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Developing student-made artifacts on nanotechnology issues in a context of interacting formal and informal learning settings

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ABSTRACT

This paper examines student-curated artifacts that were developed in the context of a teaching module on nanotechnology applications that combined formal and informal learning experiences. Deriving from the fact that the negotiation of modern scientific objects constitutes a suitable field for the harmonious connection between formal and informal education, the present study aims to delve into students' understanding of nanotechnology concepts, as reflected in student-curated artifacts. Fifteen teachers and 298 students took part in the study developing a total of 19 artifacts on nanotechnology issues and their societal implications. The results show that such a partnership can help students acquire, depending on their level and cognitive background, basic knowledge on key nanotechnology concepts and to communicate it using multiple activities of graded cognitive demands.

KEYWORDS

Student artifacts, nanotechnology, science communication, combination of formal-informal education

RÉSUMÉ

Cet article examine les artefacts développés par des étudiants dans le contexte d'un module d'enseignement sur les applications de la nanotechnologie qui combinait des expériences d'apprentissage formelles et informelles. *Partant du fait que la négociation* d'objets scientifiques *modernes constitue un domaine propice à la connexion harmonieuse entre l'éducation formelle et informelle, la présente étude vise à approfondir la compréhension des étudiants des concepts de nanotechnologie, tels qu'ils sont reflétés dans les artefacts créés par les étudiants.* Quinze *enseignants et 298 étudiants ont participé à l'étude en développant un total de 19 artefacts sur les sujets de nanotechnologie et leurs implications sociétales. Les résultats montrent qu'un tel partenariat peut aider les élèves à acquérir, selon leur niveau et leur bagage cognitif, certains concepts de base des nanotechnologies et à les communiquer à l'aide de multiples activités d'exigences cognitives graduées.*

MOTS-CLÉS

Artefacts des élèves, nanotechnologie, communication scientifique, combinaison d'éducation formelle et informelle

INTRODUCTION

Formal and informal learning settings constitute a continuum that may provide various complementary opportunities for students with differentiated learning needs in order to achieve scientific literacy (Fallik, Rosenfeld & Eylon, 2013). Given the fact that students familiarize with scientific concepts and methods by crossing the boundaries between formal and informal learning contexts, the collaboration between these two areas is considered crucial for the improvement of students' learning outcomes in terms of knowledge, skills and attitudes towards science (Monteiro et al., 2016; Stocklmayer, Rennie, & Gilbert, 2010).

Informal science learning settings have been recognized as environments that can provide opportunities to enhance students' knowledge and motivation about science and highlight the links between science and everyday life (Martin et al., 2016). In these environments, the personal, physical, and sociocultural context intersect and influence the types of learning and interactions that individuals have in these places (Falk & Dierking, 2013). Therefore a synergy between formal and informal science learning settings may counterbalance the perceived deficits of traditional school science education, such as the provision of fragmented knowledge and the outdated content, by providing authentic learning experiences and a more holistic representation of science (Falk & Dierking, 2013).

The need for efficiently interconnecting formal and informal science education becomes more apparent when attempting to negotiate cutting-edge research topics in science lessons. As both science curricula and textbooks are usually characterized by a resistance to change and content renewal, teachers in order to incorporate such issues in their lessons, have to turn to informal science learning resources for more up-to-date information and learning activities. Students' visits to science centers, can complement the existing science curriculum, updating it as regards contemporary scientific content, as they often host exhibits on cutting-edge research topics and their social dimensions (Yun, Shi, & Jun, 2020). Moreover, visits to research centers may provide students with additional opportunities to experience science in-the-making in contrast with its school representation that is usually viewed as a ready-made final product enhancing their awareness of aspects of nature of science and creating incentives for learning (Boaventura et al., 2013; Neresini et al., 2009).

Another means that falls within the broad scope of non-formal learning and that can be used by students to transform their perspective towards science is the design of scientific artifacts (Hawkey, 2001). The designing process may also contribute in perceiving science not only from the perspective of knowledge as its final product, but rather to experience science as process and method. In the context of this approach, producing and presenting science artifacts, draws upon the facets of inquiry based learning. Through the design and development of artifacts, students, under the guidance of their teacher, develop skills to formulate questions (Sleeper & Sterling, 2004), to observe, to search and use data to reach scientific explanations, analyze alternative interpretations and communicate scientific conclusions. At the same time, through the production process of an artifact, the respective creator acquires motivation to acquire knowledge, becomes familiar with the process of finding reliable and valid sources as well as with the process of effective communication of knowledge to the general public (D'Acquisto, 2006). Through the preparation of artifacts on cutting-edge science topics, students are involved in a discussion and investigation which is particularly useful for a deeper understanding of the content, processes and nature of science and technology as well as cognitive, their social, political and moral development (Hammerich, 2000).

Based on the above, the present study aims to explore the knowledge that students negotiate through a teaching module on Nanotechnology Applications that is designed to bring students in contact with both practical activities in the classroom and with informal learning processes, such as visits to science centers and research centers, studying newspaper articles and development of science artifacts. Moreover, in the context of this study, in order to capture students' understanding we used Wu & Krajcik's (2006) approach, according to which student-curated artifacts are a means of expressing and externalizing students' ideas and represent their understanding around a topic. Therefore, the overarching research question that drives our study is: *How do students transform the knowledge they acquired from a nanotechnology teaching module that incorporates aspects of formal and informal learning into knowledge to be communicated through science artifacts?*

And it is examined through the following sub-questions:

- Which nanotechnology-related concepts are reflected in student-curated artifacts?
- What kind of activities did students incorporate in their artifacts in order to communicate their nanotechnology-related knowledge?
- Which elements of the teaching module were used as resources from the students in order to develop their artifacts?

METHODOLOGY

Context of the study

The present study was conducted in the framework of the IRRESISTIBLE project, whose aim was to familiarize students and teachers with cutting-edge research topics and their social dimensions through the development of teaching modules. The teaching module "Nanotechnology Applications" was developed by a learning community consisting of primary and secondary school teachers, supported by scientists on the topic of nanotechnology, science educators and science communication experts (Stavrou, Michailidi, & Sgouros, 2018). This collaborative setting was selected, as partnership between scientists, teachers and science educators provide opportunities to enhance effective science teaching (Shein & Tsai, 2015).

The focus of the teaching module was on discussing with primary and secondary education students basic ideas of nanotechnology, in particular ideas on size and scale and size-dependent properties (Stevens, Sutherland, & Krajcik, 2009) as well as socioscientific issues arising from nanotechnology applications. The teaching module consisted of seven 90-minute lessons and was oriented towards basic principles of inquiry-based learning referring to Bybee et al. (2006) 5E instructional model. The five original phases of the model (engagement, exploration, explanation, elaboration & evaluation) were enriched with one additional phase of exchange, during which the students developed and presented scientific artifacts to the public. The main structure of the teaching module is presented in Table 1.

During the seven meetings of the module, students would interact with different types of activities held both in school and out of school settings. Specifically, the module included the conduct of practical, exploratory activities *in the classroom*, in order students to familiarize with the basic concepts of nanotechnology (size and scale scale and size-dependent properties) as well as to get acquainted with the social dimensions of nanotechnology applications, such as the risks for human health & environment, the ethical role of nano-scientists and citizens' responsibility. Moreover, critical part of the module constituted students' visits to Nanotechnology *research centers*, in order students to get in direct contact with scientists working on the specific scientific topic and to get to know current applications of nanotechnology that are being developed there and to *science centers* to get acquainted with ways of communicating science.

TABLE 1

Outline of the "Nanotechnology Applications" module

Phase	Lesson No	Lesson content	Activities
Engagement	Lesson 1	Introduction	-Video projection -Discussion
	Lesson 2	Visiting the science center	-Interaction with nanotechnology exhibits -Discussion on science communication methods
Exploration & Explanation	Lesson 3	Nanoscience applications: self-cleaning materials I. How small nano is?	-Cut paper stripe into pieces -Nano-ruler -Classifying objects in different scales
	Lesson 4	Nanoscience applications: self-cleaning materials II. Size-dependent properties	-Video projection -Hydrophilic/ hydrophobic materials experiment -Effervescent tablet reaction rate experiment -Cutting cubes activity
Elaboration	Lesson 5	Societal dimensions issues	-Newspaper articles
	Lesson 6	Visiting the research center	-Discussion with scientists on nanotechnology and societal issues
Exchange	Lesson 7	Development of artifacts	-Exchange of ideas -Design of the artifacts -Division of tasks -Construction of the artifacts

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This module was implemented by 15 in service teachers (4 primary education teachers, 7 physicists and 4 chemists) in schools of Athens, Heraklion and Rethymnon, with the participation of 298 students (92 elementary, 59 lower secondary and 158 upper secondary students). The implementation of the module lasted 6 months, during which students visited:

- the *Interactive Science and Technology Exhibition of the Eugenides Foundation* during which they toured around exhibits whose scientific content was associated with nanoscience topics and nanotechnology applications and examined them, with the help from a museum's expert, under the light of science communication, focusing on the communication approaches that were used.

- the *Institute of Nanoscience and Nanotechnology of NCSR "Demokritos"* and *the Institute of Electronic Structure and Laser of the* Foundation for Research and Technology Hellas (FORTH), where after a short introductory lecture, the students had the opportunity to visit the laboratories and talk to researchers about the subject of nanotechnology, the risks it may pose and the scientist's responsibility to society. The issues raised during the visits are summarized in Table 2.

TABLE 2

Discussion topics during students' visits to research centers

- Examples of nanotechnology products in market
- Nanotechnology applications that are developed in the Research Centers
    - Nanoelectronics, nanophotonics, superhydrophobic nanostructured surfaces (Demokritos)
    - Photocatalytic materials, superhydrophobic materials, thermochromic glass (FORTH)
- Natural nanostructures and biomimicry
- Nanoscale objects
- Instruments that manipulate matter and create nanostructures
- Scientists’ ethics and role
- Risks of nanotechnology

The last part of the implementation was devoted to the artifacts’ development, a process that was based upon D’Acquisto’s (2006) “School Museum Exhibition”. According to that process students followed a complete learning cycle where they acquired, used and communicated nanotechnology-related knowledge and concerns. In the context of an authentic task (“To inform their community about nanotechnology applications”) they first had to become knowledgeable about the related topic. Apart from the knowledge they had already gained through the hands-on explorative activities and their visits to the research centers, they had to conduct research by reading, talking to people, and studying relevant sources. After they analyzed, synthesized and summarized their findings, they decided how to effectively represent and communicate their knowledge to visitors through visual, oral, and written media. So they had to use their knowledge in order to create an artifact; a visual and written representation of what they had learned. The result of this process was the development of a total of 19 student-curated artifacts on aspects of nanotechnology and the concerns arising from its use, which were presented to the public in exhibitions organized at the Eugenides Foundation and the Museum of Natural History of the University of Crete.

Data collection

The main means of data collection were the student-curated artifacts which captured students' understanding of nanotechnology issues. In addition, data were collected through an open-ended questionnaire filled in by a subgroup of participating students (72 students), which focused on identifying the key concepts of nanotechnology from their point of view, the goals that students wanted to achieve with their artifacts and the contribution of particular elements of the teaching module in the development of the artifacts. Finally, field notes taken during students' visits to science centers and research centers allowed us to record the issues raised during students' interaction with experts.

Data analysis

Due to the exploratory nature of the study, qualitative content analysis methods were used (Mayring, 2015). Initially, we analyzed students' artifacts in terms of negotiated scientific concepts and social dimensions and recorded the absolute frequencies of nanotechnology concepts that students included in their artifacts (see categorization in Table 3).

TABLE 3
Categorization of nanotechnology related concepts included in the artifacts

Categories		**Criteria**
Scientific Content	Size & scale	• nanoscale size limits • typical nanoscale objects • proportions
	Change of properties	• change of properties • surface / volume ratio • interpretation of applications
	Applications	• hyperhydrophobicity • self-cleaning materials • thermochromic windows, nanoelectronics • nanomedicine, ferrofluid, photocatalytic materials
Social dimensions		• risks to human health & environment • role of scientists • need for suitable legislation • citizens' responsibility

The artifacts were also analyzed in terms of the activities students incorporated in them and through which they aimed to communicate their knowledge. The categorization of the activities was based on the revised Bloom's taxonomy of cognitive processes (Anderson & Krathwohl, 2001) in order to characterize them regarding their complexity level (Table 4).

TABLE 4
Categorization of types of activities embedded in artifacts

Categories	**Criteria**
Recollection	Visitors are called to: • Watch a video • Read information • Test their knowledge (e.g. matching the pairs)

Comprehension	Visitors are called to: • Classify (e.g. entities in micro & nano scale) • Formulate hypotheses
Application	Visitors are called to: • Manipulate the equipment and conduct an experiment • Take measurements • Apply their knowledge in new contexts to answer questions
Analysis	Visitors are called to: • Interpret a phenomenon (e.g. color change) • Explore the parameters of an experiment • Collect evidence to support their position
Evaluation	Visitors are called to: • Draw conclusions based on data • Present and defend their opinion (e.g. on the risks of nanotechnology) • Formulate arguments • Make decisions (e.g. regarding the use of nano-products)
Creation	Visitors are called to: • Find solutions to a problem • Propose alternatives

Then, these concepts and activities were compared with those included in the teaching material and those that were brought upon during the students' visit to the research centers, in order to define the module’s elements that had the greater impact on students’ artifacts. The categories of students’ resources that emerged from our data are depicted in Table 5.

TABLE 5

Student’s resources for artifact development

Categories	**Criteria**
Teaching material	• Information presented in the teaching material • Activities conducted in classroom
Visit at the research center	• Information presented at the research center from the scientists • Activities conducted or presented in the research center
Visit at the science center	• Information presented at the science center from the museum expert • Activities conducted in the science center
Newspaper articles	• Information included in the newspaper articles studied in classroom
Other resources	• Information collected by autonomous students’ research in websites, newspapers, videos etc.

Finally, data obtained from the students' answers to the questionnaires were used to cross-check our findings as well as to clarify the contribution of the teaching material but also of the out-of-school learning settings they visited.

RESULTS

Regarding the focus of the students' artifacts, according to Table 6, it appears that the majority of the students emphasized mainly the scientific content of the topic of nanotechnology and secondarily its social dimensions.

TABLE 6

Absolute frequency of aspects of the nanotechnology content on which the students' artifacts were focused per level of education

	Primary education	Lower Secondary education	Upper Secondary education	Total
Size & scale	12	4	3	19
Change of properties	1	4	6	11
Applications	5	14	20	39
Social dimensions	4	5	9	18

Specifically, the greater number of artifacts concerned superhydrophobic materials and other applications of nanotechnology, followed by concepts related to the size and typical entities of the nanoscale, while the change of properties at the nanoscale and its interpretation concerned a relatively smaller number of artifacts. The same table also highlights the different focus of students' artifacts depending on their level of education. Content related to size and scale seems to have been more accessible and easily negotiable by elementary school students while high school students seem to be more attracted to applications of nanotechnology and more specifically to nano-medicine, hydrophobic materials and other innovative applications (ferrofluids etc.) using them as a "lure" for visitors to experience aspects of nanoscience and its social dimensions.

Regarding the social dimensions of nanotechnology, there has been an increasing tendency to integrate such elements per level of education, with upper secondary students being able to more effectively integrate such considerations into their artifacts, with an emphasis on the risks nanotechnology may involve for the environment and humanity and on the role and responsibility of scientists towards them.

As far as the types of activities are concerned, Table 7 shows that most of the artifacts addressed lower levels of visitors' cognitive processes as knowledge testing through quizzes, information board games and classification of entities at the nano-, micro- and macro-scale. On the other hand activities of higher cognitive complexity as exploring the various parameters of properties' change at the nanoscale, collecting evidence to make a decision regarding the use of sunscreens containing nano-particles, and propose solutions for the limitation of nanotechnology risks were more limited.

As it derives from Table 7 there is a notable trend among students of lower grades to employ activities that mobilize visitor's recollection and comprehension while older students were also capable of incorporating to their artifacts more cognitively demanding activities. It also bears mentioning that most of the activities addressing the societal issues that derive from nanotechnology tend to engage visitors in more complex cognitive processes like analyzing and evaluating evidence in order to form an argument and develop alternatives or solutions for eliminating the implicated risks.

TABLE 7

Absolute frequency of types of activities embedded in students' artifacts

	Primary education	Lower Secondary education	Upper Secondary education	Total
Recollection	10	6	7	23
Comprehension	1	2	3	6
Application	-	2	5	7
Analysis	2	-	5	7
Evaluation	3	2	6	11
Creation	-	1	4	5

Finally, regarding the resources students recurred to in order to develop their artifacts, Table 8 shows the impact of formal (school activities) and informal learning experiences (visits, use of newspapers, internet, etc.) on the content of students' artifacts.

TABLE 8

Frequency of students' resources for artifact development

	Primary education	Lower Secondary education	Upper Secondary education
Teaching material	71%	48%	37%
Visit at the research center	11%	32%	41%
Visit at the science center	10%	7%	4%
Newspaper articles	3%	5%	4%
Other resources	4%	8%	14%

Particularly, the factors that most strongly influenced the determination of the content of artifacts were the activities that took place in the classroom and the visits to the research centers (FORTH and Democritus). The strong conceptual connection of the artifacts with the applications presented in the research centers was culminated by the use of physical nano-materials provided by these centers but also by the incorporation of excerpts from discussions with researchers. In fact, students' questionnaires showed that 57% of the students named the research center as a source from which they obtained information about the creation of their artifacts. Students' visits to the science center mostly had an effect on the type of activities included in the artifacts as there students experienced the value of interactivity in visitor's engagement. Moreover, a gradual disengagement of students from the teaching material with age and a tendency for autonomous investigation at websites to search for suitable information is also noted in Table 8.

CONCLUSIONS

Aim of the present study was to investigate the way students transform the knowledge they acquired through their interaction with a nanotechnology teaching module rich in formal and informal learning experiences, to knowledge for public communication via artifacts.

Our findings indicate that students of all grades were capable of developing artifacts incorporating fundamental nanotechnology concepts and discussing their main societal implications. Trying to engage visitor's interest, they used the impressive nanotechnology applications as a means to introduce the scientific interpretation of nanoscale phenomena and refer to ethical and societal concerns. In accordance with other studies on nanotechnology education (Ghattas & Carver, 2012), primary education students were more fluent in dealing with concepts as size and scale and while older students negotiated more complex concepts and their scientific interpretation as well.

Moreover, findings regarding the cognitive complexity of the developed activities highlight the fact that socioscientific issues may constitute a very rich ground for the development of higher cognitive skills on behalf of the students (Simonneaux, 2014). Additionally, the fact that students developed activities with various levels of cognitive demands according to their depth of understanding and their skills, may denote the perspective of employing student-curated artifacts as a means of student assessment (Wu & Krajcik, 2006). Moreover, students' tendency to delve deeper into the topic, conducting autonomous explorations using more sources that the provided ones in order to complement the needed information for their artifact, indicates a need for further investigation of artifacts also as a means for developing students' scientific knowledge and skills (Kampschulte & Parchmann, 2015).

Finally, the present study contributes to the foundation of the synergy between formal and informal learning environments, as the results show that a teaching module that incorporates balanced elements from both forms can help students acquire, depending on their grade and cognitive background, basic knowledge on key nanotechnology concepts and communicate it using multiple kinds of activities. Specifically, the students were able to successfully integrate elements from both the learning experiences that took place in the classroom, as well as from those that took place at the research center and the science center they visited. Therefore, although research suggests that the cognitive effects of visits to informal learning spaces are usually limited (DeWitt & Storksdieck, 2008), we conclude that when such visits constitute part of a broader teaching context and with consequent student preparation, the benefits are multiplied leading to more concrete cognitive gains.

REFERENCES

Anderson, L. W., & Krathwohl, D. R. (Eds.) (2001). *A taxonomy for learning, teaching, and assisting: A revision of Bloom's taxonomy of education objectives*. New York: Longman.

Boaventura, D., Faria, C., Chagas, I., & Galvão, C. (2013). Promoting science outdoor activities for elementary school children: Contributions from a research laboratory. *International Journal of Science Education, 35*(5), 796-814.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter P., Powell J. C., Westbrook A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness*. Colorado Springs: BSCS.

D'Acquisto, L. (2006). *Learning on display: Student-created Museums that build understanding*. Association for Supervision and Curriculum Development.

DeWitt, J., & Storksdieck, M. (2008). A short review of school field trips: Key findings from the past and implications for the future. *Visitor Studies, 11*(2), 181-197.

Falk, J., & Dierking, L. (2013). *The museum experience revisited*. Walnut Creek, CA: Left Coast Press.

Fallik, O., Rosenfeld, S., & Eylon, B. S. (2013). School and out-of-school science: A model for bridging the gap. *Studies in Science Education, 49*(1), 69-91.

Ghattas, N. I., & Carver, J. S. (2012). Integrating nanotechnology into school education: A review of the literature. *Research in Science & Technological Education, 30*(3), 271-284.

Hammerich, P. (2000). Confronting students' conceptions of the nature of science with cooperative controversy. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 127-136). Dordrecht: Kluwer Academic Publishers.

Hawkey, R. (2001). Innovation, inspiration, interpretation: Museums, science and learning. *Ways of Knowing Journal, 1*(1), 23-31.

Kampschulte, L., & Parchmann, I. (2015). The student-curated exhibition – a new approach to getting in touch with science, *Lumat, 3*(4), 462-482.

Martin, A. J., Durksen, T. L., Williamson, D., Kiss, J., & Ginns, P. (2016). The role of a museum-based science education program in promoting content knowledge and science motivation. *Journal of Research in Science Teaching, 53*(9), 1364-1384.

Mayring P. (2015). Qualitative Content Analysis: Theoretical background and procedures. In A. Bikner-Ahsbahs, C. Knipping & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education* (pp. 365-380), Dordrecht: Springer.

Monteiro, B. A. P., Martins, I., de Souza Janerine, A., & de Carvalho, F. C. (2016). The issue of the arrangement of new environments for science education through collaborative actions between schools, museums and science centres in the Brazilian context of teacher training. *Cultural Studies of Science Education, 11*(2), 419-437.

Neresini, F., Dimopoulos, K., Kallfass, M., & Peters, H. P. (2009). Exploring a black box: Cross-national study of visit effects on visitors to large physics research centers in Europe. *Science Communication, 30*(4), 506-533.

Shein, P. P., & Tsai, C.-Y. (2015). Impact of a scientist–teacher collaborative model on students, teachers, and scientists. *International Journal of Science Education, 37*(13), 2147-2169.

Simonneaux, L. (2014). From promoting the techno-sciences to activism. A variety of objectives involved in the teaching of SSIs. In L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 99-111). Dordrecht: Springer.

Sleeper, M., & Sterling, R. (2004). The inclass science exhibition. *Science Scope, 27*(6), 49-52.

Stavrou, D., Michailidi, E., & Sgouros, G. (2018). Development and dissemination of a teaching learning sequence on Nanoscience and Nanotechnology in a context of Communities of Learners. *Chemistry Education Research and Practice, 19*, 1065-1080.

Stevens, S., Sutherland, L., & Krajcik, J. (2009). *The 'big ideas' of nanoscale science and engineering*. Arlington, VA: National Science Teachers Association Press.

Stocklmayer, S. M., Rennie, L. J., & Gilbert, J. K. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education, 46*(1), 1-44.

Wu, H. K., & Krajcik, J. S. (2006). Exploring middle school students' use of inscriptions in project - based science classrooms. *Science Education*, *90*(5), 852-873.

Yun, A., Shi, C., & Jun, B. G. (2020). Dealing with Socio-Scientific issues in Science Exhibition: A literature review. *Research in Science Education*. (In press).