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Educational Significance of Nanoscience–Nanotechnology: Primary School Teachers’ and Students’ Voices after a Training Program

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Abstract: Most of the modern technological applications we use in our daily life originate from the progress of Nanoscience–Nanotechnology (NST). The projection, showing the great impact that these advances are going to have on society, exhorts science education researchers to incorporate the modern field into educational contexts. Among the several issues that have to be dealt with, NST’s educational significance comes to the fore. This pilot study aims to examine whether both nano-trained primary school teachers and nano-trained students acknowledge the need for the inclusion of the NST content to school contexts. Fourteen primary school teachers and ten students, after their participation in an NST training course, were interviewed in order to provide their justifications. The results show that the vast majority of the participants acknowledge the educational significance of NST. The main arguments were associated with career possibilities, the relevance of the content to everyday life, and the need for nanoliteracy attainment. The results of this study can be used by NST education researchers in order to formulate a NST content structure for primary school nanoeducation.

Keywords: educational significance; nanoscience; primary school teachers; primary school students



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1. Introduction

Modern society is characterized by astonishing technological advancements that have improved the quality of life. Smarter electronics, more efficient drug delivery systems, more advanced materials than were used in the past, have all opened up new possibilities for citizens in terms of communication, medicine, textiles, sports etc. Many of these advances have been made as a result of the progress that has been achieved in research on the small scale of “nano”. Nanoscience and Nanotechnology (hereinafter NST) are contemporary state-of-the-art fields that focus on the discovery of new materials at the nanoscale that exhibit novel properties. For example, carbon nanotubes, an extraordinary material whose dimensions fall into the nano regime, are incorporated into tennis rackets’ frames to make them lighter and, simultaneously, to boost their strength [1,2].

The impact of such advances and upcoming revolutionary developments on everyday life—both present and future—challenge science education researchers to incorporate this cutting-edge field into school contexts [3–6]. However, several challenges and issues emerge [7]. One of the main issues that has to be examined is whether teachers, and even students, acknowledge the educational significance of the inclusion of NST in school curricula. On the one hand, research findings indicate that teachers’ perspectives should be taken into account for any attempt at curriculum innovation. Undoubtedly, teachers’ ideas about the content, the teaching process, and the learning of science can hinder or promote the implementation of any reform [8,9]. For example, in the case of the innovation concerning the inclusion of NST in school curricula, teachers may believe that the underpinned content is too complex for their students to conceptualize, and as a

result, they may be reluctant to include NST in their classrooms. On the other hand, we consider that students' viewpoint about the educational significance of NST should also be examined. If students have the opinion that NST is a significant subject that is relevant to their daily lives then it is more likely to achieve notable gains in their learning.

This study focuses on the above-mentioned issue. In particular, we aim to convey both students' and teachers' voices regarding the educational significance of the incorporation of NST into school curricula. Specifically, the objective of the study is to bring to the surface primary teachers' and students' views on whether they think the inclusion of NST into classrooms is necessary or not. Until now, we have not found any studies that examine whether teachers or students actually promote the inclusion of NST in school contexts. This study aims to shine a light on this gray area of research. We stress that we are interested in examining both nano-informed teachers' and students' views, since analyzing the educational possibilities of a new field "requires informants with an understanding of the field in question" [10] (p. 127). Consequently, the research question that drives this study is: what justifications do nano-trained primary school teachers and students provide concerning the educational significance of NST?

2. Theoretical Background

2.1. *The Model of Educational Reconstruction*

The Model of Educational Reconstruction (hereinafter MER) has been conceived by German researchers as a theoretical framework for studies that explore the possibility of teaching salient concepts and principles of science. It is structured by three interdependent components. One of them, namely, the clarification and analysis of the scientific content, includes the analysis of the educational significance of the content, i.e., whether it is worth teaching a particular area of science. MER has been implemented in analyzing the educational perspectives of modern scientific topics, such as non-linear physics and NST [10–12].

Through the clarification and analysis of the scientific content, on the one hand, the content is critically analyzed through leading scientific books and key publications of the field, and, on the other hand, its educational significance is highlighted. In the case of NST, the critical analysis of the NST content has already been documented [13]. In brief, through the close examination of a large number of published papers and books regarding the content of NST, the salient concepts of the field were identified. The content of these concepts was analyzed through the lens of introducing the particular content to primary education, i.e., whether the content is appropriate for the developmental stage of the students. For example, the concept of surface area to volume ratio, which explains the surface dominated properties of nanoscale materials, constitutes a concept that primary school students may find difficult to conceptualize due to the lack of an underlying developmental level. The educational significance is the subject area of this research paper.

Among other methods, the analysis of educational significance may involve empirical studies, through which questionnaires or interviews may be used for examining the views of experts [14]. For example, Komorek et al. [15] performed an empirical study in order to examine the educational significance of non-linear physics. Likewise, this study aims to analyze the educational significance of NST by examining the relevant viewpoint of a "group of experts", i.e., nano-trained teachers and students.

2.2. *Educational Significance of NST: A Review of the Literature*

Through the relevant literature, the first issue arising is whether it is necessary to devote time and effort to educate students or teachers in NST concepts and phenomena. In the following paragraphs, we provide justifications presented by NST scientists and engineers, educational policy makers, and government agencies. Our aim is to scrutinize these in an effort to determine their validity for primary school education.

One of the most common arguments is related to concerns about the lack of specialized staff in "nano-related" fields. Since the onset of NST, education was considered to be the main way to bridge the gap between the workforce needs and the cutting-edge field [16,17].

In fact, connecting NST with the workforce needs became compulsory education. Notably, NST educators argued that since primary school students constitute the future workforce in NST, their early contact with the emerging field is essential [18]. However, we consider that the teaching of NST in primary school education is not strictly oriented towards directing the students to pursue a relevant professional career. Instead, it is closely linked to one of the goals of science education, which is to familiarize students with new research and technology opportunities and help them enhance their ambitions. This is a perspective that students seem to find really fascinating about science [18,19].

Furthermore, there are arguments that focus on the importance of students achieving scientific and/or technological literacy, two concepts that have a substantial impact on curriculum design worldwide [20]. The basic idea is that all citizens will need some kind of “nanoliteracy” to formulate an opinion in an informed and responsible way on issues that stem from NST’s advancements and affect their everyday life [20,21]. For instance, during the COVID-19 pandemic citizens had to make decisions about both their personal, as well as public, health [22]. A typical example was the modern mRNA vaccines that were based on nanoparticles and were developed due to the advancements of NST [23]. People had to decide if they would like to be vaccinated or not. It was evident in the public dialog, that misconceptions were uncovered and spread rapidly on social media. For example, some people stated that these vaccines could lead to the alteration of the recipient’s genome via the injected RNA [24].

Despite the fact that scientific/technological literacy is a frequently stated goal of science education (e.g., acquiring literacy in energy or environmental issues), in the case of NST it requires special attention, due to the previous examples of modern research, which were greeted with skepticism by the population because of low literacy (e.g., biologically modified foods) [25,26]. Such public attitudes, in the case of NST, are sought to be prevented by creating a literate population on nanoscale issues, an effort that starts at an early age [9,27]. With the introduction of NST, primary school students have the opportunity to develop reasoning skills about balancing the risks and benefits of the products they utilize in their everyday lives [28].

Additional arguments place emphasis on the pedagogical benefits, which are related to students’ interest in science. In particular, there is evidence that as students’ studies at the educational level evolves, their interest in science decreases. On the one hand, this finding has been attributed either to the fact that school science seems rather disconnected from students’ everyday lives, or, because the introduction of modern achievements in science and technology into the curriculum is underestimated [19,27]. On the other hand, NST includes a plethora of achievements and studies a wide range of phenomena of which students become witnesses through their everyday lives. Some typical examples are sports equipment (e.g., rackets), sunscreens containing nanoparticles, and superhydrophobic and self-cleaning fabrics, etc. The introduction of these products into the classroom, in combination with the underlying science principles, can guide students to the interpretation of the modern technological world and, also, can increase their interest in science [29]. Educators support the view that when teaching draws on applications of NST from everyday life all students are engaged, even those who do not consider themselves to be high-achieving in science [30].

In addition, the inherent interdisciplinary nature of NST is often seen as an opportunity for students to experience the collaboration of different fields of science and engineering to conceive the abstract nanoscale world [31,32]. Nanoscale research requires a high degree of collaboration between scientists and engineers in order to tackle complex phenomena [21]. In the context of science education, bridging and integrating scientific fields is considered to be one of the goals of curriculum reforms [32]. This effort is related to facilitating students’ ability to understand the relationships between concepts belonging to different fields when they are introduced to real-world problems [21,33]. The integration of NST into education promotes an interdisciplinary approach that can “help students build meaningful insights into the great ideas of science” [31] (p. 12).

Nano-trained science teachers also have expressed some arguments concerning the educational significance of NST. For example, in Laherto's [10] study, the majority of the science teachers that participated in a NST training course, emphasized that the modern content should be taught in schools. The main justification was associated with the NST products and applications that have invaded the modern markets, their societal impact, and the future prospects. In addition, some of the participants justified their opinion by correlating NST with the possibilities opening up to students for further studies and working life. Furthermore, teachers seemed to acknowledge that NST could be the means for promoting students' interest in science and technology in general. Finally, the fact that teachers preferred the incorporation of NST into existing traditional subject areas of science indicates that the participants identified the relevance of NST with the science curriculum. Nevertheless, there were two teachers that greeted the inclusion of NST with skepticism, since, as they argued, the curriculum is overloaded and there is no room for other scientific domain.

In the following figure (Figure 1), the above-mentioned types of justifications provided by NST educators, policy makers, industry leaders, and science teachers are depicted in three circles. The "career opportunity" circle refers mainly to the need for a skilled workforce in nano-related fields. "Nanoliteracy" is associated with the need for students to be able to develop awareness about the modern NST advances they utilize and the everyday phenomena that originate from the nanoscale structures [34]. The "relevance with the curriculum" circle correlates with the possibility of formulating an interdisciplinary science curriculum, which will bridge the gap between the discrete facts coming from different science fields and contextualize learning through the numerous NST advancements.

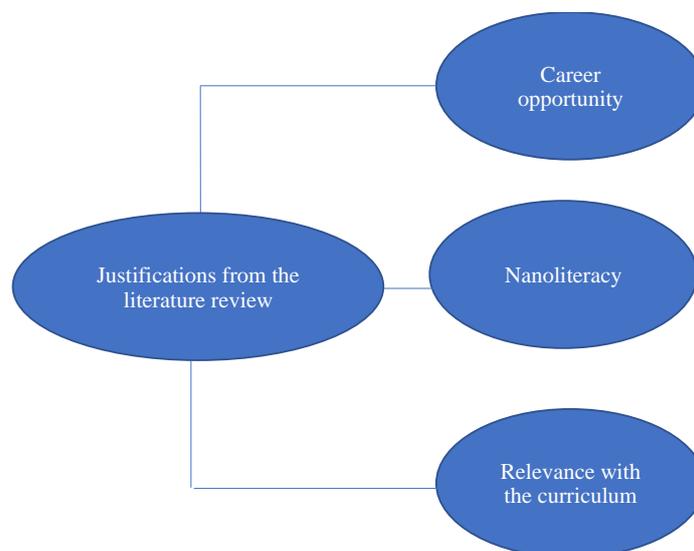


Figure 1. The three types of justifications for the inclusion of NST to education.

At the time of writing this study, from the literature review, it can be concluded that we cannot find many studies that examine teachers' or students' views about the educational significance of NST. Much of the efforts refer to measuring teachers' or students' knowledge gains before and after the training courses [35,36], the difficulties that teachers face when they intend to teach NST to their students [27], finding the NST topics that students find interesting [37], and the identification of the insertion points of the essential NST concepts into the science curriculum [38] etc.

3. Materials and Methods

3.1. The Context of the Study

Fourteen primary school teachers (PTs) (1 kindergarten) participated in a NST training program which consisted of three phases that lasted approximately 9 months in total (Figure 2). During the first 2 months, PTs were trained on salient NST concepts, phenomena, and applications, such as size and scale, lotus and gecko effects, water filtration systems, and models of nanoscale structures (e.g., models of nanoporous membranes) (approximately 27 h) (Table 1) [13,39]. Within this phase of the program, PTs were familiarized with the teaching methods that were implemented in order to be enabled to develop awareness about the modern field, such as inquiry-based teaching and learning, the Jigsaw method [40], and out-of-school activities etc. Consequently, the participants, through guidance, and in collaboration with the researchers, planned and taught NST content to their fifth- and sixth-grade students (Table 1). In the final phase of the program, the participating PTs shared their reflections about the educational perspectives of NST in primary schools (e.g., the difficulties they faced during the implementation).

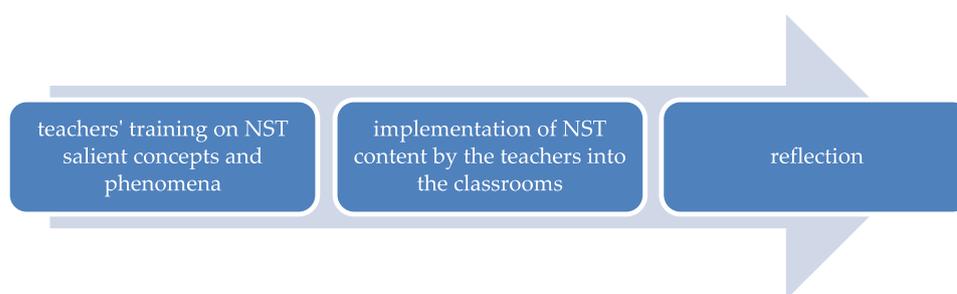


Figure 2. The NST training course [39].

Table 1. Intended learning outcomes of the NST training course for the teachers and students.

Content	Intended Learning Outcomes	
	Teachers Should Be Able to:	Students Should Be Able to:
Size and Scale/observation tools	(a) define the nanoscale by its size range, the landmark objects that includes, the tools that render the objects visible (b) acknowledge that electron microscopes can be used for viewing nanoscale objects	(a) classify various sizes objects into the macro, micro and nanoworld based on a qualitative criterion i.e., the observation tool that render each world accessible (naked eye, optical microscope, electron microscope), (b) order macro, micro and nanoworld objects based on a qualitative criterion: "which object is part of the other or fits into the other?"
Lotus effect	understand the super hydrophobic and self-cleaning property of the lotus leaf and the importance of the surface contact area	(a) explain the lotus effect using the concept of leaf's nanostructure and the trapped air in the interstitial spaces between the nanostructures (b) recognize commercial products that mimic the lotus effect
Gecko effect	understand the strong adhesion property of the gecko lizard and the importance of the surface contact area	-
Water nano-filters	realize the size-exclusion effect used in water purification systems	explain the filtration mechanism relating the size of the nanostructure to the size of the objects that excludes
Models	(a) Understand that models represent properties of macroscale, microscale and nanoscale objects (b) Realize that models can be used to obtain information about inaccessible targets	(a) create models in order to explain phenomena e.g., the lotus effect (b) recognize epistemological aspects of models i.e., the nature and role of models (e.g., the models are representations, the models focus on specific aspects of the objects)

3.2. Participants

Among the fourteen primary school teachers that engaged in the NST training program, ten of them taught the NST content to fifth grade students, while the rest to sixth grade students. The participants of this study represent the total number of teachers ($n = 14$, 10 female) and of sixth grade students that attended all of the lessons of the NST content ($n = 10$ students, 7 girls). The primary school teachers of the study volunteered to participate in a lifelong learning program entitled “Educational Innovations in Science, Environment and Technology”. Among the requirements, the participants had to be in-service teachers and, at that time of the year, to teach in the primary school grades. The teaching experience ranged from 5 to 20 years with a mean of 15 years. We note that we do not only examine teachers’ views but also their students’ views. Following this orientation, the arguments of the teachers are considered valid if they are similar to those of the students. To illustrate, we provide the following example. Suppose, on the one hand, teachers support the view that NST topics may be interesting for students, and, on the other hand, students may claim that NST topics do not belong to their field of interest, it is obvious that this particular argument provided by the teachers is not valid.

3.3. Data Collection

The research tool was a semi-structured interview protocol that was applied to the teachers and case studies of students one week after their participation in the training course and the Teaching Learning Sequence, respectively. The duration of the interview was approximately 30 min. The purpose of the interview was twofold: on the one hand, to inquire the level of both teachers’ and students’ understanding of NST concepts, and, on the other hand, to bring to the surface the participants’ views about the educational significance of NST content in primary schools. This paper focuses on the latter. Typical examples of questions the teachers were asked include: “do you think that nanotechnology content should be included in primary school?” and “do you think that a nanotechnology course is valuable?”, while, the corresponding questions the students were asked include: “how would you find the idea of other students participating in the Nanotechnology course to be?” and “how did you find the nanotechnology course?” The above questions have been addressed in other previous studies that had the goal of exploring the educational significance of nano-trained teachers (e.g., [10] secondary science teachers).

3.4. Data Coding

The data coding was qualitative and was hung upon the inductive category process [41]. Firstly, we transcribed the interviews in full. Then, we identified units of meaning (UM), namely, words or phrases that were meaningful for the educational significance of NST. After the first-round coding of the UM (9 initial codes), we increased the level of abstraction by identifying common themes among them and we developed three categories. In Table 2, we present the categories and the criteria for classifying a UM to the corresponding category. The criteria were based on the initial codes that we created. For the reliability of the coding process, two independent researchers with extensive experience in science education, coded all of the UM. We used Cohen’s kappa value in order to estimate the agreement between the two researchers. Taking into account that when the Cohen’s kappa value is above 0.80 the inter-rater agreement is considered almost perfect, we concluded that the agreement between the two researchers was high (Cohen’s kappa = 0.89) [41,42]. The minimum differences that occurred were handled through discussion until the researchers reached a consensus.

Table 2. The categories and the corresponding criteria for coding Primary Teachers' and Students' Units of Meaning about the educational significance of NST.

Categories	Criteria
Innovative content relevant to everyday life	– impressive applications & phenomena
	– students' enthusiasm
	– relevant to everyday life through modern applications and phenomena
Future career	– explaining phenomena
	– new frontiers for students' studies
Relevance of NST content to school science curriculum	– new careers
	– -mentioning concepts of the curriculum that could be related to the NST
	– in the primary school the students could be familiarized with NST concepts while in secondary school they could expand their knowledge
	– curriculum constraints

4. Results

In Table 3 the percentage of Teachers' and Students' UM per category about the educational significance of NST are presented.

Table 3. Percentage of Teachers' and Students' Units of Meaning per category about the educational significance of NST.

Categories	Teachers (21 UM)		Students (20 UM)	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Innovative content relevant to everyday life	13	61.90	17	85.00
Future career	3	14.29	3	15.00
Relevance of NST content to the school science curriculum	5	23.81	0	0.00

4.1. Innovative Content Relevant to Everyday Life

The category including the highest percentage of UM for both teachers and students was the "innovative content relevant to everyday life". For instance, a teacher highlighted that there are already available nanotechnology applications in everyday life that could be the subject of inquiry in the classroom:

"It is valuable to teach nanotechnology in schools. First of all, nanotechnology is a part of our life. We can bring into the classroom nanotechnology applications, being useful in everyday life and familiarize students with them. Working in the classroom regarding a topic that is evident in real life is very important."

Another teacher emphasized that the NST is offered so that impressive content can be brought into the classroom: *"Firstly, it [NST] is something different and its outcomes are impressive, such as all these experiments we did with the children with the lotus leaf, with a gecko lizard that is 'hovering' ..."*

Similarly, a student pointed out the relevance of nanotechnology to the resolution of real-life problems: *"I liked that we learned about the nanofilter. If there were no nonscientists, the children from Africa would have not clean water. I don't say that now they all have clean water but efforts are being made."*

Another student gave prominence to the explanations of processes that are based on nanoscale agents, such as viral infections: *"I find the knowledge of what is happening in the nanoworld very useful. (For example) how we catch a virus in order to protect ourselves"*.

4.2. Future Career

The category "future career" comprised three UMs for both teachers and students. The participants referred to opportunities for new jobs related to the NST field, or to further

university studies in the same field. For example, a teacher highlighted opportunities for NST-related jobs:

“For example, I saw that there are 300,000 nanotechnology companies. Since I can realize what these companies can do, I think that a lot of other companies will shift their interest towards NST. In other words, it is not bad for Greeks to start involving in this kind of work.”

Another teacher referred to university studies in the NST field:

“This is the future of our students. In recent years, computer science has attracted students’ interest for studying at the university because we thought that it was a good prospect. We started teaching computer science both in and out of schools from early stages. I think that nanotechnology is something similar and we have to start teaching it in schools because it is an excellent prospect.”

Similarly, a student explained that it is important that nanotechnology content is included in schools, in order for students to be informed about the new field for future university studies: *“Maybe I would choose to study nanotechnology [at the university] if I had some basic knowledge about nanotechnology”*. Another student referred to a future career as a nanoscientist: *“Because it can be something that may gain my interest at this age and will make me continue when I grow up. Maybe I want to become a scientist in the field of nanotechnology.”*

4.3. Relevance of NST Content to the School Science Curriculum

Not surprisingly, the category “relevance of NST content to the primary school science curriculum” was found only in the teachers’ UM. Teachers think that in primary schools, students should be familiarized with NST concepts and construct some basic NST knowledge in order to expand it by understanding more sophisticated concepts in higher grades:

“If we introduced a unit about nanotechnology in 6th grade, students could be aware that nanotechnology already exists and be familiarized with some concepts. Then in secondary schools it would be easier to expand their knowledge.”

Moreover, another teacher found a point of insertion for NST content to the primary school science curriculum. Specifically, it was mentioned that an optical microscope, that is included in the curriculum, could be a pathway to other NST concepts:

“First of all, the primary school science book includes some pictures that depict an optical microscope. When my colleagues see this picture, they turn the page considering that it is just a picture, underestimating it. After the training program in nanotechnology, I realized that, that picture was very important at this part of the book, the optical microscope should be taught into the classroom as well as, other NST concepts could be incorporated to this specific part such as the electron microscope.”

Only one teacher expressed her disagreement for introducing NST concepts into the primary science curriculum, justifying her opinion based on curriculum constraints:

“I admit that I don’t teach physics in school. [...] All we learned was interesting. However, I would prefer the training program focus on the concepts that we already teach in primary schools, because I could apply that knowledge into the classroom immediately . . . I consider that in the way that our curriculum is structured today, as well as due to the existing deficiencies, nanotechnology is not so necessary in primary schools.”

To summarize, the findings indicate that both of the groups acknowledged the educational significance of NST, taking into account, on the one hand, the innovative content, which, as the participants argued, has close connections with the everyday life, and, on the other hand, the career possibilities that open up due to the rapid development of the field. In addition, primary school teachers justified their view, mentioning the relevance of NST content to the current primary school science curriculum.

5. Discussion

The purpose of the study was to highlight nano-informed primary teachers' and students' views about the educational significance of the modern field of NST. This aspect is considered a first step towards any educational innovation and is often examined by educators and policy makers. This particular study differs to the studies that examine the educational significance from the perspective of nanoliterate primary teachers and students, as "the teachers who are implementing the curriculum innovation must be heard in the first place" [10] (p. 136).

To maintain objectivity in the research, we stress that the educational significance of NST was not discussed during the training programs with the teachers or the students. The opinions that we presented belong solely to the participants, since the training courses focused entirely on developing their NST content knowledge and not on introducing other aspects such as the educational significance of NST.

Answering the research question, we notice that both the nano-trained groups (i.e., students and teachers) acknowledged the significance of introducing NST content in school contexts providing several justifications. The main one was the close relevance of the NST content to everyday life. The participants agreed that there are phenomena, such as the strong adhesion of a gecko lizard because of which it defies gravity, and applications, such as the water filters, which are closely connected to real life. We note that, during the reflection phase of the NST training course (Figure 2), some teachers noted their students' curiosity, enthusiasm, and engagement when conducting experiments in order to observe the superhydrophobicity that some plants and artificial fabrics exhibit.

The fact that teachers and students acknowledged the close relevance of NST to their modern everyday life (innovative content relevant to everyday life) reflects the justification of scholars for the educational significance of NST that is associated with nanoliteracy (Figure 1). Indeed, all of the members involved seemed to reach a consensus that one significant aspect of the educational significance of NST lays on the need of citizens to develop their nanoliteracy in order to handle issues that relate to NST and occur in their everyday lives (e.g., nano-based vaccines and nano-based fabrics etc.).

In addition, both PTs and students seemed to project the opening of career opportunities with the advent of NST. The science curriculum of our country introduces scientific concepts to students in order to describe phenomena (e.g., the concept of force, or the concept of energy), however, they are not correlated with future careers or studies. Our findings indicate that PTs see the inclusion of NST in school contexts as an opportunity to discuss career issues with their students, which provides several pedagogical benefits, such as "inform students of the possibilities and door openers and thus developing the range of their aspirations" [19] (p. 72). To this direction, there were some students, who, in their interviews, did not close the door on becoming nanoscientists.

Concerning the relevance of NST to the already existing curriculum, this particular argument is expressed by educators in order for teachers to be persuaded to include NST in their lessons. Some teachers tend to believe that there is no room for any new subject to the science curriculum, and as a result, they reject the educational significance of NST [29]. However, the nano-trained PTs of our study, consider that NST applications is a context in which abstract scientific concepts can be introduced to their students. For example, the strong reverse adhesion of the gecko lizard constitutes a good example that teachers can use to teach the concept of the electrical forces. Furthermore, the results show that neither teachers nor students thought NST to be the means for designing an interdisciplinary curriculum. This finding is likely based on the fact that the training program did not include any activities regarding the interdisciplinary feature of NST. On the other hand, scholars see NST as an appropriate subject for promoting interdisciplinarity. It seems that NST educational designers should provide learners with the opportunities to experience the interdisciplinary feature of NST, in order to enable learners to enrich their views about the educational significance of NST.

In particular, concerning the teacher who stated that NST content should not be introduced in primary schools, we think that the disagreement could be justified as follows: during the training program this teacher expressed several times her lack of experience regarding teaching science to primary school. We consider this teacher as a case study of the category of teachers who do not teach science, and, as a consequence, don't feel confident to approach innovative science content, such as nanotechnology. In the literature, it is argued that for primary school teachers, the acceptance of the innovation and the willingness to bring it into the classroom is sometimes hindered by low self-confidence, related to the lack of knowledge of the new content [43].

Since teachers play a crucial role for any educational innovation and teachers' and students' viewpoints may contribute to the development of a curriculum and instructional materials, we consider that the findings should be taken into account by training programs' developers and educational policy makers. The findings, concerning educational significance, indicate that an appropriate NST content for primary schools should comprise NST applications that are meaningful to students' lives and that could be correlated with concepts that are included in the curriculum. In addition, the proposed content could include activities in order for students to be familiarized with nano-related professions.

To conclude, this pilot study raises the question of whether nano-trained teachers and nano-trained students view NST as an important content area that should or should not be included in the school curriculum. It consists of the first attempt to map primary nano-trained teachers' and students' voices regarding the educational significance of NST. All in all, the participants agree for the need to incorporate NST content into the school science curriculum. Their justifications seem to be in line with those expressed by science education researchers, industry leaders, and education policy makers. The findings of the current study are limited by the small number of participants (students and teachers). Further research is needed; with a larger number of participants to verify the findings of the study. In addition, we should notice that the findings originate solely from participants' interviews that took place only after the implementation of the NST content to the student. We did not examine teachers' justifications that were expressed during all of the phases of the training course (Figure 2). The above limitations inspire the formation of future studies concerning the educational significance of NST.

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