about the term nanotechnology?
- RQ2. What are primary school students' preconceptions about the filtration mechanism of a nano-filter?

2. Method

The participants of this research were 250 for the RQ1 and 132 for the RQ2: primary school students (10-12 years old) from Greece. A written questionnaire with two open-ended questions was developed for the data collection:

- "A student has read on the internet about the term nanotechnology and wondered what it means. How would you explain to him/her what nanotechnology is?" (RQ1).

- "Suppose that you have gone fishing to a lake with your friend. You forgot to bring your water bottle but your friend has a bottle with a water nano-filter. Would you drink water from the lake using the water nano-filter? How do you think that the nano-filter works?" (RQ2).

Students' answers were broken down into Units of Meaning (UM). Concerning coding, a deductive as well as an inductive qualitative content analysis approach revealed theory-driven and data-driven categories, respectively. In particular, the categories revealed for the RQ1 formulated on the "Big Ideas" of NST [1] as well as on the data (Table 1).

Table 1. Coding rubric for the term nanotechnology (RQ1).

Category	Subcategory
C0 Vague or no answer	-
C1 Anthropomorphism-related terms	-
C2 Size	Sub2.1 General references to small size Sub2.2 References to the term microworld or/and microworld objects Sub2.3 References to the atomic world objects
C3 Observation tools	Sub3.1 References to the limit of the observation tool of the macroworld (naked eye) Sub3.2 References to the observation tool of the microworld (optical microscope) or its limit
C4 Applications of nanotechnology	Sub4.1 Relating nanotechnology to electronics Sub4.2 Relating nanotechnology to medicine Sub4.3 Relating nanotechnology to the industry of water repellent textiles Sub4.4 General references to improvements in life
C5 The new technology	-

The categories for the RQ2 formulated on the relational and linear reasoning models in combination with the accuracy of the specific information that students mentioned [8] [9] (Table 2).

Table 2: Coding rubric for the water nano-filters (RQ2).

Category	Subcategory
C0 Vague or no answer	-
C1 Linear causal reasoning including vague specific information about the water purification process using nano-filter	Sub1.1 Linear causal reasoning including vague specific information about the structure of the filter or/and the pattern (use of the filter) Sub1.2 Linear causal reasoning including incorrect information about the purification process, e.g. wrong mechanism
C2 Relational causal reasoning with vague specific information.	-
C3 Relational causal reasoning with correct specific information about the filtration (relating the size of the nanostructure to the size of the objects that excludes)	-

3. Results

Concerning the RQ1, the category with the highest percentage of UM was the "size", followed by the "vague or no answer" and the "anthropomorphism-related terms". For instance, a student mentioned *"Nanotechnology is the technology of dwarf"*.

Table 3. Categories for the term nanotechnology: Frequencies/Percentages of the UM.

Category	Frequency	Percentage (%)
C0	74	27,82
C1	63	23,68
C2	76	28,57
C3	13	4.89

C4	33	12,41
C5	7	2,63
Total	266	100

In Table 4, it is evident that most of the UM about the size were connected to small size in general (Sub.2.1). Only a small percentage of UM was related to non-visible objects such as *"It is the study of microscopic parts of our body, like cells"* (Sub.2.2, Sub2.3).

Table 4. Subcategories for C2 Size: Frequencies/Percentages of the UM.

Subcategory	Frequency	Percentage (%)
Sub2.1	69	90,79
Sub2.2	3	3,95
Sub2.3	4	5,26
Total	76	100

Most of the UM about observation tools were connected to the microscope (Sub3.2). An illustrative UM was *"This technology utilizes strong microscopes"* (Table 5).

Table 5. Subcategories for C3 observation tools: Frequencies/Percentages of the UM.

Subcategory	Frequency	Percentage (%)
Sub3.1	2	15,38
Sub3.2	11	84,62
Total	13	100

Concerning the applications of nanotechnology, the highest percentage of the UM was connected to electronics (Sub.4.1) (Table 6). An indicated UM was "*This technology builds small chips".*

Table 6. Subcategories for C4 Applications of nanotechnology: Frequencies/Percentages of the UM.

Subcategory	Frequency	Percentage (%)
Sub4.1	29	87,88
Sub4.2	2	6,06
Sub4.3	1	3,03
Sub4.4	1	3,03
Total	33	100

Regarding the results about the RQ2 (Table 7), most of the UM included linear casual reasoning with vague specific information about the water purification process (C1). Most of these UM were connected to the structure of the filter or/and the pattern (Sub1.1); an illustrative UM was *"The filter includes holes"*. Fewer UM included a wrong mechanism (Sub1.2), such as *"The filter includes cells that purify the water".*

Table 7. Categories for the mechanism of the water nano-filters: Frequencies/Percentages of the UM.

Category	Frequency	Percentage (%)
C0	25	18.94
C1	87	65.91
C2	20	15.15
C3	0	0
Total	132	100

4. Discussion

Concerning students' preconceptions about the term nanotechnology, we found that almost half of the students related nanotechnology to the size, the observation tools and the applications of NST even in a vague manner. We assume that the contrast between our findings and literature [5] is due to the following two reasons: firstly, the related study [5] was conducted more than thirteen years ago. More specifically, in 2006 were reported proximately 380 nanotechnology consumer products [9], while in 2020 there are available more than 5000 products (http://nanodb.dk/en/). Secondly, the Greek language maybe made students to relate the term nanotechnology to the small size since the prefix "nano" in Greek means small or dwarf. Consequently, some of the students related nanotechnology to small things, such as cells, while other students related it to dwarfs. Regarding water nano-filters, students' answers included linear causal explanations about the filtration process. It is evident that students are not aware of the nanostructure of the filter and could not relate the size of the objects that are dispersed in the water to the size of the filter's pores.

The findings of this research could contribute to designing educational interventions about the NST content through the lens of the constructivist approach. More specifically, since students' preconceptions about the term nanotechnology were related to the three concepts of the NST (i.e. the size, the observation tools and the applications of NST), an instructional approach could be designed that will include all of these concepts. Concerning water nano-filters, an educational approach could consist of tasks that will help students develop an understanding of the size of both the filter's pores and the unwanted particles that could be contained in the water (e.g. viruses), enabling them to develop their relational causal reasoning.

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