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Including Responsible Research and innovation in cutting Edge Science and Inquiry-based Science education to improve Teacher's Ability of Bridging Learning Environments

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Case studies about the impact of the project on teachers' personal and professional development and on students' skills

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EXECUTIVE SUMMARY

During the IRRESISTIBLE Project, more specifically, under its Work Package 3, groups of teachers and students were involved (and supported by the local Community of Learners - CoL) in the development of interactive exhibitions addressing the concept of Responsible Research and Innovation. The process of development of such exhibitions is closely related to the Exchange phase of the extended 5E IBSE model approach used within the Project.

On the *first chapter* we present the **potentialities** of having students and teachers developing IRRESISTIBLE exhibitions in the context of Science Education. Through it, teachers and students will understand that uncertainty and risk are inherent to scientific and technological enterprises. So, Research and Innovation must be driven by *Responsibility*. The process of exhibits' development and presentation allows students to move beyond analysis and discussion, creating an opportunity for them to participate in (and even to instigate) **community action** on socio-scientific controversial matters. Community action is frequently considered a major aspect of scientific literacy, and a way to empower students as critics of knowledge and producers of knowledge rather putting them in the role of knowledge-consumers as the Education systems often seems to make.

The *second chapter* is devoted to **methodogical aspects**. In order to understand the process of exhibition development and evaluate its impact on students and teachers, in each of the two years of module implementation, each partner developed (at least) 1 case-study focusing one particular exhibition, gathering data through semi-structured interviews of teachers and students. There have been developed a total of 26 case-studies. Each case study corresponds to an exhibition on Responsible Research and Innovation, implemented at school, university, science center or museum. In order to guide partners in the development of their case-studies we developed guidelines that were used by all during the process of data collection – those guidelines, presented in this chapter, were very important as they guaranteed that the data featured in all cases were comparable. It also assured that the evaluation of the process of exhibition development to be made by all partners would take into account important aspects for the Project, not to be left aside. Also in this chapter we describe the process of case-study analysis, which followed a qualitative approach through content-analysis.

The *third chapter* is dedicated to present the **cross-analysis made on the 26 case-studies** developed within the IRRESISTIBLE Project. For the 1st CoL round, there were produced 14 case-studies and for the 2nd round, 12 case studies. The 26 case-studies were analyzed as a whole group of case-studies. We start be describing the process of exhibition development – a) who were the participants?; b) what sort of activities and tasks were implemented before the actual planning of the exhibition took place?; c) what happened during the phases of planning and construction of the exhibition?; d) what were the places chosen to display the exhibitions? After describing the process of exhibition development, we move forward presenting and discussing on the difficulties faced by students and teachers throughout that process, and also on the learning achievements. After discussing on the more or less importance attributed from students to the topics of their exhibitions, we present an overall balance of the process of exhibition development, highlighting the most positive and less positive aspects mentioned by students and teachers, and also their suggestions of improving the experience. There have been involved 72 science teachers, 1357 students distributed over 59 classes from 5th to 12th grade, supported by 51 science educators and experts from museums and science centres. Although the development and construction of an interactive exhibition was the final task common to all modules, they all included several previous tasks and activities designed to engage students in the scientific theme and in the dimensions of the RRI. These activities were all conducted with a focus on generating content and input to the exhibition in both areas. The activities with higher implementation were: a) lectures/talks from experts, b) brainstorming/debates, c) hands-on activities/experiments, d) and visits to University labs, Museums and science centres. All exhibitions were planned and constructed by students: the process started with a group brainstorming or debate about the topics to include in the exhibition, followed by the distribution of students through small groups of work, focused on the design and construction of the objects for the exhibition. Games, models, experiments/demonstrations and posters were the prevalent objects. Schools were the favourite place to hold the exhibitions, even though some have been displayed in Museums and Science Centres. As in what concerns the main difficulties perceived by students during the process of exhibition development, the main challenges were: a) organization and management of group work; b) novelty of the scientific topic and RRI; c) planning the exhibition; d) time management; and e) constructing the exhibition. As for the main difficulties for teachers, those included: a) time management; b) novelty of scientific topic and RRI; c) project and group work management; and d) exhibition planning and construction. As for the perceived main learning achievements, students mentioned: a) the scientific topic and RRI; b) project management and group work; c) development of interactive exhibits; and d) selection and organization of relevant information. Regarding teachers, the major learning achievements concerned: a) the didactic strategy and its potentialities; b) the scientific topics and RRI; c) organizational and project management skills; and d) interpersonal skills. The majority of the interviewed students have mentioned that the topics worked throughout the module and during the process of exhibition development were important for their present lives, which showed us that they attributed personal meaning and a sense of relatedness to the scientific topics and also to the theme of

Responsible Research and Innovation. Regarding the overall balance of the experience, for students the main positive aspects were: a) the development of an active learning; b) the learning off new scientific topics and RRI; for teachers, the main positive aspects were: a) students' active learning; b) satisfaction by achieving such a new project; c) the development knowledge about cutting-edge science topics and RRI. As for the negative aspects, the main ones pointed by students were: a) the planning of the exhibition; and b) the building of the exhibition. Concerning teachers, the main negative aspects were: a) time management; and b) group work management. Both students and teachers indicated improvement suggestions of their performance in order to overcome the felted difficulties. For students it could be important to improve the design of their exhibitions in order to achieve more interactive exhibitions, and a better integration of the RRI domain. Teachers would have liked to manage better the tasks implied in the development of the exhibition – this first experience gave them knowledge to better plan, in the future, and better distribute the time needed for the different tasks. This long chapter provides very valuable insights on how did the students and teachers experienced this new didactic strategy.

On the *forth* chapter we discuss on the **impact that the participation on the IRRESISTIBLE Project had on students' perceptions in what concerns the use of exhibitions in the context of science classes**. We present the results of the analysis of the pre and post-questionnaire applied to all partners' students participating in the Project. The questionnaire was answered by a total of 3368 students on the pre-test application and 2433 on the post-test application, from a total of 10 different countries. We focused our analysis on the participants' answers to sections 4 and 5 of the questionnaire: section 4 included 8 closed questions about the student developed exhibits; section 5 included 8 closed questions about the students' science classroom environments. In order to validate the developed sections, for this new population, the Cronbach's alpha index was calculated for both. The attained values for Cronbach's Alpha on these sections was respectively .853 and .876, indicating that the internal consistency of both topics was high (Cronbach's Alpha larger than .8), illustrating the reliability of the proposed topics. We've calculated the overall progression of the sample: almost all questions showed a significant raise in their scores favouring the post-test results. We have also conducted an analysis per country to identify possible differences: it became clear that participants' from different contexts had diverse perceptions regarding the topics covered by the questionnaire. The overall results indicate that students' had improved their perceptions in what regards their competences for developing exhibitions in science classes as a way of creating awareness on topics relating science-technology-society-environment: at the end of the project, they feel capable of attaining this goal. Also they realize that this sort of project improves the relationship between students and teachers. Concerning their classroom environments, the Project contributed to students' improved perceptions that in their science classes: a) they discuss current issues and how they impact their lives; b) they develop socially and relevant projects; and c) they learn how to influence other citizens' decisions about social issues related to science, technology and environment.

On the *fifth chapter* we present an **overall view of the total of exhibitions** developed within the 3 years of the Project. There have been developed 218 interactive exhibitions on several cutting-edge scientific topics and RRI, involving 7340 students and 439 science teachers. The main topics of the exhibitions were: a) Nanotechnology; b) Plastic Pollution in Oceans; c) Carbohydrates in Breast Milk; d) Climate Change; e) Oceanography; f) Polar Science; and g) Climate Geoengineering.

On the *sixth chapter* we present and discuss on the partners' reflection on the **potentialities and limitations of integrating RRI in the process of exhibition development**. We also present ways of improving that integration. The majority of partners agree that the integration of RRI in the process of exhibition development creates an opportunity for students, and also teachers, to take into account global problems that are not normally included in sciences classes. By having the task of developing an exhibition that expresses the integration of RRI into the scientific topic, students and teachers feel more willing to learn about RRI, and this happens also because of central role that students assume (and that poses a novelty for the majority of them) related to the task of creating something that will be shared with others as a means to create awareness on a topic that has global implications for society. As a result of having to integrate the Responsible Research and Innovation into the exhibition – hence, creating something that expresses the interconnections of a particular theme of science and society – students and also teachers end up by deepen their understanding of RRI. As for limitations on the integration of the RRI component, one major aspect has to do with the support that teachers can give to their students. We cannot forget that not only the RRI topic is new to students, but also the task of having to plan and develop an interactive exhibition to be presented to an audience. That is why the support of teachers is crucial – but also for them, these are novelties. Without the proper support of teachers – in highlighting the relevance of RRI in connection with the science, and in helping the development of the exhibition – students feel lost and leave out the more demanding tasks, creating exhibitions more centred in the science facts, and less in the RRI aspects. The proper support of teachers begins with the work in the classroom – if teachers don't find any potentialities or relevance in bringing RRI into their science classes, or if their approach is merely superficial and brief, students will not value RRI nor will develop any efforts of trying to integrate it in their exhibition.

Finally, on the *seventh chapter* we synthesize all of the new knowledge brought by each chapter and conclude that the impact of the process of exhibition development on teachers' personal and professional development and students' competences is a positive one: based on the case-studies and on other data reported by the IRRESISTIBLE partners, we can conclude that developing interactive exhibitions focused on RRI and cutting-edge science topics promotes the development of students' competences and enables teachers to redefine their role as science teachers, growing as professionals.

Deliverable 3.3 has the purpose of:

a) **Discuss on the potentialities of having students planning and developing exhibitions on RRI;**
b) **Describe the process of case-study development;**
c) **Present, and reflect on, the results from the cross-analysis of the case studies in order to better understand the impact of exhibition development on both teachers and students;**
d) **Present the potentialities and limitations of integrating RRI in the process of exhibition development;**
e) **Present and discuss on the impact of students' participation in IRRESISTIBLE in what concerns their perceptions of the process of exhibition development;**

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1. INTERACTIVE SCIENTIFIC EXHIBITIONS ON RESPONSIBLE RESEARCH AND INNOVATION: POTENTIALITIES FOR SCIENCES TEACHING AND LEARNING.

The main goal of Project IRRESISTIBLE was to design activities that foster the participation of students, and the community in the process of Responsible Research and Innovation (RRI). Each IRRESISTIBLE partner organized a Community of Learners (CoL). Each CoL was responsible for the development of a teaching module that included the construction of public exhibitions addressing the concept of Responsible Research and Innovation. The process of exhibition development falls under the **Exchange** phase of the IBSE 6E model followed by the Project. This phase requires students to communicate and *exchange* knowledge acquired during the previous phases of the model (Engage, Explore, Explain, Extend/Elaborate), with a wider audience. Therefore, exchanging their research based opinions regarding a specific scientific issue they studied. Although the IRRESISTIBLE approach relies on the extended 5E model, adding the extra level of Exchange, makes it a 6E model. For the Portuguese partner this Exchange phase is closely related to another extra *E*, the *Empowerment* level. In fact, we believe that giving students the opportunity to express their research based knowledge through the development of an exhibition aimed at the general public is in close relation with their active citizenship rights and responsibilities. Unfortunately, most young students do not see themselves as *citizens* until they earn the right to vote. Students participation in the IRRESISTIBLE Project comprises an excellent opportunity to promote their empowerment and their active citizenship skills. This engagement also develops the awareness that their actions can be as valid as any other social actor's as long as they are based on research.

Students devising and presenting an exhibition is a means of **transforming science from product to process** (Hawkey, 2001). One of the advantages of both producing and presenting an exhibit is that it draws upon the features of Inquiry Based Science Education (IBSE): in producing an exhibition students can represent scientific facts as speculative questions; transmissive teaching can be transformed; and the audience at the exhibit can construct their own learning. By presenting frontier knowledge or by using an exhibit to raise questions they become learners with their visitors. Encouraging students to research their own interests under the guidance of a teacher promotes their development of key skills such as: formulating questions; collaborating with other participants; and observation (Sleeper & Sterling, 2004).

The construction of exhibits encourages **inquiry-based approaches** and the use of Responsible Research and Innovation. In the process of either creating an exhibit or modifying an existing one, the emphasis should be on stimulating personal reflections by those engaging in the exhibit. Narratives can be created from a multidisciplinary perspective. In designing an exhibit, or a narrative/inquiry focused dialogue to accompany an exhibit, students need to consider how the exhibit gets the audience thinking about Responsible Research and Innovation issues.

Through the construction and presentation of exhibits on Responsible Research and Innovation (RRI) both teachers and students are introduced to a **different type of science** from the one that is usually presented in science classes. Most of formal science education focuses on a conventional, non-controversial, established and reliable science. On the contrary, cutting-edge scientific and technological matters highlight a "borderline science", that is controversial, preliminary, uncertain and under debate. The controversial dimension refers to "differences over the nature and content of the science such as the perception of risk, interpretation of empirical data and scientific theories, as well as the social impact of science and technology" (Levinson, 2006, p. 1202).

"Science is messy in application, often associated with complexity, uncertainty and controversy" (Jarman & McClune, 2007, p. 122). Therefore, students must be helped to understand that relevant science knowledge may be considered as incomplete, uncertain and contested. Frequently, decision-making regarding scientific and technological matters depends on **knowledge from different domains** (not only from science and technology).

The production and presentation of exhibits can involve students in **inquiry and discussion**. The discussion inherent to the preparation of exhibits on Responsible Research and Innovation can be particularly useful both in terms of learning about the contents, the processes and the nature of science and technology, and in terms of the students' cognitive, social, political, moral, and ethical development (Hammerich, 2000; Kolstø, 2001; Millar, 1997; Sadler, 2004).

Exhibitions about RRI, as a socio-cultural context, can raise questions, elicit personal reflection and stimulate conversations between students and visitors, transforming **both into learners** (Braund & Reis, 2004).

The process of exhibits construction and presentation allows students to move beyond analysis and discussion, creating an opportunity for them to participate in (and even to initiate) **community actions** on socio-scientific controversial matters. Community action is frequently considered a major aspect of scientific literacy (Hodson, 1998; Roth, 2003), and a way to empower students as critics and producers of knowledge, rather than putting them in the role of knowledge-consumers as the education system often seems to do (Bencze & Sperling, 2012; Linhares & Reis, 2014; Reis, 2014a,b).

For these collective actions of democratic problem solving, initiatives involving art (e.g., drama, cartoons, comic strip and posters) and the use of social networking and Web 2.0 tools (e.g., for the production and dissemination of podcasts, vodcasts, discussion forums, blogs, comic strip, posters and leaflets) can be particularly effective (García-Bermúdez, Kings & Vázquez-Bernal, 2014; Reis, 2014a,b; Scheid & Reis, 2016).

The preparation of exhibits on Responsible Research and Innovation helps learners to see that **uncertainty and risk** are inherent in scientific and technological enterprises: however strong the evidence for a theory, there are always possible alternatives; data on which evidence is based is never certain, always having an associated degree of error; the interpretation of data is influenced by many factors including contemporary knowledge and social contexts.

When developing exhibitions, learners will ask questions, use logic and evidence in formulating and revising scientific explanations, recognizing and analysing alternative explanations, and communicate scientific arguments.

2. METHODOLOGY

In the Project's first phase, more precisely during the 2014/2015 school year, a total of 32 exhibitions on RRI were developed involving 2069 students. In the second phase, during the 2015/2016 school year, a total of 142 exhibitions were developed, involving 5271 students.

In order to understand the process of exhibition development and also the impact that this process had on both teachers and students, each partner developed (at least) one case study focusing on one particular exhibition – in each of the two phases of the CoL.

In order to guide the process of case-study development, we developed a prototype version of case study guidelines and asked partners to give feedback in order to improve them (May 2014). The final version of the guidelines was made available and shared, via e-mail and dropbox, with all partners. These guidelines were clarified during the Scopia meeting on the 15th April 2015.

The construction of one tool to be used by all partners in the process of collecting teachers', students' and experts' perceptions regarding the process of exhibition development. With this tool – a Guide, indicating all the procedures to be taken, and also the goals, structure and sections of the case-study – it was guaranteed that the data featured in all partners' cases were comparable. It was also assured that the evaluation of the process of exhibition development to be made by all partners would take into account important aspects for the Project, which should not be leaved aside.

Also aiming at helping partners with the construction of the cases, we elaborated two cases-studies concerning the process of development of two Portuguese exhibitions and sent them to all partners in late August 2015. By developing the efforts of building and sharing these two case-studies we intended to help those partners that revealed having more difficulties in conceptualizing how should the case-study be. Our two case-studies served as models for the development of the other cases.

2.1. Case-study Guidelines

In order to guide the process of case-study development, we developed a prototype version of case-study guidelines and asked partners to give feedback in order to improve them (May 2014). The final version of the guidelines was made available and shared, via e-mail and Dropbox, with all partners. These guidelines were clarified during the Scopia meeting of 15th April 2015.

The guidelines included: a) Objectives, b) Procedures (regarding participants and data collection), c) Case-study structure and, d) Teachers', Students' and Experts' items guide (**figures 1-5**).

A. Important information

- Each partner has to develop at least one case study per CoL phase;
- The 1st case study has to be delivered, in English, until the end of October 2015;
- The 2nd case study has to be delivered, in English, until the end of June 2016 (preferably) or, at maximum, until the 15th of July 2016;
- Whenever the science-museum expert is, at the same time, the person in charge of collecting the data, he/she will make a self-reflection having in mind the Experts' Guide items;
- The data collection must happen at the end of the process (example: if there is an exhibit at school, and after, one at the university, you need to collect the data after the university exhibition takes place, and you can enrich the case-study adding the perceptions of students and teachers regarding the dimension "school exhibit vs university exhibit").

B. Objectives

In order to know the impact of exhibitions development and construction, addressing the concept of Responsible Research and Innovation, on teachers' personal and professional development and to understand how students experience these exhibitions and their effects on students' competences, WP3 will develop several case studies.

C. Procedures

During the first year of the CoL, each partner is responsible for developing one case study. The case study corresponds to an exhibition on Responsible Research and Innovation, implemented at school, university, science center or museum.

C.1. Participants

The participants of the case study correspond to the target population of the exhibition.

i. Teacher(s) who coordinated the exhibition
ii. Students involved in the exhibition
iii. Experts from universities, science centers, museums or exploratory and researchers from the thematic field.

C.2. Data collection

In order to collect data for constructing the case study, several methods should be used.

i. At the end of the construction and development of exhibitions at schools, universities, and science centers or museums, each partner has to collect data from the teachers, using an individual interview or an open questionnaire, with the goals of understanding: difficulties with the construction and development of exhibits; professional learning; impact on students learning; and evaluating the construction and development of exhibits (Annex A).

ii. Focus group interview with the students (each group constituted by six to ten students), with the goal of understanding: difficulties in the construction and development of exhibits; competencies developed; and evaluating the construction and development of exhibits (Annex B).

iii. At the end of development of the exhibition, each partner has to collect data from the scientists and the experts of science centers/museums, using an individual interview or an open questionnaire, with the goal of understanding: perspectives about the process of construction and development of exhibitions; and evaluating the construction and development of exhibits (Annex C).

Figure 1 – Front page of the Case-study Guidelines.

D. Case Study Structure

Exhibition name	
Topics addressed (General topic and RRI topics)	
Teacher(s)	
Student group and grade	
Links to materials	

1) Description of the process of construction and development of the exhibition
2) Evidences of teachers' perceptions
3) Evidences of students' perceptions
4) Evidences of the experts' perceptions
5) Overall balance
6) Partner evaluation

Figure 2– Case-study structure.

Annex A

TEACHERS'ITENS GUIDE

Dimensions	Objectives	Questions/Topics
Teacher's characterization	To identify the teacher	• Gender and age • Professional experience • Academic education
Students' characterization	To identify the students	• Gender and age • Grade • Number of students involved
Topics addressed	To identify the general topic and RRI topics addressed in the exhibition	• Selected topics • Reasons to select the topics
Exhibition' selection	To identify the exhibition	• Type of exhibition selected • Reasons to select the exhibition
Exhibition' construction and development	To understand teachers perspectives about the processes of construction and development of the exhibition	• How was the exhibition constructed and developed? • How much timing was spent? How were the students organized? What difficulties have you experienced in the construction and development of the exhibition? • What have you learned in the construction and development of the exhibition? • What were the main difficulties that your students faced? • What were the main learning goals achieved? • Do you consider that the exhibition had any effect on students? Why? Please give us some details.

Figure 3 – Teachers' items guide.

Annex B

STUDENTS' FOCUS GROUP INTERVIEW GUIDE

Dimensions	Objectives	Questions/Topics
Students' characterization	To identify the students	• Gender and age • Grade
Topics addressed	To know what students learned about the topic	• What have you learned about the general topic and the RRI topics? • Do you consider these topics important in our daily life? Why?
Exhibitions' construction and development	To understand students perspectives about the process of construction and development of the exhibitions	• How was the exhibition constructed and developed? What difficulties have you experienced during the construction and development of the exhibition? • What have you learned during the construction and development of the exhibition?
Evaluation	To reflect on the experience	• Positive and negative aspects. • What would you do differently?

Figure 4 – Students' focus group interview guide.

Annex C

EXPERTS'ITENS GUIDE

Dimensions	Objectives	Questions/Topics
Experts' characterization	To identify the experts	• Gender and age • Professional experience • Academic education
RRI Topic	To understand the experts' perspectives about the general topic and the RRI topics addressed in the exhibition	• Do you consider these topics important? Why? • What was your influence on the decision about these topics? • If it were now, you still had the same opinion. Why?
Exhibitions' construction and development	To understand the experts perspectives about the process of construction and development of the exhibitions	• What was your contribution to the construction and development of the exhibition? • How was the exhibition constructed and developed? What have you learned with teachers and students during the construction and development of exhibition? • What were the main difficulties that teachers and students felt? • What were the main learning goals achieved by students and teachers? • Do you consider that the exhibition had any effect on teachers and students? Why? Please give us some details.
Evaluation	To reflect on the experience	• Positive and negative aspects • What would you do differently?

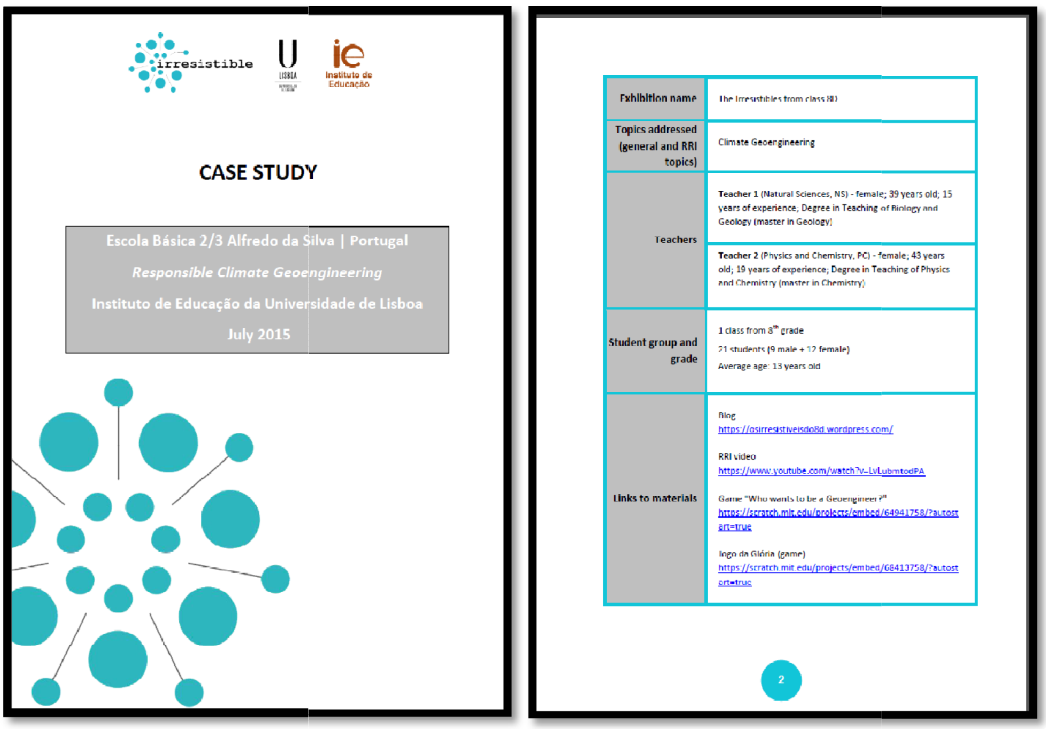
Figure 5 – Experts' items guide.

2.2. Case study analysis

In order to evaluate the process of students' exhibitions development, each partner was responsible for developing at least two case studies (one in each phase of the project). The participants in the case study were: (1) teacher(s) who coordinated the exhibition, (2) students involved in the planning and construction of the exhibition, and (3) experts from universities, science centres/museums and researchers from the thematic field of the exhibition.

Data collection comprised three steps, the first of which corresponded to (1) an interview with the teacher(s) or an open questionnaire, focusing on their *difficulties* with the construction and development of exhibitions, their *professional learning*, their thoughts on the *impact on students learning* and their *overall evaluation* of the process of construction and development of the exhibition; (2) a focus group interview with a group of students who planned and developed the exhibition, focusing on their *difficulties* in the construction and development of the exhibition, the *skills developed*, and their *overall evaluation* of the process of construction and development of the exhibition; and (3) an interview with the scientists and the experts of science centre/museums or an open questionnaire, focusing on their perspectives regarding the process of construction and development of the exhibition, and their *overall evaluation* of the process.

Each case study had to follow the same structure, including (a) the exhibition name, (b) the covered RRI topics, (c) teacher(s) name, (d) student group and grade, and (e) links to materials (**figure 6**). Each case study addressed the following questions: (1) description of the process of construction and development of the exhibition; (2) evidence of teachers' perceptions (data collected from the interview or open questionnaire); (3) evidence of students' perceptions (data collected from the focus group interview); (4) evidence of the experts' perceptions (data collected from the interview or open questionnaire); (5) overall balance (regarding teacher, students and experts perceptions), and finally, (6) partners evaluation.


irresistible
Instituto de Educação

CASE STUDY

Escola Básica 2/3 Alfredo da Silva | Portugal
Responsible Climate Geoengineering
Instituto de Educação da Universidade de Lisboa
July 2015

Exhibition name	The Irresistibles from class 8D
Topics addressed (general and RRI topics)	Climate Geoengineering
Teachers	**Teacher 1** (Natural Sciences, NS) - female; 39 years old; 15 years of experience; Degree in Teaching of Biology and Geology (master in Geology)
	Teacher 2 (Physics and Chemistry, PC) - female; 43 years old; 19 years of experience; Degree in Teaching of Physics and Chemistry (master in Chemistry)
Student group and grade	1 class from 8th grade 21 students (9 male + 12 female) Average age: 13 years old
Links to materials	Blog https://osirresistiveisdo8d.wordpress.com/ RRI video https://www.youtube.com/watch?v=LvLubmtodPA Game "Who wants to be a Geoengineer?" https://scratch.mit.edu/projects/embed/64941758/?autostart=true Jogo da Glória (game) https://scratch.mit.edu/projects/embed/68413758/?autostart=true

2

Fig. 6 – Front page of one case-study and table of characterization of the exhibition, participants and links to materials.

The individual and focus group interviews **analysis** followed a qualitative approach, with the integral transcript of the answers and the discussion generated followed by the corresponding content analysis. Transcription facilitates further analysis and establishes a permanent written record of the group discussion that could be shared with the project partners. Once the transcript was finished, it served as the basis for the qualitative analysis through content analysis. **Figure 7** synthesizes the process of case-study development and analysis.

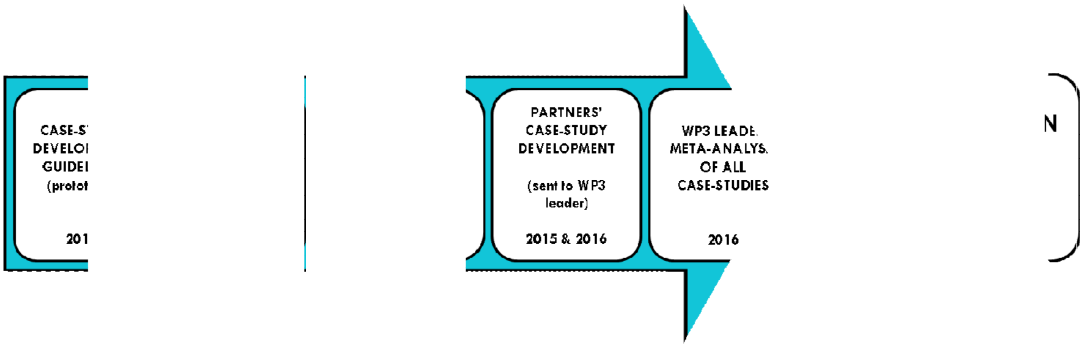


Fig.7 – The process of case study development started in 2014, with the development of the Guidelines made available to all partners. In each of the two CoL's each partner produced at least one case study. The whole group of cases was then analysed by the WP3 leader.

From the 1st CoL round, 14 case-studies were produced and from the 2nd round, 12 case studies (table 1). The 26 case-studies were analysed as a whole group.

Table 1 – Total of case-studies analysed (CoL1 + CoL2)

	Partner	Exhibition topic	Teachers	Students	Classes	Grade
CoL1 (2014/2015)	**Finland**	Climate Change	4+16=20	86	4	6th
	Germany - IPN	Ocean Plastic Pollution	1	22	1	9th
	Germany - DM	Oceanography	4	60	2	9th
	Greece	Nanotechnology	1	16	1	8th
	Israel	Nanotechnology	1	16	1	9th
	Italy - UniBO	Nanotechnology	1	23	1	12th
	Italy - UniPa	Nanotechnology	3	73	4	8th & 11th
	Poland	Nanotechnology	1	35	1	10th
	Portugal	Climate Geoengineering	2	21	1	8th
		Polar Science	1	46	2	10th
	The Netherlands	Carbohydrates in Breast Milk	2	81	3	11th
		Carbohydrates in Breast Milk	2	18	1	11th
	Romania	Nanotechnology	1	210	-	10-12th
	Turkey	Nanotechnology	1	20	1	5-9th
CoL2 (2015/2016)	**Finland**	Climate Change & Geoengineering	1+2=3	30	4	6th
	Germany – IPN	Ocean Plastic Pollution	1	27	1	11th
	Greece	Nanotechnology	1	21	1	10th
	Israel	Carbohydrates in Breast Milk	1	32	1	11th
	Italy - UniBo	Nanotechnology	1	136	6	4-9th / 1 -10th / 1-11th
	Italy - UniPa	Nanotechnology	4	61	4	10th & 11th
	Poland	Nanotechnology	1	35	1	8th
	Portugal	Climate Geoengineering	1	27	1	10th
		Polar Science	1	27	1	10th
	The Netherlands	Carbohydrates in Breast Milk	2	55	2	11th
	Romania	Nanotechnology	1	25	1	7th & 8th
	Turkey	Climate Change	15	154	6	5th-10th
			72	**1357**	**52**	

3. CASE STUDY CROSS-ANALYSIS

3.1. The exhibition development process

In order to know the impact of exhibitions development and construction, addressing concepts of Responsible Research and Innovation (RRI), on teachers' personal and professional development and, to understand how students experience these exhibitions and their effects on students' competencies, case studies were developed by each IRRESISTIBLE partner in two distinct moments: Col1 – during the 2014/2015 school year, and Col2 – during the 2015/2016 school year.

Within the two Project modules' testing phases, a total of 26 case studies were developed on the exhibition development and construction process about the scientific cutting-edge topics and RRI dimensions, as described in **table 2**.

Table 2 – Selected exhibitions for the development of the case-studies in each CoL round.

Partner	CoL	Module	Case Study Exhibition
Finland	1	Climate Change Prevention and accommodation	Climate change
	2	Geo-engineering Climate Control	Climate change and geo-engineering
Germany IPN	1	Plastic - Bane of the ocean	Plastic - Bane of the ocean
	2	Plastic - Bane of the ocean	Human impact on the Oceans
German DM	1	Oceanography and Climate Change	Oceanography
Greece	1	Nanoscience and Nanotechnology Applications	Nanoscience and its applications
	2	Nanoscience and Nanotechnology Applications	The nanotechnology of self-cleaning materials
Israel	1	Perovskyte Based Photovoltaic Cells	Perovskyte- Based Photovoltaic Cells
	2	Carbohydrates in Breast Milk	The Milk Exhibit
Italy UNIBO	1	Nanotechnology for Solar Energy	Ecopoly
	2	The RRI of Perovskite- Based Photovoltaic Cells	Find the end": RRI & Energy Sources
Italy UNIPA	1	Nanotechnology for Solar Energy	RRI and Solar Energy
	2	Nanotechnology for Solar Energy	RRI in an Inquiry-based approach
Poland	1	The Catalytic Properties of Nanomaterials	Nanoworld
	2	Nano in Health Science	Nanoworld
Portugal	1	Polar Science	RRI and Polar Science
	1	Geo-engineering Climate Control	The Irresistibles from class 8D
	2	Polar Science	RRI in the Portuguese Polar Science
	2	Geo-engineering Climate Control	Geo-engineering of climate
The Netherlands	1	Carbohydrates in Breast Milk	Healthy ageing starts with mama (Goningen)
	1	Carbohydrates in Breast Milk	Healthy ageing starts with mama (Wolvega)
	2	Carbohydrates in Breast Milk	Healthy ageing starts with mama
Turkey	1	Nano in Health Science	Nanotechnology applications in Health Sciences
	2	Climate Change	RRI in the Context of Climate Change
Romania	1	Nanomaterials and Energy	Applications of Nanomaterials in Energy Area
	2	Nanomaterials and Energy	Nanoscience - A Facilitator Background for a United Group

Each partner developed one or more case studies for each module produced, and tested by the respective CoL1 and CoL2 emphasizing: the process of development and construction of exhibitions, the difficulties highlighted the learning achievements, and positive and negative aspects of the development of the exhibits.

Some of the modules tested by the CoL2 were adapted taking into account a) the students' level and necessities (Finland, Greece, Turkey); b) the curriculum content of the country that tested the module (Israel); and c) the time available to apply the module (Portugal).

3.1.1. Participants

Regarding the CoL1 and CoL2 participants, were involved in the development and construction of scientific interactive exhibitions 55 teachers (plus 18 student teachers), 1357 students distributed over 59 classes from 5th to 12th grades of partner countries' schools, supported by 51 science educators and experts from museums and science centres (**table 3**).

Table 3- Study cases participants from partners CoL1 + CoL2 members.

Partner	CoL	Exhibition name	Total number of Teachers	Total number of students	Total number of Classes	Grade	Total number of experts
Finland	1	Climate change	4 (16)	86	4	6th	3
	2	Climate change and geo-engineering	1 (2)	30	4	6th	3
Germany - IPN	1	Plastic - Bane of the ocean	1	22	1	9th	1
	2	Human impact on the oceans	1	27	1	11th	2
Germany - DM	1	Future Ocean	4	60	2	9th	3
Greece	1	Nanoscience and its applications	1	16	1	8th	*
	2	The nanotechnology of self-cleaning materials	1	21	1	10th	*
Israel	1	Perovskyte- Based Photovoltaic Cells	1	16	1	9th	*
	2	The Milk Exhibit	1	32	1	11th	*
Italy - UNIBO	1	Ecopoly	1	23	1	12th	*
	2	Find the end": RRI & Energy Sources	1	136	6	9th(4), 10th,11th	6
Italy - UNIPA	1	RRI and Solar Energy	3	73	4	8^{t}h & 11th	*
	2	RRI in an Inquiry-based approach	4	61	4	10th & 11th	*
Poland	1	Nanoworld	1	35	1	10th	5
	2	Nanoworld	1	35	1	8th	9
Portugal	1	RRI and Polar Science	1	46	2	10th	2
	1	The Irresistibles from class 8D	2	21	1	8th	2
	2	RRI in the Portuguese Polar Science	1	27	1	10th	1
	2	Geo-engineering of climate	1	27	1	10th	1
The Netherlands	1	Healthy ageing starts with mama (Goningen)	2	81	3	11th	1
	1	Healthy ageing starts with mama (Wolvega)	2	18	1	11th	1
		Healthy ageing starts with mama	2	55	2	11th	1
Turkey	1	Nanotechnology applications in Health Sciences	1	20	1	5th - 9th	3
	2	RRI in the Context of Climate Change	15	154	6	5th - 10th	5
Romania	1	Nanomaterials and Energy	1	210	7	10-12th	1
	2	Nanoscience - A Facilitator Background for a United Group	1	25	1	7th & 8th	1
		Total	**55** (18)	**1357**	**59**		**51**

*information not provided

Teachers who tested the modules where aged between 26 and 59 years old (**table 4**). Of the total 55 teachers, 31 had been teaching for more than 10 years, with 15 having 20 or more years of experience. Five teachers where less experienced having only between 9 and 5 years of experience and one of the teachers was in practical training. Regarding their level of training, 4 teachers had a PhD, 7 had a Master degree in Science and 2 a post-graduation specialization degree. The level of training of other teachers was not indicated. The subjects taught by teachers where mainly in the physical and natural sciences areas, particularly Biology, Physics and Chemistry.

All modules were tested and the exhibitions developed and constructed in the context of regular science classes, with the exception of:

a) CoL 1 – Plastic module - Bane of the ocean, Nanotechnology applications in Health Sciences and Nanomaterials and Energy. The first one was tested in the course of the WPK, a new interdisciplinary subject recently introduced in high schools (Gymnasium) in Schleswig- Holstein area, Germany. The second one was tested by a group of students ranging from grades 5 to 9 as an extracurricular activity. The third one was developed as a Unit of non-formal education offered to students and teachers by the Scientific and Technological Institute of Multidisciplinary Research of Valahia University.

b) CoL2 – Nano in Health Sciences and Climate Change modules tested by Poland and Turkey Col2 partners. The first one was tested as an extra-curricular school activity. The second one was implemented as a science club project by 10 of the 15 teachers that tested the module.

The Climate Change Prevention and accommodation implemented, from the Finnish partner, was implemented in four 6th grade classes by a group of 16 student-teachers from the University of Jyväskylä, as well as the Geo-engineering Climate Control tested by the same partner in four 6th grade classes by a group of 2 student-teachers from the University of Jyväskylä.

Table 4 – Case-studies: CoL1+CoL2 teachers' characterization

Partner		CoL	Age	Area	Formation level	Years of experience
Finland		1	*	*	*	5
		2	*	*	*	In training
Germany	**IPN**	1	29	Bio	Diplo	5
	IPN	2	26	Chem/Bio	In training	5
	DM	1	50 43 32 48	Math/Phy Chem/Bio	Msc PhD Msc Diplo	23 9 6 10
Greece		1	36	Phy/Chem	PhD	10
		2	38	Phy/Chem	Msc	9
Israel		1	46	Phy/Chem		25
		2	46	Phy/Chem	*	25
Italy	**UNIBO**	1	51	Phy	PhD	26
		2	57	Chem	Post-G	30
	UNIPA	1	44 50 58	Phy/Chem	-	18 20 20
		2	45 47 59 54	Chem	*	19 21 30 17
Poland		1	44	Chem	Msc	*
		2	50	Bio/Chem	PhD	*
Portugal		1	52	Chem	Msc	28
		1	39 43	Nat. Sci. Chem	Msc Msc	15 19
		2	43	Bio/Geo	Pos-G.	22
		2	36	Phy/Chem	PhD	13
The Netherlands	**Gron.**	1	50 50	Phy/Chem	-	25 5
	Wolv.	1	50 50	Chem Bio	-	25 16
	-	2	45 40	Chem Biol	*	20 16
Turkey		1	37	Chem	Msc	15
		2	*	*	*	*
Romania		1	42	Phy	Msc	18
		2	47	Phy/Math	*	24

*information not provided

3.1.2. Description of exhibition development process

The development and construction of an interactive exhibition was the final task common to all modules. The exhibition had to highlight the scientific subject explored in the module and explicitly emphasize the RRI dimensions in order to elucidate the visitors, whether on the scientific subject or the RRI concept, giving insights into current research, and stimulating visitors' thoughts and opinions on controversial subjects.

The development and construction process was described in twenty-six interactive exhibits developed by the CoL1's + CoL2's of each partner (**figures 8-20**) about cutting-edge scientific topics from an RRI perspective, namely, climatic change, polar science, oceanography, geoengineering, breastfeeding, nanotechnology, nanoscience and photovoltaic cells.

Fig. 8 - Climate change exhibition, Finland

Fig.9 - Plastic- Bane of the ocean exhibition (CoL1) and Human impact on the Oceans exhibition (CoL2), Germany IPN

Fig.10- Future Ocean exhibition, Germany DM.

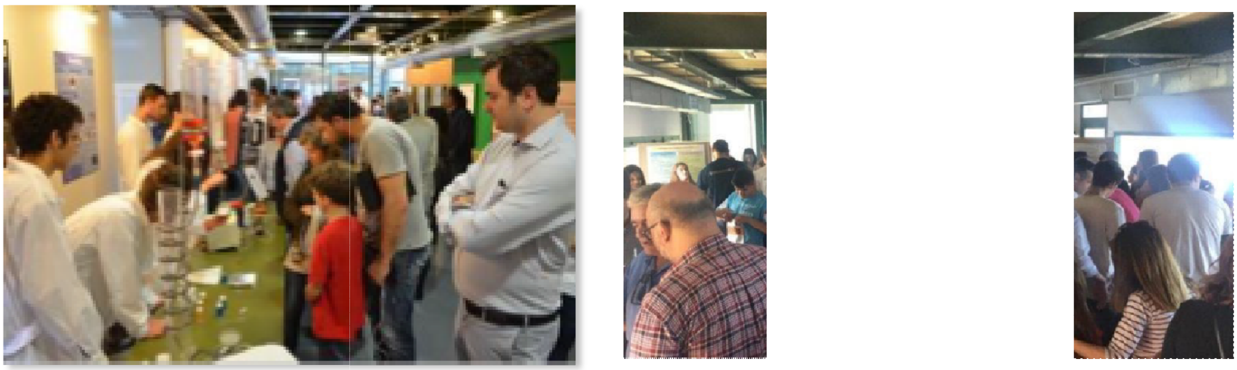


Fig. 11 – The Nanoscience and its applications exhibition (CoL1) and the nanotechnology of self-cleaning materials exhibition (CoL2), Greece.

Fig.12 - Perovskite photovoltaic cells exhibition (CoL1) and the Milk Exhibit exhibition, Israel.

Fig. 13 - Ecopoly exhibition, Italy (UNIBO).

Fig. 14 - EsperienzaInsegna IRRESISTIBLE booth (CoL1) and IRRESISTIBLE booths at the school fair, I.I.S.S. "E. Ascione" (CoL2) Italy (UNIPA).

Fig. 15 - Nanoworld exhibition (CoL1), Poland.

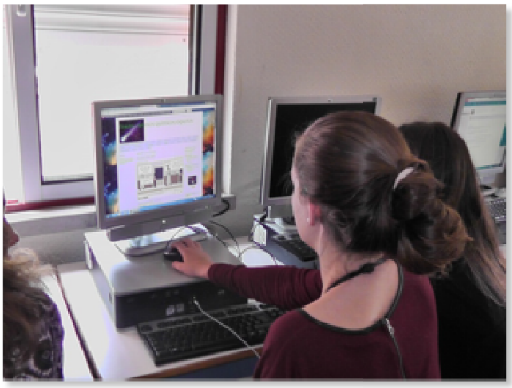



Fig.16 - The Irresistibles from class 8D digital exhibition (CoL1) and Geo- engineering exhibition (CoL2), Portugal.

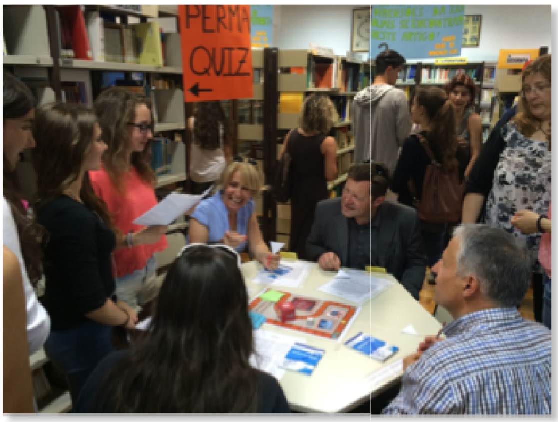


Fig. 17 - The RRI and Polar Science exhibition (CoL1) and the RRI in The Portuguese Polar Science exhibition (CoL2), Portugal.


Fig. 18 - Carbohydrates in Breast Milk exhibition (CoL1) and Carbohydrates in Breast Milk exhibition (CoL2), The Netherlands.

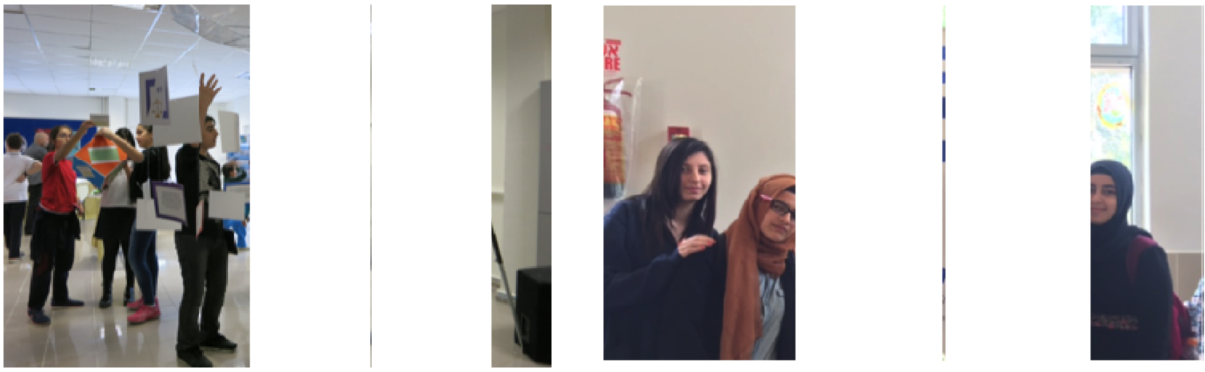


Fig. 19 – Nanotechnology applications in Health Sciences exhibition (Col1) and RRI in the Context of Climate Change exhibition (CoL2), Turkey.

Fig. 20 - Application of nanomaterials in energy area (CoL1) and Nanoscience - A Facilitator Background for a United Group (CoL2) exhibitions , Romania.

Previous activities and tasks

The modules include several tasks and activities designed to engage students in a scientific topic and in the dimensions of the RRI. These activities were all conducted with a focus on generating content and input to the exhibition in both areas. As we can see in **table 5**, lectures/talks from experts (22), brainstorming/debates (14), hands-on activities/experiments (14) and visits to University labs, Museums and science centres (13) were the most implemented.

Table 5 - Occurrences of types of tasks/activities developed before the planning and construction of the exhibitions.

Type of previous tasks/activities		Number of exhibitions which developed these type previous task/activities
Lecture/talks	Scientific Topic	**9**
	RRI	**6**
	Exhibitions	**7**
Visits	University labs & research centres	**8**
	Museums & Science Centres	**5**
Student Presentations about the topics		**9**
Brainstorming/Debates		**14**
Games/ role play		**5**
Hands on activities/experiments		**14**
Watch videos /documentaries		**4**
Field Trips		**2**
Research information	Tablets inquiry	**1**
	Critical study of newspaper articles	**1**
	Scientific papers analysis	**1**

Lectures/talks about exhibitions were used to help students in the development of scientific knowledge related to the scientific topic of a given module, as well as the RRI concept and its dimensions (**figure 21**). They were also used to help students in the exhibition development and construction process. Besides giving insights about the different ways of communicating content in the exhibition to the students, they were also given practical tips on how to write museum texts, how to research images, and how to plan an exhibition, as well as, some motivation to why exhibitions are developed.

The meeting with Michelangelo was crucial, without this some good ideas may not have come out (Student, Italy).

Fig.21 - Students attending a scientific lecture, Italy UNIBO

Often lectures/talks were associated with **visits to University labs, Museums and science centres**, and/or given by local scientists/staff, before or after the visit. This approach is supported by the IRRESISTIBLE project purpose to combine formal and non-formal teaching (**figure 22**). These site visits intended to give students the opportunity to: a) experiment real science contexts; b) talk and share ideas with scientists about their research topic; c) to allow students to explore scientific labs; and d) to allow them to experience different scenarios of interactive exhibitions. This close contact allowed students and teachers to get support and clarify any questions or doubts with experts in science, RRI, and/or scientific interactive exhibits.

> *The visit to the museum and the contact with the staff was a key moment in the construction of the exhibit and for the students themselves. They came to the museum with a different idea but Michelangelo confronted them with the reality and the feasibility of their ideas. (Teacher, Italy)*

> *During our tour in the EF exhibition we had the opportunity to discuss with the exhibits expert on specific problems we had faced building the exhibit, we took precious advice on how to ameliorate it and even new ideas emerged. For example, we were trying to find a way to build a model about self-cleaning surface and Mr. Alexopoulos suggested to use somehow magnetic forces to simulate the way water drops attract dirt. And that's how we came up with the sphere magnet and iron filings model. (Student, Greece*

> *The meeting with Michelangelo was crucial, without this some good ideas may not have come out. (Student, Italy)*

> *Being at the JU, we learned what the work of scientists looks like, we saw various machines, and we just learned what it all looks like and how much you need to achieve to get there. (Student, Poland)*

> *We were impressed by the nanomaterials developed in Greek laboratories; we didn't know that this kind of innovation is taking place in Crete. Scientists' workplace was awesome and I am fascinated by the tools they use. (Student, Greece)*

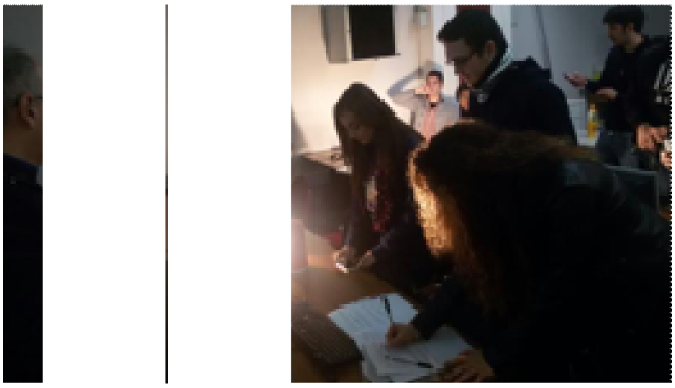


Fig. 22- Students testing the effect of radiation on matter, at the Palermo university laboratories, Italy UNIPA

Hands-on activities and **laboratory experiments** allowed students to understand scientific concepts, test scientific principles and promoted critical thinking (**figures 23 and 24**). These activities helped students to clarify concepts promoting a deeper understanding of a scientific topic.

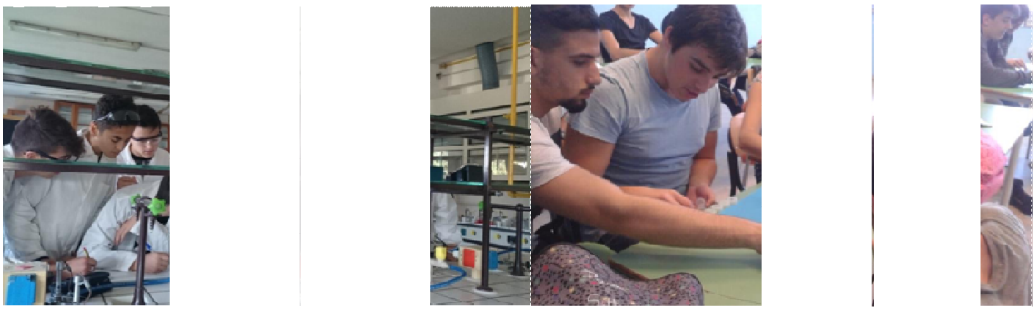


Fig. 23 – Students assembling Graetzel cells in the lab, Italy UNIBO (left) and Students working on a model of absorption using bottle caps, Italy UNIPA

The experiment and discussion revealed that the experiment helped pupils to understand how the colour and material of a house roof influences the emission of infrared (IR) radiation from the roof. (Finland)

I didn't know anything about nanoscience. I was very surprised when I learned that properties of elements, such as silver nanoparticles, change at the nanoscale. The colours may change as well. Yet, for example, iron loses its magnetic property. Things like that... They all made me surprised. I mean simply, the properties such as colour or fluidity may change, but as I said, the change in the intense properties such as magnetism made me so surprised. (Student, Turkey)

Fig. 24 – Experimental classes carried out as part of the Project, Poland.

Brainstorming and debates were carried out either on the scientific topic and/or the RRI dimensions (**figure 25**). Students had the opportunity to clarify issues, present arguments, express their opinion and present examples and suggestions about RRI aspects related to the scientific topic explored.

Fig. 25 - Poster showing ideas about science education RRI dimension presented by students, Turkey (left) and Radar chart (spider net) resulting from discussion on topics of scientific research (right), Poland.

Student presentations about the topics was another task used several times (**figure 26**). It worked as an opportunity to exchange the content between groups, allowing teachers to check the knowledge researched, that would later be used in the exhibition. This also promoted a wider understanding of the researched topic showing the relationships between subtopics of the different groups, promoting the development of a coherent exhibition.

Fig. 26– Presentation about scientific article (left) and the good practices identified and suggested by students to improve RRI, Portugal.

Time constraints in both Portugal and The Netherlands CoL2 geoengineering case study prevented the complete development of RRI topic.

> *(...) The issue of Responsible Research and Innovation turned out not to be as explored as what I would have liked, because of lack of time, it turned out to not be so explored. I made them, giving them a leaflet to explain each of the principles associated with the RRI, we had to discuss ... But it was, perhaps, a little briefer; so much that they know when they were doing the final questionnaire also came back to me to with the same questions they asked at the beginning, in relation to ethics - what is this ethical!? - And ready confirmed that, in fact it was ... (Teacher, Portugal)*

> *Both teachers worked hard to make the module fit in the curriculum, they both moved some other topics to other time periods to fit the module in …The part about RRI was left out because of limited time available. (The Netherlands)*

It was a consensus among the diverse CoL1 and CoL2 members that the tasks and activities that led to the exhibition design were crucial for students learning, allowing them to develop ideas on the approach to be used when planning and constructing their exhibits. In fact, the construction of the interactive exhibition as a final task turned out to guide and give direction to the development of the previous tasks, creating a goal to guide them since the beginning of the project.

> *Definitely I think that it would be impossible without the previous tasks! Besides guiding us, because we have to walk for getting a better final product later, also gives us a context. We learn what we really have to search, some things may also not appear in the exhibition but we have to know it all to be able to convey some knowledge! And I think eventually every task lead to the next and when we got to the end we have an idea more or less formed, at least from what we want to talk! (Student, Portugal)*

> *Without such research work performed in the frame of IRRESISTIBLE Units, we couldn't have created such exhibits. The resources used for documenting helped us a lot! But if we had not been directed by the researchers and our teachers, it would have been quite*

difficult! And we also worked with our teachers on the materials which are needed to assemble the exhibits! The research laboratory equipment enabled us to achieve high quality products which now are exhibited! (Student, Romania).

Because, I think, that all these tasks were the basis of everything! All the knowledge that we ... The RRI, even the module itself, all we had to take that knowledge to the exhibition and to interactively. (Student, Portugal)

The module tasks leading up to the design of the interactive exhibition on the subject (final task), were crucial to the construction of knowledge by students on the scientific topic discussed on the current polar research and about RRI, enabling them to develop ideas as the artefacts to build and define the way forward for the development of interactive exhibition. (Portugal)

The phase leading up to the exhibition design was essential to the students' construction of knowledge about both the subject and RRI. Indeed, the exhibit stage represented a functional and helpful part of the module and oriented the whole project since the beginning. (Italy)

On the other hand, for some students and teachers the scientific topics were new and the tasks allowed them to have contact with these new concepts and the controversial aspects surrounding them.

I didn't know anything about nanoscience. I was very surprised when I learned that properties of elements, such as silver nanoparticles, change at the nanoscale. The colours may change as well. Yet, for example, iron loses its magnetic property. Things like that... They all made me surprised. I mean simply, the properties such as colour or fluidity may change, but as I said, the change in the intense properties such as magnetism made me so surprised. (Student, Turkey)

I think that it [initial tasks] was important for us to frame in with the theme and not be a surprise theme for us. Otherwise, if they told us to build an exhibition on the Polar Science when some of us - I think most of us - it was not a subject we knew well, or at least, had any idea of its importance, maybe the final exhibition would not be as interesting or appealing as it is. (Student, Portugal)

Most of the work done during the task of the planning and constructing the exhibits module was carried out in groups. These tasks were developed during class time as well as extracurricular activities. In the cases of Romania, Israel and Poland the tasks were done jointly with Science Museums, Science Centres and Universities, through visits (**figure 27**).

Fig. 27 – Polish students in different activities during the workshop day at Jagiellonian University.

Planning and construction phase

The exhibition planning and construction - the final task common to all modules - was taken into account since the beginning of the module development. The exhibitions had to be planned aiming to highlight the scientific cutting-edge topics and also the concept of RRI and its dimensions, taking into account that they must be interactive.

Most exhibitions were planned and constructed by the school students. The Finish case was the only exception. In CoL1 student-teachers designed and created almost the entire exhibition. However, students' ideas were gathered for the topic of the exhibition by the student teachers and some of objects built by students were integrated into the exhibition, such as the videos related to climate change and the CO_2 equivalents. In the CoL2 student-teachers designed and created some additional experiments to be incorporate in the final exhibition.

> *The pupils' own handwork did not show in the exhibit that did not make a movie […] but what our group built for the exhibit came from pupils' ideas. (Student-teacher, Finland)*

In all cases the process of planning and construction was performed in groups, most of the times with the same group organization from previous tasks and activities.

In the majority of the exhibitions developed, the process was initiated by a group brainstorming or debate about the topics to include in the exhibition. In other cases, (i.e. Plastic - bane of the ocean) the topics were defined from the beginning of the module implementation.

> *"So in terms of organization at our 1st meeting on the exhibits I simply called students to think about the content their exhibits they would like to have. At the next meeting I gathered on the board their interests and grouping them we jointly decided to create 3 exhibits as a class…" (Teacher, Greece).*

The selection of topics to include in the exhibition was followed by the organization of the students in small groups and the topic assignment to each group. Each group was them responsible for the design and construction of the objects related to their topic.

> *During our first 3 meetings on exhibits, students elaborated their ideas and finalized the topic and the design. At first, they wanted to focus on super hydrophobic materials' properties but as they brainstormed and more ideas emerged, they ended up dealing specifically with their self-cleaning properties. (Teacher, Greece)*

Regarding the selection of topics by each group, students mentioned that their choice resulted from the topics that they had researched during the previous tasks or related to the topic that impressed them the most during the module implementation as well as being more relevant, in their opinion to society.

> *At the beginning we had to come up with an idea for the exhibit. We didn't know what to choose. Most of our classmates wanted to deal with the super hydrophobic properties because it was something that we were impressed about! And we definitely wanted to impress the visitors too, so we worked towards this. (Student, Greece).*

> *The choice was made by the whole group after discussing various options and gathering the ideas of the entire group. (Student, Poland)*
> *We wanted to do an exhibit about nano-medicine because people are very interested in the treatment of cancer and nanotechnology can provide this capability through nanorobots. So we did it for public awareness and concern (Student, Greece).*

> *We wanted visitors to be impressed by the properties of nanomaterials and to provide authoritative information about them to decide which ones they would like to use if needed and which ones not (Student, Greece).*

> I liked the fact that we were very free in what to make. With most other subjects, you have to make something in a certain format (e.g. poster) but here that was not the case. That is stimulating for the creativity (Student, Netherlands)
> *We've made a good match together and we thought quite a long time which topic to deal with, but no one imposed it on us and we tried to find a topic that we would be interested in, in order not to do this as if forced, but derive some pleasure from that and also work together. (Student, Poland)*
> *The content and form of the exhibit was selected by the students. (Student, Poland)*

> *Working in such a group, I gave the students great freedom in planning the exhibits. I only provided advice during the concept verification stage. (Teacher, Poland)*

Both teachers and students used different tools to manage the exhibition planning, as well as during some of the other tasks. Some of the resources used included: a workflow with tasks and a time frame to help students to keep track of their assignments (Germany); expert panels (German); mind maps (German); Edmodo (Greece); Wordpress (Portugal); Moodle (Portugal); and Facebook groups (Greece, Portugal and Poland) (**figures 28 and 29**). These tools helped to ensure a wide variety of choices and avoid having duplicate topics, while supporting their motivation when working on a topic of their choice. The tools were used to: a) intra and inter group communication, and between student groups and the teacher; b) feedback on some tasks performed by either the teacher or the researcher who supported the implementation of the module; c) sharing the work done by different groups, since some of the tasks where developed outside the classroom.

> *As the 21 students were from several different classes and their meetings didn't take place in the same space or hour each week, we used a Facebook closed group to communicate, arrange their meetings and to exchange opinions. At first, it was mostly me who initiated the discussions in the group and students were just responding. But as immediate problems arose, students started using it by their own initiative to coordinate their tasks(...). (Teacher, Greece)*

> *To foster the exchange between the student groups on the content as well as on the way of presentation in the exhibition, several expert panels with one representative of each group were established. One of these panel groups discussed the distribution of the content and thematic overlaps, another group exchanged ideas on presenting the content in interesting, adequate and diverse ways. (Case study, Germany)*

> *In the course of the meetings, the students, either during the weekly lessons, either via the Edmodo platform we used for the program, they agreed on the type of exhibits, on the texts and images that would include in their exhibits etc. (Teacher, Greece)*

> *Working meetings would not be enough. We had to think some things over outside the classroom, at home, on Facebook, for example, we wrote, solved the problems that we came across. (Student, Poland)*

> *Facebook group, in which the tasks for the students were published, and discussions on the proposed issues were conducted. (Case Study, Poland)*

Fig. 28 – Facebook group *to communicate, organize meetings and exchange opinions,* Greece (left) and closed group on the Facebook platform to boost the Polar Science module, Portugal (right).

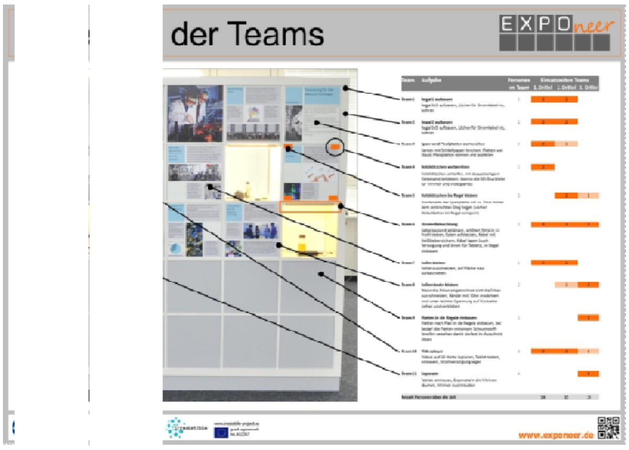


Fig. 29 – Poster used as tool to distribute tasks within group in teams, Germany.

Student groups were responsible for producing one or more objects for the exhibition about the selected topic, focusing mainly on the researched topic and in RRI. Each working group designed a plan or contributed to building an object - object type, size, exhibition mode, materials and a general outline of the object's content (**figure 30**).

At the beginning, a detailed plan was created, then the necessary materials were purchased. Then we started working on the model. At the end we polished the details and created an accurate description. (Student, Poland).

First when they showed us what we had to do, the task, we did not have any ideas! We had, but then we always thought it was impossible ideas... So we decided each one of us will bring ideas and then we voted on the best one, and try to give it a bit more and develop further the idea we had chosen. The most difficult part was the thinking process, the doing part was very easy and it was much faster than thinking about the project. And we ended up as we wanted! . (Student, Portugal)

When we got together we carried on some ideas, we evaluated the pros and cons of each idea. Then we chose what we judge to be easier to figure out, what would allow us to exploit all our ideas, and what could to be easily understandable by the public (Student, Italy).

The groups chose the subject area of their exhibits independently. They also made independent decisions on how their exhibit would be built, what materials to use and how the final product would look like. (Poland)

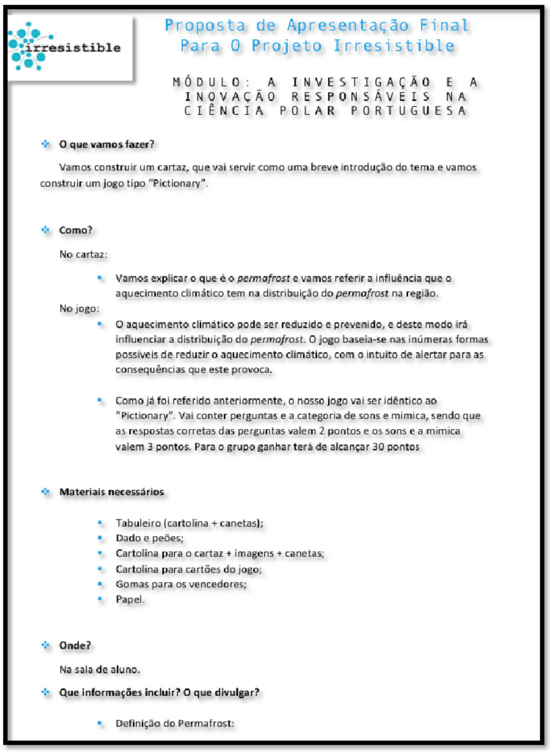
The plans designed by each groups were reviewed by the other groups (Germany), by the teacher, and in some cases also by expert members from the University or Science Centres (i.e. Finland, Portugal, Greece, Israel, Italy The Netherlands, Romania and Turkey).

First, we wrote the plan, then we presented it to our whole school group. Then, after making the amendments, we proceeded to the creation of the exhibit. After some time, we *presented ready-made models to the group again. Getting further advice from schoolmates, we could already improve our exhibits to perfection. (Student, Greece)*

The exhibits were presented to a jury composed of some experts and all the students taking part in the project. The experts of the jury were some CoL members: a university professor, an education expert and a teacher, plus some students who participated in the first round. (Case Study, Italy).

We starting modifying the first ideas, making it better and then we received feedback from teachers and from there we tried to give specific tasks to everyone ... we tried to exploit the strengths rather than the weaknesses of each, so that we could do this as soon as possible and as efficiently as possible. (Student, Portugal)

Through the focused field visits, students understood that designing an exhibit is not an easy process. They realised that further research is needed in order to communicate the subject matter to the general public, before getting to the hands-on phase of the process. (Science Museum Expert, Greece)


irresistible

Proposta de Apresentação Final
Para O Projeto Irresistible

MÓDULO: A INVESTIGAÇÃO E A INOVAÇÃO RESPONSÁVEIS NA CIÊNCIA POLAR PORTUGUESA

O que vamos fazer?

Vamos construir um cartaz, que vai servir como uma breve introdução do tema e vamos construir um jogo tipo "Pictionary".

Como?

No cartaz:

- Vamos explicar o que é o *permafrost* e vamos referir a influência que o aquecimento climático tem na distribuição do *permafrost* na região.

No jogo:

- O aquecimento climático pode ser reduzido e prevenido, e deste modo irá influenciar a distribuição do *permafrost*. O jogo baseia-se nas inúmeras formas possíveis de reduzir o aquecimento climático, com o intuito de alertar para as consequências que este provoca.
- Como já foi referido anteriormente, o nosso jogo vai ser idêntico ao "Pictionary". Vai conter perguntas e a categoria de sons e mimica, sendo que as respostas corretas das perguntas valem 2 pontos e os sons e a mimica valem 3 pontos. Para o grupo ganhar terá de alcançar 30 pontos

Materiais necessários

- Tabuleiro (cartolina + canetas);
- Dado e peões;
- Cartolina para o cartaz + imagens + canetas;
- Cartolina para cartões do jogo;
- Gomas para os vencedores;
- Papel.

Onde?

Na sala de aluno.

Que informações incluir? O que divulgar?

- Definição do Permafrost:

Fig. 30 – Planning example for the construction of one object to be included in the final exhibition, Portugal.

Students were free to choose the type of object they wanted to construct, taking into account the interactive character that the exhibition should have and using accessible materials that could be easily bought or recycled.

I think if each one of the groups had a predefined specific task from the beginning I think it would be very damaging for this exhibition. If the intent is to have interactivity and creativity, our imagination cannot be limited. I think having this freedom is very important to us, even to explore knowledge and do things we've never done before. I think it's very important! (Student, Portugal)

We didn't want the visitor to read the texts, because we knew we wouldn't do so either. So we had to find a way to "pass" them the knowledge indirectly, by interacting with the exhibit. That is why we decided to include hands-on models to simulate the water-surfaces interactions instead of writing down a theoretical text. (Student, Greece).

The students were free to choose both the contents and the form of the exhibit. The class has been grouped in groups of four with assigned roles. Then each group had to decide the contents and the format of the exhibit and to write a short description of it. Then they started to create the exhibit. They had to find and manage the material and technology useful to build up the final product. (Teacher, Italy).

Most objects were built outside of the classroom due to the time required for this process. By condensing the curriculum content into a smaller number of lessons teachers were able to create additional time for the project. Despite these efforts, a large part of the work still had to be conducted outside regular school lessons.

The students worked in the design and construction of their part of the exhibit at their homes. The main reason for this practice was that the students had to take the Bagrut in chemistry later in the year, and needed more time to study the material that would be covered on the test. (Case Study, Israel)

But there were many things they had to do outside of the classroom, those who have developed more complex things, almost everything was done out of the classroom (Teacher, Portugal).

The parents, in some cases, have collaborated and assisted in the process of the objects' construction (e.g. Poland, Italy) (**figure 31**).

They had to work in group also at home and this part, even if problematic for some students because of bus connection and time, has been highly appreciated both by students and parents. Parents valued a lot the opportunity given to the students to meet and study informally. And the students appreciated the extra time they had to spent with classmates even if sometimes emerged problems of conflict management (Teacher, Italy).

Fig. 31 – A father contributing to the construction of the exhibit entitled "Nanosilver In Our Body" , Poland.

Concerning the interactive scenarios selected and the type of objects built by students, some exhibitions were more homogeneous and others more eclectic. **Table 6** presents the results regarding the type of objects produced within the 26 developed exhibitions analysed in the case studies.

Table 6 -Occurrences of types of objects within the 26 exhibitions. Numbers correspond to the type of objects indicated in the case study. In parenthesis is presented the number of objects made by students.

Type of object		Number of exhibitions with this type of object (total number of objects)
Game	Physical (e.g., cardboard, soccer table)	**9 (70)**
	Digital (e.g., quizzes)	**3 (4)**
Poster	Physical	**11 (29)**
Multimedia presentations (e.g. videos, audio)		**8 (11)**
Cartoons (digital or printed)		**2**
Models		**15 (54)**
Experiments/demonstrations		**12 (23)**
Digital App		**1 (1)**
IKEA bookshelf (EXPOneer system)		**7**

In **table 6** we can see that **games**, **models**, **experiments/demonstrations,** and **posters** were the main types of objects presented in the exhibitions.

The option for developing **games** either physical or digital, was chosen by the majority of students involved in the development of the interactive exhibitions (**figures 32-36**). Students believe that games can be a very powerful strategy for stimulating the participation of visitors, prompting them to interact and creating an atmosphere where the discussion and reflection about important issues can be accomplished in a more playful way.

> *We choose games because we thought that they captivate people a lot, people from different ages. And it helps people to interact with each other, and also to play a little bit with the subject. In that way we can teach the topic to others in a funny and simple way. (Student, Portugal)*
>
> *We thought that it is interesting to learn through games and electronic devices. It is interactive and keeps the user's attention. Besides, to me it was easy to construct an android application because I have this kind of knowledge (Student, Greece)*
>
> *The idea came out when we went to the museum and met Michelangelo, we talked about various things, and then we had the idea of the board game ... we were enthusiastic and put a lot of effort in it. For example, one of our classmate fond of computer graphics, built all the logos and graphics. (Student, Italy)*
>
> *We chose to make a quiz of general knowledge because we thought in this way the user can learn pleasantly for many aspects of nanotechnology and RRI (Student, Greece)*

Fig.32 – Interactive games developed by Polish students presented in the The “Nanoscientist” exhibit

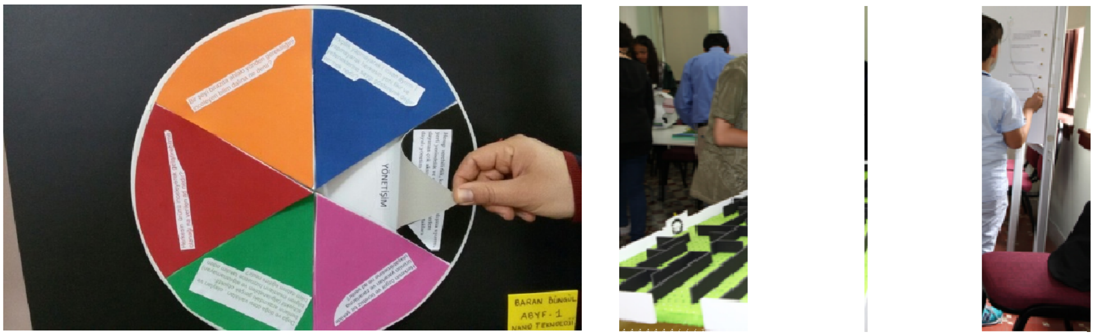


Fig.33 – Interactive games developed by the Turkish students.

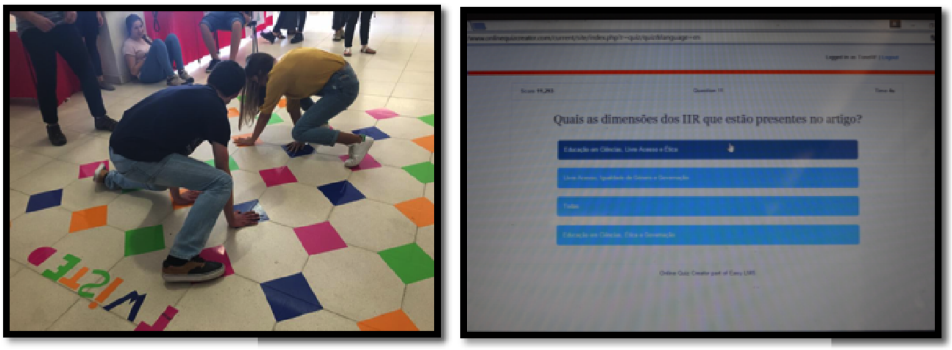


Fig.34 – The Polar Twist game and a digital game developed by Portuguese students, RRI in the Portuguese Polar Science exhibition.

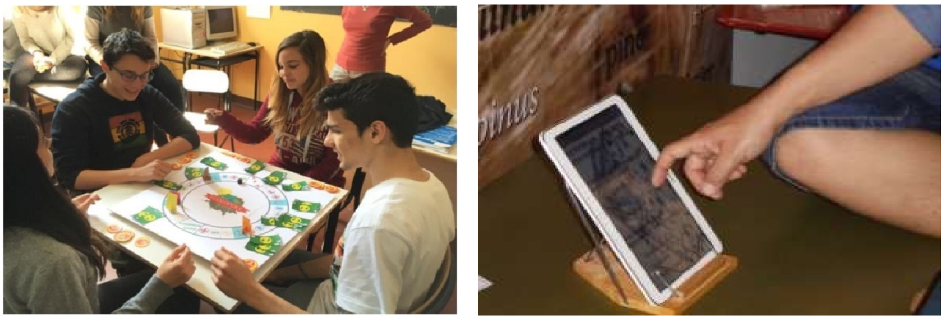


Fig. 35 – The Ecolopoly game - a cardboard game developed by the Italian students (left) and The nano-quiz developed by Greek students (right).

Fig. 36 – Interactive game used to help "raise" visitors' engagement in the activities. Students walked through the park grounds with a bumpy sheet: when a passers-by was interested in visiting the exhibition, filled one of sheet holes and went "fishing" for more visitors, Geoengineering exhibition, Portugal.

The development of **models** was also one of the most frequent type of object produced for the exhibitions. Students and teachers made this choice especially when their exhibitions concerned physical and biochemical concepts and phenomena. This strategy supported an interactive approach allowing visitors to understand more abstract concepts, and see its impact in real life contexts (**figures 37 and 38**).

> *When we were first presented the nanorobot in class we were really fascinated, and we thought the visitors would think the same way. So we used the model of the robot to attract visitors to see the poster that otherwise might not be noticed, because we wanted to give them the necessary information on the nano-medical (student, Turkey)*

> *To be honest I liked nanotechnology, and all the experiments we conducted but I couldn't always understand the science underneath. It was when we made the nail- model that I understood what surface to volume ratio was all about, and what it had to do with nanotechnology. (Student, Greece)*

Fig. 37 – Miniature table, half treated with a waterproof coating, allowing to watch the different way the two parts behaved when water was poured with the push of a button (left) and hands-on model about different behaviour of materials (right), Greece.

Fig. 38 – Model simulating aerosols dispersion by a miniature aircraft, Portugal (left) and Models made by Turkish students (right).

Experiments/demonstrations were also a frequent choice of students as an object capable of stimulating the interaction between visitors and the exhibition (**figures 39 and 40**).

> *The visitor understands better conducting experiments himself, so we chose this way to talk about the properties of nanomaterials (...). From our own experience in visiting NHMC, we noted that we liked more exhibits that were calling us to do something (Student, Greece).*
>
> *The experiment was an important part of the exhibition. Especially, the exhibition mirrors everything we did with pupils. (Student teacher, Finland)*

Fig. 39 – An experiment developed by Greek students (left) and a demonstration developed by Polish students (right).

Fig. 40 – Demonstrations about nano materials in energy solutions developed by Romanian Students.

The development of an **interactive poster** was a scenario chosen several times according to the case studies (**figures 41 and 42**). Students believe this type of object can give information to the visitors, but can also engage them on the topics when interactivity is promoted. Asking visitors to make decisions about the information presented in the poster, requiring them to connect concepts, or classifying statements as true or false, were some of strategies used in the interactive posters.

> *To address the RRI aspects they planned to make an informative but yet interactive poster that would sensitize and inform visitors about the possible disadvantages of nano-products and call them to decide which they would use or not. (Teacher, Greece)*

Fig. 41 – Interactive poster where visitors need to decide which materials they would use or not, sticking the corresponding images on the specific areas in the poster, Greece (left) and Big expressed mottos that depicted the need to respect labour and their colleagues' opinions concerning efficient teamwork, Romania (right).

Fig. 42 – The "Features of a Scientist" exhibit, Poland.

Other objects presented in the IRRESISTIBLE exhibitions were **multimedia presentations**, **books** and **cartoons** (printed or digital). The option for developing such objects was also taken into account by the students involved in the Project, as a way to engage visitors with the scientific topic researched by students (**figures 43-34**).

Fig. 43 – Brochure / booklet that included "The Ethical Charter of Cantacuzins", Romania (left) and Book made by turkish students (right).

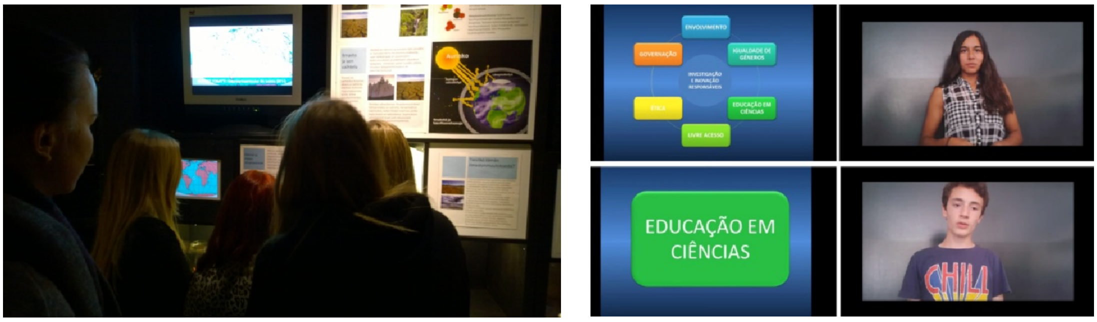


Fig. 44 – Videos promoting awareness about climate change developed by Finnish students (left) and videos with the purpose of clarifying the 6 dimensions of RRI developed by Portuguese students (right).

A **digital application** (**figure 45**) was another object developed by Turkish students to include in the Nanotechnology applications in the Health Sciences exhibition.

Fig. 45 – A digital application developed by Turkish students.

A special remark has to be done to the EXPOneer system that has been chosen to support 7 exhibitions. This it is a modular exhibition system, based on furniture from the Expedit/Kallax- series of IKEA. Each case of the shelf can allocate different types of objects, depending on the student's choices. This enables the creation of high quality, semi-professional exhibitions, that stand out from usual school exhibitions.

The role of teachers during the process of planning and construction exhibitions required them to provide guidance and support to their students'. The Finnish exhibition was the only exception, since the process of planning and construction was developed also by student-teachers as already mentioned. In all other cases, teachers oversaw students' work and gave them advice concerning both content and form for the exhibits. They tried to act as moderators and not to intrude more than necessary in students' creations, only supporting them when asked directly, or if they observed significant difficulties or problems. In some cases, teachers made suggestions regarding the selection of materials, or in finding external support when carrying out particularly difficult tasks (e.g. Polish exhibition, cutting out a large circle of plywood or cutting the housing of a car catalytic converter).

> *I would say that I mostly provided them with advice or ideas. I wanted the exhibits to be theirs, to represent them and to be the result of their own interests and not mine. […] For example, I had to constantly remind students to include RRI issues in the exhibit as they showed a trend to focus exclusively on aspects of nanoscience. Or to advise them about the exhaustiveness and the comprehensiveness of the information they wanted to include in their poster (Teacher, Greece).*
>
> *Students decided the topics and the objects to be present at the exhibition, with the guidance of the teachers (The Netherlands)*
>
> *The implementation of the project classes often required work in groups. During the class on the scientific method, RRI, I imposed the group division on the students. In two cases, the group I selected was not able to cooperate effectively. Therefore, I decided that in order to construct the exhibits, the students would form the groups themselves. (Teacher, Poland).*
>
> *The teacher acted only as a consultant and advisor if the students needed any assistance. (Poland)*

Several collaborations were established during some of the exhibits construction processes. Art students developed 'plastic sculptures' as illustrative items for the Plastic - Bane of the ocean exhibition, while the media technology presented in the exhibition was built with external specialists, supported by a computer science teacher. In the case of Climate geoengineering exhibition, a collaboration was established with the ICT teacher for the creation of digital games.

Display of exhibits

Regarding the place of display of the exhibitions, according to **table 7**, schools were the favourite location. Twenty-one of the twenty-six developed exhibits were displayed at schools. The Finish exhibition was displayed in the Natural History Museum of Central Finland. The Italian RRI and Solar Energy exhibition was displayed as a booth at the EsperienzaInsegna, a general science fair held in Palermo. The Portuguese Climate Geoengineering CoL1 exhibition was displayed on the Web. The Greek CoL2 exhibition was displayed at The Natural History Museum of Crete in Heraklion. The Portuguese Climate geo-engineering CoL2 exhibition was displayed in the City Sports Park, during the Children's Day event.

Table 7 – Number of exhibitions held in different locations.

<table>
<tr><th colspan="2">Place of display of the exhibitions</th><th>Number of exhibitions</th></tr>
<tr><td colspan="2">School</td><td>21</td></tr>
<tr><td colspan="2">Museum</td><td>6</td></tr>
<tr><td colspan="2">University</td><td>2</td></tr>
<tr><td rowspan="4">Events</td><td>Science fair</td><td>1</td></tr>
<tr><td>Conference</td><td>1</td></tr>
<tr><td>Thematic day</td><td>1</td></tr>
<tr><td>Science Day</td><td>3</td></tr>
<tr><td colspan="2">Web</td><td>1</td></tr>
</table>

In addition to being shown in school, the Polish exhibition was also displayed at the 43CIMUSET CONFERENCE and at the SPIN DAY in the courtyard of the Jagiellonian University Museum. Also, the Romanians exhibition was displayed at the "Simeza Hall" of the History Museum of Dâmboviţa County, the Turkish exhibition was displayed at Bogazici University, the Italian UNIBO exhibition in Museo del Balìthe, the CoL2 Polish exhibition in the Jagiellonian University Museum, and Carbohydrates in Breast Milk exhibition from The Netherlands was displayed in the Night of Arts, a science event at a large church in the centre of Groningen.

In the exhibitions displayed at schools, students guided visitors through the several objects of the exhibitions. These exhibitions had the school students and teachers as the target audience, as well as, the school community when the exhibitions were open to the parents (e.g. Portugal, Poland and Turkey). The diversity of open spaces to the public where the others exhibitions were presented allowed also the general public to contact with the concept of RRI and the scientific topic addressed in the exhibitions.

The Greek CoL1 exhibition opening happened in parallel with the other Irresistible Exhibition in Athens. This was a special moment for students because they could virtually share their exhibitions.

> *In early May a parallel opening of the exhibitions took place both in Crete and Athens, a process that excited the students who were present there, and especially their communication via Skype with students in Athens and their digital browsing at their exhibits (Teacher, Greece).*

The Portuguese Geoengineering exhibition was a very successful case reaching approximately 24 000 visitors. Both media and government officials were present and visited the exhibition, allowing students to spread the word about their work.

> *The students and the teacher had the opportunity to give brief interviews journalist with Radio and explain not only the reason to be present at that event, but also the work they had developed throughout the year, under the IRRESISTIBLE. (Portugal)*

The amount of time that the exhibits were on display varied a lot. There were exhibits that were exposed only one day (Israel, Portugal, and Italy), one week (Germany, Portugal, Italy UNIPA), two weeks (Poland) and some more than a month (The Netherlands).

3.2. Difficulties during the exhibition development process

The exhibition development process posed difficulties for both students and teachers. After the analysis of the 26 case-studies, the difficulties were categorized separating the ones regarding students' difficulties (either mentioned by them and/or by their teachers) and the ones regarding teachers' difficulties (mentioned by teachers themselves).

3.2.1. Difficulties for students

According to the case studies analysis, students' difficulties were organized in 10 categories. Some were only mentioned by students, others only by teachers, and some by both (**table 8**).

Table 8 - Difficulties for students in the exhibition development process (N=26).

Group work organization/management	**18**
Novelty of scientific topic and RRI	**17**
Planning the exhibition	**17**
Time management	**16**
Constructing the exhibition	**12**
Resources and materials	**5**
Motivation	**5**
Presenting the exhibition	**2**

As seen on **table 8** the **organization and/or management of group work** in order to develop the exhibitions represented the biggest challenge for students. Sometimes the strategy of having groups of students specializing in one topic or in one part of the exhibition development led them to lose the bigger picture of the process. Students also mentioned the fact that working in group led to situations where there were divergent ideas, and unequal contributions – dealing with it and trying to solve this situation posed a challenge.

Another practical problem that also showed up in a less severe form in earlier EXPOneer exhibition projects was the challenge of dividing the group in several teams for the different building tasks. Students tend to lose the whole picture of building the exhibition when too closely focused on their individual tasks. (Germany - Kiel)

There were students that wanted to do all things by themselves and I didn't have the chance to participate at the extent I wanted to. (Student, Greece)

For some, working in groups was a bit more difficult; some students didn't put as much work in as others; that is something for us to look at next time. (Teacher, The Netherlands)

In some groups the students worked on unequal bases, in others a leader emerged. In both cases, positive and negative aspects can be individuated: in the first case, it was more problematic to reach a common opinion, whereas in the latter situation, students worked more quickly. However, it is clear that the opportunity to compare and stress different ideas produce deeper and more permanent outcomes. (Teacher, Italy – UNIPA)

Some had difficulty to manage group work, to work in a team; others did not, and even helped other groups of colleagues, but there were some difficulty. (Teacher, Portugal)

When working on the materials for the exhibition, conflicts often appeared with colleagues, due to the fact that each of us imagined the exhibit in his/her own way... It is normal, because we have different personalities but after a while, I managed to understand and to function within a team. I think we did a good job together! (Student, Romania)

My team members didn't contribute to the exhibit as much as I did. I was producing ideas, drawing plans on how to construct our project and showing them. Then, my teacher helped me. (Student, Turkey)

I didn't like the group I was in. We did not really discuss among each other. My group members were not really serious and they had to do everything at the last moment. That was a pity. We did not plan well enough. (Student, The Netherlands)

In such an activity, group commitment is important, so the roles must be organized. Each member needs to know exactly what to do, what to say and when. So the success of such an activity depends on team work. (Student, Israel)

There were also conflicts within the groups, because everyone has a different opinion on a selected topic. (Student, Poland)

The exhibition requires a lot of work and sometimes it can lead to a conflict between the persons in the group. (Student, Poland)

Although the opinions are more divergent, and sometimes it is more complicated! In fact, because opinions are more divergent, more time is spent trying to plan, trying to reconcile the views so we could have a project we all like, in which all we want to join in! (Student, Portugal)

That difficulty existed, to work in group, because in the shared documents everyone was working at the same time. And, sometimes, one wanted in a certain way, and other wanted in different ... So we really needed to learn how to work better in group, in team, for things to work well! Sharing tasks... That was a major difficulty, by the way! It was hard but, at the same time, it was an apprenticeship. (Student, Portugal)

In some cases, due to the time demanding task of constructing the exhibition, groups developed their objects at home, which posed a challenge when managing students' contributions to the group.

The arrangement of having students work on the exhibit at home in groups was not ideal; for example, a group of male students took a long time to organize themselves out of school; such an activity would have been much easier if the students had worked in their classroom. (Israel)

The problem most frequently indicated by the project participants resulted from the fact that the construction of the exhibits itself was usually taking place outside school. Different groups claimed that it had been problematic at times to agree on the time of the meeting. (Poland)

The truth is that we didn't work very well together... We could not coordinate. We had difficulty to gather in extracurricular hours and some of us didn't bring all the material we needed each time. So we were late and we only completed the exhibit a few days before the public opening. (Student, Greece)

Another challenge faced by the students during the process of exhibition development was the **novelty of the scientific topic**, both the science and the Responsible Research and Innovation dimensions. Although some case studies mention that students faced the challenge of *understanding an unfamiliar scientific topic*, others specifically mention that the difficulty was mainly in *selecting and organizing information* that was truly necessary for the exhibition development. Mostly because of the large number of information sources and the length of some texts that students needed to read. However, it was also clear that the development of the objects for the exhibition helped students clarifying the scientific concepts and better understanding the topic.

> *The biggest difficulties in the constructing of the exhibitions were related to the variating timetable and the difficult concept of Geoengineering. Therefore, student teachers started their teaching with concepts of climate change, which took time. (Finland)*

> *As far as content is concerned, some students pointed out that some themes and topics were difficult to understand at the beginning and the preparation of tools for the exhibit helped them to achieve a better understanding. (Italy – UNIPA)*

> *As far as RRI issues are concerned, all teachers claimed that students had problems in linking science concepts to a wider context. One teacher stated: "Probably because of their age, in spite of the many discussions also with teachers of other subjects, students were somewhat uncertain about the connection between science and, for example, society. However, the importance of these issues emerged clearly". (Italy – UNIPA)*

> *In the beginning, I will be very honest, the language was quite complex and this did not catch my attention. And also had plenty of new scientific terms. But then my group was organized, shared tasks and it was easy and we finish everything and did it well. (Student, Portugal)*

> *And the part of interpreting what is there… to understand what is there: it seems that they do a diagonal reading and fail to understand well what is there, and then make a copy & paste, and that's it, their work is ready!! That's what they are, well, used to do, is not it!? Delivering papers or simply making Power Points, presenting them – and very often they do not know what they are saying, or understand things that are in the Power Point... And here, with the requirement to make the interactive exhibition and having to contact with other people and explain to them - on top of the public being smaller kids! – that demanded for them to deeply understand the things that were there, in the texts, and that had to make sense to them. (Teacher, Portugal)*

> *For some students, having to conceive objects and discourses capable of explaining such complex issues to small children was the most challenging aspect of the project. (Portugal)*

> *The students considered they came across a series of difficulties regarding: understanding the specific conceptual framework of nanoscience and nanotechnology, identifying benefits and especially the risks posed by nanotechnology, finding arguments for marketing antibacterial socks from the perspective of the played roles. (Romania)*

> *The curriculum for lower secondary education in Romania does not address topics related to nanoscience, nanomaterials and nanotechnology. Therefore, it was a challenge for me as a teacher to approach this subject, considering the students' prior knowledge. But given that we are in an era of cutting-edge technologies, the students proved to be particularly interested in this theme and have been further informed. (Teacher, Romania).*

> *RRI issues were difficult in the pre questionnaire. Ethical issues in research making include many levels of conceptualisation (low, middle and higher level) and my assumption that they cannot understand is just my assumption… … pupils' speechlessness (when asked for*

RRI issues) may reflect pupils' thinking that this issue does not belong to them. (Teacher, Finland)

They had a lot of difficulties – as they normally do – in identifying the essential information! I think that was the major difficulty... and also the topic itself, since it's not an easy one. And most certainly the great number of information sources for students to analyse was a challenge for them; we should have selected the sources given in the module, that's what I think! We should have selected and given them less sources but, but very good ones... because I believe they were lost in so much information. (Teacher, Portugal)

Some of the problems mentioned by the students were matched by the opinions of the teachers. In particular it was noticed that the students did not seem to be able to identify the really essential concepts from a variety of less important aspects and, as a consequence, in the first draft of their presentation produced screenshots full of text. However, they were ready to accept suggestions and willing to modify their work accordingly. (Italy)

It was hard to produce a synthesis of the material that we selected in order to identify the key concepts to use in our interaction with the exhibit visitors. (Student, Italy)

It was not easy to organize all the information together. We had to summarize the scientific issues and connect them to the 6 RRI dimensions. (Student, Israel)

Teachers also pointed out that concepts such as renewable resources and environmental impact were rather confused but, once again, students were eager to adjust their perspective. (Italy)

The pupils had difficulties in setting priorities regarding content, including the reduction of exhibition texts to the essential facts. (Germany)

We found it difficult to know what exactly to put in. We wanted to use a certain image, but we were not able to find it. It was difficult to find the information. (Student, The Netherlands)

For me the most difficult part was to distinguish what information to include in the poster and what not to, but also to make it simpler so as the visitors to be able to understand it when they interact with the exhibit. This tired us most (Student, Greece).

One of the ground breaking aspects of the IRRESISTIBLE Project concerning the didactic strategy of exhibition development is having the students assuming a central role in the process of **exhibition planning**. Students must complete the module tasks in order to develop knowledge allowing them to plan the exhibition, having in mind that its goal is to create awareness on the scientific topic explored. For many students, the exhibition planning step posed a challenge, especially because it was *difficult to integrate in it either the scientific topic and/or the Responsible Research and Innovation dimensions*. For others, this integration was even more challenging taking into account the requirement of producing an *interactive* exhibition.

The students also had problems with planning the right amount of materials needed to build their exhibits. If there had not been enough materials, it would have been necessary *to visit the store again. Fortunately, when there were too many materials, they could be returned to the store. (Poland)*

Actually I found a bit difficult because the fact of being an interactive exhibition, having an audience of people who had not read the article and also the difficulty of having to talk about the albatross… well, I found it a bit difficult to achieve the interactive part of the exhibition. Because what came to our heads, for example, was to make basically an albatross and placing him there, just that. But, since it had to be interactive we had to get something, a game to interact with people, instead of just showing our work. (Student, Portugal)

Another difficulty was the part of having ideas to achieve the objects; this was a great difficulty that I felt in them. As I said, there was only one group that initially had some more concrete ideas… and that made sense. (Teacher, Portugal)

We were very excited and confused at the beginning. We had no idea about how to develop exhibit. Then, we examined each RRI aspect to get ideas and developed a good exhibit. (Student, Turkey)

Integration of all aspects in one exhibit. Some of the aspects are harder to integrate than others for students. (Turkey)

What I observed along the way was that my students, perhaps because they were quite young, needed to be given ideas, to be guided. If I let them free they didn't bring any ideas. It was difficult for them too because before their participation in the program did not even know what a scientific exhibit was. So I had to get involved more actively in the process trying mainly to highlight their own ideas through discussion with them or give them alternatives to choose those that fit most. I did not want to influence the exhibits development, but to help them implement their ideas. (Teacher, Greece)

The more problematic phase was to figure out what they could do. At the beginning they were embarrassed because they did not know precisely what an exhibit was. From an organizational point of view, once the choice was made there was no difficulty. (Teacher, Italy)

Other students failed at *correctly planning the needed space for assembling the exhibits*, or the space available was not enough; in other cases, they failed when *predicting the requirements when developing objects outside school*.

Moreover, the students pointed out to the already mentioned problem: the room where the exhibition was held was too small. (Poland)

Another problem, as indicated by the teacher, was the fact that the exhibits were made outside school. Therefore, unexpected difficulties arose, e.g. the transport of the exhibits. (Poland)

Our game required space, I think the size of the exhibition itself was a bit disorganized and there was no room for so many activities and I think the space available itself was a bit poorly distributed. (Student, Portugal)

I thought the most difficult part was to plan everything well, trying to get ... well, a support for our exhibition, because we were there, outdoors, without the possibility of having audio *support, or video… That makes it more difficult to show something, and to be interactive… (Student, Portugal)*

When I learned the need about integrating RRI into our exhibit item, I thought a little bit. I knew 'gender equality', but I have heard 'governance' and 'engagement' for the first time. Hmm, and, these concepts and the 'ethics' are not concrete, so I had difficulty in how to integrate those. I couldn't find examples in the lesson, I searched internet and found some examples, but the hardest one was the 'governance'; I couldn't understand well, I experienced difficulty in that (Student, Turkey).

Well, first couple of weeks we tried to find an idea. After finding the idea we needed to actualize it, but it was hard to find an idea (Student, Turkey).

We wanted the exhibit items to be interactive, so we eliminated the ideas about the ones that were not interactive. In this context, we tried to incorporate the 6 aspects of RRI in nanoscience.... In fact, I can say that it was a difficult process for my students. (Teacher, Turkey)

In our exhibit (hydrophobic materials) we could not find aspects of RRI matching and introduce them. So we talked generally about biomimicry as materials manufacturing process by scientists that resemble the natural materials (Student, Greece).

Time management in order to prepare the exhibitions represented another of the main challenges for students. Taking into account that the exhibition planning and developing tasks are very time consuming, for some, the *schedule* chosen to implement the project was not the most adequate given its longer duration then the available time period, or due to the *large amount of other school tasks* (mostly, tests and exams) happening at the same time. It was difficult to coordinate the tasks of the project with all the other assignments that students had to complete, especially the older ones with more responsibilities at school – this created tension on both students and teachers.

The pupils need a lot of time to come up with something creative. They just sit there for a long time and do nothing, before they really start working. But when they have an idea, they put a lot of time in it without realizing how much it actually is. (Teacher, The Netherlands)

The bad thing is that the project lasted a bit too much. Besides the project there were the commitments of the other school subjects, so it would be better to make it last a little less (Student, Italy).

Concerning the difficulties experienced during the development and the building process of the exhibit, students mostly emphasized the little time available, even though such difficulties didn't limited their creativity and the level of their performance, but increased the scholastic commitment. (Italy)

A considerable difficulty was also the time for the exhibits' construction, which was not very long (about three weeks). In addition, the planned opening of the exhibition was scheduled for the end of the semester, i.e. the period of intensive learning for students and closing the school year period for teachers. (Poland)

First and foremost, it is the fact that the work on the construction of the exhibit that is to be presented at the exhibition is time-consuming. (Student, Poland)

Our teachers give us too much homework, so I sleep late. When I was doing this project I had problems with the time management, but I tried to overcome this difficulty. For instance, I couldn't go to stationery store [to buy materials for their exhibit item], because I was arriving really late, but eventually, I managed. (Student, Turkey)

One problem was the time! Because although we had two weeks - and two weeks is something - with the rest of the classes and with tests to do and also with other work still to be done too, it turned out to be all together and all very short notice, and all too much ... we had much less time than what we would like to have to assemble and to create our final object, but I think it went well. (Student, Portugal)

Students were asked to prepare their exhibition as a part of the school annual scientific exhibition. They had only 2 days to prepare for it. (Israel)

In addition, also timing issues were mentioned. The project was done in spring, when there are many public holidays and the period at school was a bit shorter than other periods. Students indicated that that caused restrictions in time. (The Netherlands)

First and foremost was the issue for both students and teacher to juggle the implementation of the module, including the student-curated exhibition, with the demands of the 11th grade Bagrut. This issue was always "in the air," so to speak, and it created a tension that would otherwise not be present, say, for 9th or 10th grade chemistry students (Israel)

Issues of time management appeared not only during the module, but also at the end, when the students worked together to integrate the different parts of their exhibit, shortly before the exhibition. (Israel)

Although the students began their work on the preparation of the exhibition quite early, most of that time was used to work on the design of the exhibit. In some groups, the time that remained for the execution of the exhibit was too short. And though eventually all the groups managed to make their exhibits, time was an additional stress factor. (Poland)

In my opinion - at least for our group - it was a question of time ... we had only this period to do it; and it's the smallest of all three school periods, so is the one with more tests. So, that, in a way, hindered us to work preparation and, of course, the end result. (Student, Portugal)

Related with the aspect of time, another issue mentioned by partners was the *delay* between the start of learning of the scientific topics and RRI and the actual time of implementation of the exhibition building/presentation.

For both modules the anticipated time requirements were somewhat underestimated. As a consequence, the final exhibit was actually held too long after the initial introduction on the basic concepts with a noticeable lack of continuing interest. (Italy - UNIPA)

A more practical problem was the long time span between developing the exhibition content and the actual day of building the exhibition. Due to holidays and other school system-based restriction, there were about 8 weeks in between, lessening the obligation in

> *finalizing the material and probably slightly lowering the commitment in the start of the building day. (Germany - Kiel)*

Another aspect highlighted as a difficulty for students was the step of **exhibition construction**, which posed challenges either because of *technical difficulties*, or difficulties in the *implementation of students' ideas* or either due to difficulties during the process of *assembling the exhibition*. The young age of students and their lack of skills were also mentioned as possible causes for the difficulties during the construction phase.

> *Further, many students were not familiar with the software used to prepare the slides to be later printed on adhesive foil – usually Microsoft PowerPoint is used and the template for the slides is optimized on that, but that school had only LibreOffice installed. This showed problems with the layout and fonts of the original template, and students were not used to work with LibreOffice. (Germany - Kiel)*

> *One difficulty was the transfer of the materials between the groups to one computer all the time. We had to combine the materials from the 4 different groups (we were 16 students). We had to work again and again on the selected information that is important to be presented, to relate it to each of the RRI aspects, so continuously transferring this information to the same computer was difficult. (Student, Israel)*

> *I tried a couple of times but there was a problem in the electrical circuit. Here, still. Sometimes it works, sometimes it doesn't. We still don't know why (Student, Turkey).*

> *There were difficulties related to the materials from which we are to make the exhibits, with placing them in the room. We had technical problems, for example the paints did not cover the panel, plywood well. (Student, Poland)*

> *The biggest problem that we came across was the circle. We wanted to make it aesthetically and at the same time to be practical and interactive. It was important how the wheel would rotate and what it would be stopped by. (Student, Poland)*

> *Some ideas were difficult to implement. (Teacher, Poland)*

> *When I designed the lucky wheel to represent RRI aspects, I wasn't sure which material will make it turn fast. (Student, Turkey)*

> *Well, I constructed the Dart Game for three times. The first one was too small, then I made it again but I crashed it because the text inside the board was too small. The space for the text was not enough, and then I erased the text again. Then, my teacher gave me the idea of putting the image of graphene at the back. Then, I constructed one more time. Finally, I ended up with an exhibit item at the right size, with enough space for the text and having the image of graphene at the back. (Student, Turkey)*

> *In the final group discussion, students saw the main difficulties in the 'long building day' stating that 'their ability to focus on the project was suffering'. (Germany)*

> *Due to the age of the pupils (15-16 years old), they lacked some necessary skills for building the exhibition (e.g. working with a band saw, soldering...). In some cases, the school janitor was required to assist in the construction. (Germany)*

> *Because my students were not used to do these kind of activities [developing exhibit item]. This process requires higher order thinking skills, therefore they had difficulties in that sense. ... of course this is because it is not given much emphasis in our educational system. Motor skills, organizational skills, design skills, and also higher order thinking skills are not emphasized much. This is similar to 'evaluation' step in Bloom's Taxonomy, it requires higher order thinking skills, that's why they might have experienced difficulties (Teacher, Turkey).*

Developing an exhibition made of several objects – some, very creative in order to promote the desired interactivity – required the use of several **resources and materials**. This can represent a difficulty when they are *not available* and the *costs have to be supported by teachers and/or students*. Nevertheless, there were situations where this difficulty was successfully overcome.

> *Sometimes it was difficult to use appropriate lab spaces, and, particularly for multimedia presentations, personal computers were sometimes used in the classroom. (Italy – UNIPA)*

> *We developed the exhibit "Seed Balls". We had difficulty in acquiring the materials at the beginning. We overcame this situation with the support of our teachers. Then, we started to think on whether we can implement it in the exhibition area or not because the area may get dirty with the soil and fertilizer we used, but then we found a solution and implemented our project with visitors in a clean way. It was good. (Student, Turkey)*

> *The materials' costs were partly sustained by school and partly by the students' parents. Anyway... we chose simple and inexpensive materials, but which, if are properly harnessed, could lead to visually appealing exhibits, with considerable impact. (Teacher, Romania)*

> *Another challenge was the different resources needed for the different groups simultaneously: One group developed experiments thus needed a lab, another had to research and should have been in the computer room, a third group was about to record audio tracks and thus would have needed a very quiet room … But with only one teacher as supervisor, this is not doable in different rooms. This problem even increased when the teacher additionally installed a 'production group' that started to sand the chipboard panels and prepare the LED lighting. (Germany)*

> *We needed a series of resources (mostly raw materials), for making the products. Then we asked for help coming from the museum specialists and experts. They put at our disposal wooden and metallic frames, showcases, windows and space - everything needed for exposing. The collaboration with their experts was excellent. Inside the working groups, we distributed all the tasks. Each of us tried to answer to all the requests. (Student, Romania)*

Motivational issues – meaning **students lack of motivation and engagement** – can represent a difficulty for the success of a long term project like IRRESISTIBLE. Several partners did mention this aspect as being noted as a difficulty for students. However, the contagious effect of other students' high engagement allowed for an increased motivation of the more reluctant/less motivated students. One partner did indicate that their students mentioned *not having fully understood the goal of the exhibition*. This is a very important aspect of the Project. We understand that it is very important for students to understand the purpose of the exhibition both to validate all of their precedent work, but also to allow them to attribute more meaning to their learning.

> *The class was somewhat difficult due to a lack of motivation and engagement to the topic of chemistry in general. Nevertheless, three out of five of the groups worked very well, the other two were rather reluctant with deadlines for handing in and presenting material. The teacher itself found it hard to intervene, but since the other students were dependent on the material, they build up pressure on their peer students and were unexpected successful in making them work and deliver the material. When the expert panel groups were introduced, this problem was even further reduced, due to the intermixing of the groups and seeing some first results slowly increasing motivation. (Germany - Kiel)*

> *During the exhibition development several motivational issues showed up, that are not directly related to the exhibition but a mere problem of the developmental character of the module at that time. For instance, several experiments that students should perform and subsequently should present in the exhibition did not work out as planned by the teacher, thus the students had difficulties with what to show in the exhibition. (Germany)*

> *In the groups there were students who did not contribute equally to the exhibit development fact that had as result other students to be charged with more work. To resolve this, I started assigning tasks to the team members always trying to respect the planning that had been done by the students. (Teacher, Greece)*

> *The explanation by the teacher was not completely clear. We had to also make a presentation about what we made in the box, and we didn't see which one was more important. So the teacher's role is very important. (Student, The Netherlands)*

> *The teachers have to make clear what the goal of the bookcase is. Will it just stay in the classroom or not? Now you don't know what will happen to what you make. (Student, The Netherlands)*

One other aspect mentioned by two partners was the embarrassment that some students felt when **presenting the exhibition** to the public.

> *The fear of presenting an interactive exhibition to the public, since it was something new, was also identified as one of the initial difficulties experienced by students. However, it was over passed. (Portugal)*

> *It was hard and embracing to show off among others, but the more we talked about we were doing, the easier became. (Student, Italy)*

3.2.2. Difficulties for teachers

According to the analysis of the case-studies, the teachers' difficulties were organized in 8 categories (**table 9**).

Table 9 - Difficulties for teachers in the process of exhibition development (N=26).

Time management	**10**
Novelty of scientific topic (including RRI)	**7**
Project & group work management	**7**
Exhibition development & resources	**6**
Cooperation with other participants	**3**
Students' motivation	**2**
Students' lack of skills	**1**
Managing students' creativity	**1**

Similarly, to what happened with students, **time management** issues were also a big challenge for teachers, because the tasks of developing knowledge, planning and developing the exhibition are very time consuming. The majority of teachers that mentioned this aspect felt that the *time allocated for the exhibition development was not enough*, and that this process required more time in order to fully accomplish the Project goals and create an interactive exhibition.

> *The biggest difficulties in the constructing of the exhibitions were related to the variating timetable and the difficult concept of geoengineering. Therefore, student teachers started their teaching with concepts of climate change, which took time. Initially, student teachers thought that the final exhibitions would have included hands-on experiments also for visitors. However, as the following quotes indicate, the delay in the schedule affected the final implementation: "The initial purpose was to make real experiments also to be tried out at the exhibition made by pupils. But lack of time made this impossible". (Finland)*

> *They would have liked more interactive parts, particularly the experiments, in the exhibit. But letting pupils participate in the planning of the exhibit proved to be time consuming pedagogy. (Finland)*

> *The whole process took more time than expected. (Germany)*

> *The pupils need a lot of time to come up with something creative. They just sit there for a long time and do nothing, before they really start working. But when they have an idea, they put a lot of time in it without realizing how much it actually is. (Teacher, The Netherlands)*

> *All three teachers interviewed stressed that one of the main problems was connected to having underestimated the time required by students to complete independent work. Homework was seldom completed and it had to be continued during class hours. (Italy)*

> *Regarding to difficulties experienced by the teacher in the development and building phase, the teacher emphasizes the lack of time to be able to work with students. (Portugal)*

Similar to some students, one teacher did mention that the problems she faced regarding time management were related to the schedule chosen to implement the module and to present the exhibition, acknowledging that the final weeks of the school year are not the best time to have students developing and building the exhibition, since there are many other demands for students and teachers time.

The period of the year when we developed the module with the culmination of the exhibition in the last week of classes, perhaps was not the most appropriate, since the 3rd period is a period of completion of all the work done throughout the year. (Teacher, Portugal)

Along with the novelty of tasks, also the **novelty of the scientific topic** that was explored both by students and teachers, and in which they would base their exhibition, created some difficulties to teachers.

For the teacher, the biggest difficulty was dealing with the doubts and worries associated with teaching new concepts (relating to RRI). (Israel)

When I started this project I did not - I mean, I've been seeing some things, obviously - but I have not been studying in depth each of the themes – I confess not! And I really felt this need when I had to help students: in order to be able to help them, I had to have a very clear notion of all things related to Geoengineering, how the scientific principles worked. So I had to go searching what, supposedly, they would have already researched to be able to help them. (Teacher, Portugal)

For student teachers, it was a difficult concept regardless in depth examples in the Geoengineering module. (Finland)

As far as the difficulties experienced by the teacher are concerned, she emphasized her personal difficulties in having to deal at the same time with new methods and a new topic: if one knows too little on the topic from a disciplinary point of view it is also difficult to have creative ideas for constructing something original. (Italy)

As a teacher I knew little about nanotechnology, therefore I would have needed a deeper specific training. (Teacher, Italy)

Both teacher felt, additionally, some difficulties regarding RRI – not so much in understanding its six dimensions but more in explaining them through examples that could be significant for students, since addressing them in an abstract manner would be less understandable for students. (Portugal)

I think that understanding the six dimensions was easy; the challenge was connecting them to the subject of Climate Geoengineering. We too felt that difficulty. It was a little bit hard to think of examples for students to better understand the dimensions. (Teacher, Portugal)

Another perceived difficulty inherent to the development of the IRRESISTIBLE project in classrooms was **group work management**. In some cases, the *large size of the group* of students created an additional difficulty for teachers that had to manage and help students organize their work. For other teachers, *managing the project* was a challenge.

The size of the group (60 pupils) created difficulties in ensuring an equal distribution of tasks and participation in the curation process. (Germany - DM)

Furthermore, it was difficult to ensure equilibrated participation of individual students in the groups. (Italy)

Another problem I had to resolve was how to distribute the tasks among the students in a way that all 21 of them would engage in the procedure. Finally, the fact that the exhibit was built only during school hours and many times different student groups were working simultaneously was quite difficult to manage, as I had to be in many places at the same time. But this was also resolved by engaging other teachers in the procedure. For example, students worked on the electronic circuit during the hours of the electronics laboratory, under the supervision of the corresponding teacher. (Teacher, Greece)

It was the first large project for the pupils, which was challenging in respect to project management tasks. (Germany)

From the teacher's point of view, her main challenge was to coordinate the students' work: I had to cooperate with the students within the four groups; each group took a different dimension of the RRI, translated it and tried to find ways or example explain it to younger students. My students and I worked as a team and I had to help them find the right examples to be presented and be understood by younger students. (Teacher, Israel)

The **development of the exhibition**, which includes the planning and construction phases – and all the **materials and resources needed** –, represented a challenge for some teachers. The phase of exhibition construction, during which students needed to implement their ideas concerning the exhibition they would like to develop, created difficulties to some teachers that had to support their students in the process. One teacher solved this problem promoting the contribution of experts.

After somehow we finally gathered the ideas, my next problem was the construction of the exhibit, the technical part. As I do not have the fluency to solve such issues. Fortunately, I had the support from experts of the EF and the Primary Education Department who helped students in this part (Teacher, Greece).

The exhibits development process was completely new for both teacher and students. It was indeed one of the issues that according to the pre-questionnaire caused him great stress. Asking the teacher at the end of the process what were the biggest challenges he faced, he stated: "The exhibit development phase was a procedure that both me and the students learned together and from each other. At the beginning, I was scared that I wouldn't be able to support them sufficiently, as I didn't have a specific idea of how the exhibit would look like. Fortunately my students had many ideas and that made things easier, as my role limited to resolving the arising problems and coordinate them." (Greece)

Some teachers feared *not being able to support students* in the process of exhibition development. However, by dispensing the creative tasks to students, teachers felt more confident since students were able to have innovative ideas for the exhibits.

The exhibits development process was completely new for both teachers and students. It was indeed one of the issues that caused great stress to teachers in the beginning of the project. (Greece)

As far as the difficulties experienced by the teacher are concerned, she emphasized her personal difficulties in having to deal at the same time with new method. (Italy)

For the teacher, the biggest difficulty was dealing with the doubts and worries associated with teaching new concepts (relating to RRI) and a new pedagogical method (focused on student-created exhibits). In her own words, the teacher had two main fears: "I feared that the exhibit wouldn't be good enough and I worried that we wouldn't finish it on time." (Israel)

Assuring the *necessary resources* for students to develop their exhibitions was also a challenge for some teachers. Several partners mentioned the fact that their teachers felt difficulties in engaging other colleagues in order to achieve **cooperation** during the implementation of the project.

I think that if the colleagues were able to follow regular meetings all the classes should be able to produce their exhibit. Nevertheless, this was impossible because the teachers declared to be overloaded. Unfortunately, the students of the upper grades who took part in the project did not created any exhibit. I think this may depend on the teachers that were too focused on the mandatory syllabus. In service training is crucial in facilitating the teachers' participation. In fact, the ones who were accustomed to follow Continuing Professional Development were successful in finishing the Project. (Teacher, Italy – UNIBO)

The cooperation with teachers of other subjects was difficult, almost impossible (e.g. the arts teacher had been asked to assist in the design of the exhibition, but was not able to attend the process at the crucial stages due to other school duties). (Germany - DM)

Moreover, the museum worker did not assist student-teachers as much as would have been necessary. Also scheduling pupils' visit dates to the museum was difficult and the visit dates changed a couple of times. Therefore, student-teachers became frustrated because they unnecessarily went to the museum to work on the exhibitions. (Finland)

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Keeping students **motivated** during the exhibition developing and presentation processes was another aspect highlighted by some teachers as difficult.

As far as the experimental work in assembling the DSC apparatus is concerned, the only real problem was managing the disappointment of those students whose cell did not work properly. This difficulty was tackled by explaining the science progresses by trials and errors and a failed experiment is useful to plan a better one. (Italy)

The excitement for the topic 'Plastic and the Ocean' that the class developed in the beginning was mostly gone, some of the experiments the teacher asked them to do in their group work did not work out, some groups were overburdened with the immense range of the topic they researched. This lead to the "problem to present 'the washed-up 'in the

> *exhibition and thus dramatically decreased the motivation to build the exhibition". (Germany – Kiel)*

Other aspects mentioned by one partner each included: a) dealing with **students' lack of necessary skills**; and b) **managing students' creativity**.

> *They verified their ideas several times. The barrier was the lack of appropriate skills (e.g. one of the groups wanted to develop a computer game and, in consequence, a board game was created). (Teacher, Poland)*

> *As a teacher for me was the fact that they have so many different ideas - and I think students were very creative in this respect ... But, it's sometimes difficult to realize how we are going to manage all this. For them, the most difficult part is the beginning, but then it is hard to settle them back! Because then they wanted to do much, so much... (Teacher, Portugal)*

3.3. Learning achievements

During the process of exhibition development, both students and teachers were confronted with tasks and situations that led them to learn something. At the end of the of the exhibition development process, students and teachers were asked about what they thought were their learning achievements. Teachers were also asked about the learning achievements of their students. After the analysis of the 26 case studies, the learning achievements were categorized considering the ones that respect students learning achievements (either mentioned by them and/or by their teachers) and the ones that respect teachers learning achievements (mentioned by teachers themselves).

3.3.1. Students learning achievements

According to the analysis of the case studies, students learning achievements were organized in **9** categories (**table 10**).

Table 10 – Learning achievements for students through the process of exhibition development (N=26)

Scientific topic and RRI	**25**
Project management and group work	**12**
Development of interactive exhibits	**7**
Selection and organization of relevant information	**7**
Communication skills	**6**
Practical/experimental work skills	**6**
Self-confidence on abilities and skills	**4**
Empowerment/Sense of usefulness to others' education	**3**
NoS	**3**

Considering **table 10**, almost all case studies mention the fact that students learned about the **scientific topic** of the exhibition and its related aspects of **Responsible Research and Innovation**. The degree of learning depends on several factors, one of which the topic itself – and the complexity of concepts associated with it.

> *According to interviews, pupils learned the objectives of the principles of climate change quite well. However, during the classroom conversation pupils often confused every day climate choices, such as using public transportation, to Geoengineering. Therefore, it is necessary to clarify these concepts more explicitly. All in all, pupils were confident in their learning. (Finland)*

> *I learned a lot and I think it will be useful for me in the near future. Also about RRI I learned its fundamental points and I think that many people should know about it. (Student, Italy – UNIBO)*

> *And, furthermore, the students realized that science is not disconnected from their surrounding context, particularly when nanotechnology is involved. Overall, students became aware that technological advancements can only happen in a responsible and sustainable way by taking into account all its implications. (Italy – UNIPA)*

> *We have learned that it is important to make responsible decisions because nanosilver can have both positive and negative effects. (Student, Poland)*

> *Also we get a sense of how to improve the climate and also how to revert our actions, but we also get a sense that it is not as easy as it sounds. (Student, Portugal)*

> *People's opinion are rooted in ignorance, that is, it is not a reasoned opinion; hence it is so important both science education and engagement and politics, because if people are informed, then they can have a more informed opinion and have a better sense of what others are doing. (Student, Portugal)*

> *RRI principles taught me that we must respect our colleagues and their opinions, to work as a team and that research results should ALWAYS be transparent. (Student, Romania)*

> *I knew that there is an ongoing deforestation, but I didn't know that the rate was that much high. This topic is also given place in our science book. I learned many statistics and got really upset about the case. (Student, Turkey)*

> *Sometimes politicians come together and discuss. Now we learned for what purpose they are coming together. We learned that non-governmental organizations and institutions come together and discuss. I am very clear about the equality of woman and man. All can come up with a good idea and all should be provided with equal opportunities and rights. (Student, Turkey)*

> *While searching for information to include in the poster we learned much more about nanomedicine than we discussed in the class. I believe this knowledge will be useful in the future. (Student, Greece)*

> *I did not know about the existence of the RRI aspects. And the connection between them and scientific research. I am instinctly aware of the importance of information open access, but I did not know about its existence. (Student, Israel)*

I was impressed by the whole amount of information learned by me and my colleagues, not just about nanotechnology, but also on how we saw several unsolvable problems that can be resolved using nanoscience. (Student, Romania)

Interestingly, some partners mentioned the fact that the task requiring them to develop the exhibition helped students to better understand the scientific topic and some aspects of the RRI related to it. Because of the effort of creating an exhibition aimed at educating an audience, students faced the need to develop deeper knowledge about the scientific topic of their exhibition, and also the aspects of RRI that were – for them – in close relation with it.

To be honest I liked nanotechnology, and all the experiments we conducted but I couldn't always understand the science underneath. It was when we made the nail-model that I understood what surface to volume ratio was all about, and what it had to do with nanotechnology. (Student, Greece)

When we were trying to waterproof the surface for the exhibit, using that special spray, I noticed all the hazards mentioned on packaging, that I started having second thoughts about the safety of using all that nanotechnology stuff. I'll be more careful from now on! (Student, Greece)

Students indicated that they learned a lot about the topics they built their exhibitions on. Mostly, they mentioned that, differently from normal learning, they had to dive really deeply into the science to be able to understand everything, which was needed to build something. (The Netherlands)

Some really thought deeply about how everything works before making their exhibit, you have to have a decent amount of knowledge if you want to make something like that. (Teacher, The Netherlands)

Certainly I learned here much more about nanosilver, also during the construction of the exhibit I learned about its impact on our body, our organism. (Student, Poland)

While developing our exhibit, I learned which energy sources do exist and how much they are used in detail. (Student, Turkey)

All students developed the project working in groups. For some, that work lasted several weeks, and it had already started much earlier, in the beginning of the module. It comes with no surprise that the second most mentioned achievement was the improvement of **group work skills** and also **project management skills**. The ability to listen to others opinions, taking them into account, share responsibilities and develop joint efforts to accomplish common goals may represent challenges for students not used to work in collaboration with their peers.

From the students' perspective, autonomous work in the teams when developing the content was the most important achievement in the exhibition process. Working closely together and discussing features to tackle the topic and to shape it into a presentable frame for them was a core issue of the project. (Germany – IPN)

What is important is cooperation and careful planning of everything, because spontaneous making important decisions may have serious consequences. (Student, Poland)

So we really needed to learn how to work better in a group, in a team, for things to work well! Sharing tasks... That was a major difficulty, by the way! It was hard but, at the same time, it was a learning experience. (Student, Portugal)

It also teaches group work and as if listening to each other, what others have to say, what ideas they have, because maybe it will be better than mine. (Student, Poland)

I think the exhibition revealed an amazing characteristic of this class, that I was unaware of... which was the spirit of sacrifice! We all gave everything in order to make this exhibition happen! We all helped each other, whether it was our job or not; on the day of the exhibition we covered each other's flaws. (Student, Portugal)

Sometimes we got stressed because we stopped at a point and couldn't make it as we planned, then we got anxiety like "What if we can't?". Then we figured it out somehow with the help of other groups. We used other groups' ideas and preferred an alternative way for developing our exhibit. (Student, Turkey)

For some students the process of exhibition development lasted several weeks. This process can be understood as a project, inside of a larger one that begun with the module implementation. That's why some students highlighted that this experience led them to develop **project management skills**, which are indeed very important when dealing with a major event such as the development of an exhibition.

The pupils learned a lot about curating and building an exhibition, far more than would be usual in a 'standard' school exhibition. This included Project management, the selection and definition of topics and content from a wide and complex field, as well as various methods of presentation. (Germany)

We've learned how to manage time and financial resources. (Student, Poland)

We've learned that everything must be done in advance, when planning and constructing such exhibitions. (Student, Portugal)

From the students' perspective, practical team work is the most important achievement in the exhibition process. Working closely together to tackle the topic and to shape it into a presentable frame was a core issue of the project. Further they mentioned that they learned about the importance of "precisely structuring a project to finish it in time". (Germany)

Interestingly, some students pointed out the fact that they had learned how to **develop interactive exhibits**. This comes with close relation with the fact that they had to develop an *interactive* exhibition – which was a new experience for most of them. Some teachers specially emphasized this aspect, discussing with students what should be the characteristics of an interactive exhibition. However, this feature of the project was easily embraced by all students, especially in the context of science classes, allowing them to express their creativity and imagination.

I think we are all to be congratulated because we created very interactive things and this is not very normal! Normally we always used those posters and things are very boring, but no! This time we managed to do more interactive things and I think that's very important. (Student, Portugal)

Among all the possibilities, I think the exhibit is important to attract toward the discipline and inspire students, a way to engage even those who are usually less interested. (Student, Italy)

Then we realized that it's not so easy to organize an exhibition to the public and that there are several steps that have to be followed and not just get out there and put things in places! It's a long process, coming from behind. (Student, Portugal)

Concerning the achieved learning outcomes, students felt they had learned not only about the concepts developed in the topic, but also on the development and construction of interactive exhibits. (Italy – UNIBO)

Perhaps one of the things we have learned was manipulating some materials and also thinking of materials suitable for the objects… for instance, in my group, we had to create things… well, we had to use a lot our imagination! And we learned how to be more creative. And of course that working in group helped a lot. And the fact that the whole class was engaged in this task helped, we were helping each other. (Student, Portugal)

With relation to this category, some students' answers revealed their understanding about the importance of developing an interactive exhibition as a way to engage the audience, which can lead to a more effective education of visitors.

Although it is, obviously, more difficult for us to create an exhibition that stimulates the participation of visitors, interact with us, build games and all sort of didactic things – it's much more difficult than just building a poster, right? – it is much more interesting developing an interactive exhibition in which we are talking with the audience and in which we feel, in a way, that we are teaching them something. It's much more gratifying for us to build an exhibition in which we are really there, with the people, an in which they participate in the exhibition, than to place something in a wall and walk away. (Student, Portugal)

To be able to create an exhibition that could engage the audience, students felt the need to be creative and to develop objects that were not overloaded with information. Hence, the need to **select and organize** the more relevant ideas and information on the topics. This aspect was pointed out by some partners as something that students learned to do better, due to this project.

With a focus on developing exhibitions, they [students] realized the importance of "only showing the most relevant aspects of a topic". (Germany - Kiel)

The pupils learned a lot about curating and building an exhibition, far more than would be usual in a 'standard' school exhibition. This included Project management, the selection and definition of topics and content from a wide and complex field, as well as various methods of presentation. (Germany, DM)

Students found by themselves that it was indispensable to select the important information to convey. (Italy - UNIPA)

The strongest positive point emerging from the preparation of the exhibit was that students were forced to select appropriate content and tools in order to make effective presentations. These choices were crucial in developing their critical thinking. Once the selection of the material was made, additional positive inputs came from going through the material and by reflections about the concepts which were necessary for a satisfactory understanding. (Italy – UNIPA)

I think they did immense learning! In the research phase they learned how to find and select relevant information. (Teacher, Portugal)

By creating an exhibition aimed at sharing information with an audience, students faced the task – for some, a challenging one – of having to communicate with visitors, either by explaining their work, or by answering questions – some of them very unpredictable. However, some students valued this opportunity, and shared their opinion that it allowed for the development of their **communication skills**.

Above all we have learned how to present things in front of other people and this is not a trivial matter. …to do that we had to develop some abilities... this was encouraging … it was the first time we made something like that. (Student, Italy)

Through the guided tours that each of the pupils had to give, they also gained experience in orally presenting a topic to an audience. (Germany)

They also learned how to collaborate and how to present their work (during the exhibits opening day). (Teacher, Greece)

I think it was a big challenge that led to our improvement in order to better communicate with children; and I even think that the interaction among us, class, is much improved and I think everyone benefited from it, (Student, Portugal)

Other achievement was the **development of practical/experimental skills**. This comes in close relation with the characteristics of the specific module that was tested – and the degree of experimental activities in it. Some students valued the more practical activities related to the construction of the exhibition objects, highlighting the fact that those activities fuelled the development of important skills.

The mere application of paint – for the second, third time, so that it didn't show through, was also some kind of learning. And not only learning chemistry, but learning life, because one day we will have to paint a wall. (Student, Poland)

While developing the exhibit students gained more knowledge not only about nanotechnology, but knowledge and skills related to their typical lessons of electrology, hydraulics etc. (Student, Greece)

Mainly technical issues concerning the treatment of polystyrene. (Student, Poland)

I learned my lesson. This process helped me to socialize more with my friends. We developed our project with teamwork. I also developed my handcraft skills. (Student, Turkey)

Four cases mentioned that their students developed **confidence on their abilities and skills**. We consider this aspect a very important one, given the fact that the tasks of having to improve their knowledge on cutting-edge topics and RRI, planning and developing an interactive exhibition to be presented to an audience, are very challenging. Several students did mention that at the beginning they were not very self-confident on their abilities to fulfil such tasks. But they did it, and the fact that these students mentioned that, illustrates how this was important and meaningful for some of them.

I think that during this - during the course of this last task - I realized that as we strive a little more or when we try to work a little bit more as a team and when we want a little, a little more than usual, we build things or create things that at first we had no idea we could do because - I speak for myself and my group - we never thought at the beginning in the first class or the first time that we speak of this task, we never thought to create an object like that we created - at least I was quite proud of what we have created! (Student, Portugal)

[One of the main effects of the module was] The very deep effect of giving my students lots of confidence. You can't see this effect with normal testing, but it's there, especially with the average and below average students. You know, the ones who usually don't participate in class. For them, especially, the module's effect was enormous. Because now these same students participate in class! (Teacher, Israel)

Most of them liked the experience, and they said that at the beginning they were with a little bit of fear of not being able to accomplish this, but that in the end it come up exceeding their expectations. They started really pessimists! (Teacher, Portugal)

Aligned with the goal of developing an interactive exhibition with the purpose of creating awareness on visitors regarding different scientific topics and RRI, comes the sense of **usefulness** that some students have experienced and mentioned in their interviews. For them, the experience of developing something for others to learn was very rewarding. These students learned that they are able to develop actions – the exhibition – with the purpose of educating others. They felt empowered.

They gained that perception that they are citizens, and that their opinion is worth, it counts, and that we have to fight when we don't agree with something that we think it could be different, that we need to work to achieve it. They gained that seed. (Teacher, Portugal)

I felt that they [the visitors] were actually learning something with me, and that was really good! We felt useful, we were teaching. And the children were having fun! (Student, Portugal)

Yes, I felt that this road they have walked represented a major apprenticeship about how they can… in these complicated matters like Geoengineering… how they can pass the message to younger students. So, I think they learned, in the end, strategies of how to *engage the public and transmit them some knowledge, even when the public are people they are not familiarized with. So this process ended up giving them some background, some thoughts on what they can do and are able to do in the future, when they try to engage others in something they are researching. (Teacher, Portugal)*

I learned that we should work in a more planned and detailed way by using our minds and I think that it is very important. We developed our project for all individuals and our society. We explained it for the visitors. My friends did explain as well. We think that these will be transferred from generation to generation and be effective for many people. We are very glad for doing that. (Student, Turkey)

This process was very good for me because creating an exhibition in ITU Science Centre for the first time was very important for me. Visitors came here and see our exhibits and this is very valuable for me. (Student, Turkey)

As my colleague said before, the exhibition may not be enough, but it is something! If nobody does something, if nobody acts, then we will not be able to pass what we know to others – and not just about the topic we have worked in the project. And I think that people that visited the exhibition learned something, even if not everything, but something… and that can cause some impact, and then they will spread the word to others, and it's a good start! (Student, Portugal)

I think that if we unite, we can achieve amazing things, and pass the information – but, only if we are willing to do that. When we don't accept things as they are, we can actually say that we want things in a different way! And with these exhibitions, and taking into account that we are in the age of having those creative skills… we can say to others that we don't accept something, either because we do not understand it, because we have done research and because of that, we don't agree and we should give our opinion. And sometimes we can surprise older people, because they will not be expecting that we can do things so elaborated and so serious! (Student, Portugal)

Finally, related to the specificities of the module that was tested, some students mentioned that they have learned issues that can be linked to the **Nature of Science**.

We learned that a study or research does not always have the results that are expected and not always reach results that contribute so much to the advancement of science, but may contribute to future studies. (Student, Portugal)

I thought scientists were limited only to research but I realized that they also have to communicate and make papers from there, and they have to be creative in their displays so that everyone understands what was researched in an effective way. (Student, Portugal)

We've learned how the system of scientific research works, what scientists really do, because I think that before we had not been aware of that in fact. (Student, Poland)

Because they dealt with scientific papers, they end up coming closer to what is science and what scientists do. (Teacher, Portugal)

3.3.2. Teachers learning achievements

According to the case studies analysis, teachers' learning achievements were organized in 4 categories (**table 11**).

Table 11 – Learning achievements for teachers in the process of exhibition development (N=26)

Didactic strategy and its potentialities	**11**
Scientific topic and RRI	**5**
Organizational skills & Project management	**5**
Interpersonal skills	**1**

With the IRRESISTIBLE Project, students and teachers were engaged in the development of interactive exhibitions about cutting-edge scientific topics, based on research made by students, following an IBSE approach. For the vast majority of teachers, this was the first time working in a project with the characteristics of IRRESISTIBLE, and with this specific didactic strategy. Therefore, when asked about their learning achievements, several teachers highlighted the **potentialities of such a didactic strategy**. For some, this strategy allowed for the *development of students' creative and soft skills*.

> *The teacher highlighted also the importance of having done something practical and informal in which the students can re-elaborate their knowledge in a creative and personal way. (Italy)*

> *They [the teachers] think it is important for students to develop certain creative skills, as later in their careers/studies they will be required to make (poster) presentations about their research. Such creativity can be learned by these kind of activities. (The Netherlands)*

> *When carrying out the project classes, I was aware that I was showing students new issues and that I taught them a different approach to already known problems. I thought that was the most important aspect of the project. I underestimated the impact of the participation in the project on students' soft skills, on the integration of the class, on building the sense of responsibility for the result of collaborative work. Now I think it was just as important as delivering new knowledge to the students. In the future, in my work, I will definitely pay more attention to teaching social skills. (Teacher, Poland)*

For others, it had the potential of *increasing students' motivation*, and *helped to consolidate their learning*.

> *In regard to their classes, teachers learned that it is possible to strongly motivate pupils through such a project. However, they also noticed that students were not equally motivated. Some were very actively engaged, others were more reserved. (Germany - DM)*

> *The part of having an exhibition is very enriching, because after a theoretical part, there is a playful part but, through this part they will again cementing concepts that were discussed in the theoretical part and that will be again worked, and that can lead again to discussion, reflection. I think this approach is richer! Like the phrase: what is done with the*

hands, stays ... What stirs with the heart then stays in the head. I think here is a bit of this: the fact that it is interactive, playable, I think leads to deeper learning. (Teacher, Portugal)

Others mentioned that this strategy introduced them to a *new way of assessing students' skills*.

Finally, I discovered that there are many more ways of assessing students' knowledge by the end of a project. As by the end of every school year students are called to present what they learned by the projects they participated in, I'm thinking we could adopt this method instead of just showing a powerpoint presentation. (Teacher, Greece)

Some teachers did mention to be quite surprised by the way students performed – especially the ones with lower academic achievements. Those came out revealing a *positive engagement and motivation* during the whole process.

I learned that students can make more out of it than what you expected at first. (Teacher, The Netherlands)

Some students who were not usually involved in physics became protagonists in the project. I have just seen them with a different attitude in the school context (Teacher, Italy UNIBO).

Two teachers mentioned increased *bonding with their students* as a result of working along them for the development of the exhibition.

As regards the teacher, she considers that the process of supporting students in developing their scientific exhibits helped her develop collaborative skills, and bond with her students and developed with them a more close and personal relationship than the typical school one. (Greece)

They relate to me differently than before I taught the module. They seem to know now that I'm on their side! I was always on their side, you know, but there were not a lot of opportunities for me to show them. But working on the exhibition, and receiving my assistance, showed them that I care about them, that I support them in their work. So now they believe in me – and I believe in them – more than ever before. The experience closed the distance which normally exists between teacher and students. (Teacher, Israel)

Apart from the advantages of the didactic strategy, several teachers mentioned having learned new aspects of this strategy: the (7E) IBSE method, the use of ICT, and others.

The student teachers also gained in their understanding of inquiry-based science education and had a positive experience in applying it. (Finland)

For me it was the part of the various ICT tools. I was not used to them! And I think they are very useful, and also very appealing to students. When students had to work on Wikis, they did it very easily; the same with Padlet. And I never used them... because I simply was unaware that they existed. And our school provides just that, because we have computers in the classroom that we could use more often! For me that part was really important. (Teacher, Portugal)

> *What I liked most, in fact, was the 7E model because whenever I did this sort of work with students... projects... I never used a sequence like this one. So, this sequence, I loved it! I really liked a lot. I did not know it and I think it's really important for students. (Teacher, Portugal)*

> *All in all, it would be important to take pupils' ideas of the topic into account before teaching because pupils' participation would increase their motivation for learning. (Finland)*

> *They [the teachers] also discovered that it is worth having the courage to freely use the less precisely defined areas of the curriculum. (Germany)*

Through the process of exhibition development, and by supporting students in the development of their exhibits, some teachers mentioned having learned about the **scientific topic and about Responsible Research and Innovation**.

> *Regarding to the learning that the teacher considers to have done, the teacher highlights the knowledge on polar science, especially that produced by Portuguese scientists, and a variety of research fields covered. She also stated to be more attentive and appreciative of the importance of Responsible Research and Innovation and its 6 dimensions. (Portugal)*

> *Any step taken in research and innovation should be done in the context of the ownership expressed by the researcher, in strong relation to social and individual responsibilities. This means that research and innovation must meet a set of principles of social ethics, be beneficial for the society as a whole, and for each individual, considering the ratio of benefits and risks, contributing to the progress of mankind, subordinated to positive purposes. (Teacher, Romania)*

> *[The teacher] highlights having developed knowledge about RRI and its dimensions, a topic she considered quite relevant, and which she claims to have been more attentive and appreciative, and indicating that this should be addressed in school systematically. (Portugal)*

> *I think I learned a lot, and I still have much to learn about this issue of Geoengineering that seems to me, indeed, very important, as the students pointed out; and therefore it was one of my learning, the content itself. (Teacher, Portugal)*

> *Any step taken in research and innovation should be done in the context of the ownership expressed by the researcher, in strong relation to social and individual responsibilities. This means that research and innovation must meet a set of principles of social ethics, be beneficial for the society as a whole, and for each individual, considering the ratio of benefits and risks, contributing to the progress of mankind, subordinated to positive purposes. (Teacher, Romania)*

Several teachers highlighted the fact that they have developed their **organizational skills** and learned more about **project management**.

> *The teachers learned a lot about specific project management and the coordination challenges required in such a project, things that are not necessarily an integral part of the teaching profession. (Germany)*

The teacher mostly mentioned [having learned] organizational issues. Structuring and leading a student-curated exhibition project of this size for the first time is a challenging task. Keeping track of all the groups working parallel on different (new) topics as well different presentation formats is demanding. (Germany)

First of all, I was called to coordinate 21 students and make them work for a common task. That was difficult but useful too. Up to now I was avoiding to undertake such obligations. But I discovered it was fun to help students resolve the difficulties that arose, even if that was a bit stressful. (Teacher, Greece)

Finally, one teacher did mention that the participation in the project also allowed for the improvement of his **interpersonal skills** – patience, forbearance and perseverance.

3.4. Importance of the topics for students' lives

Throughout the process of exhibition development – and in the previous tasks of the modules – students developed their learning about the scientific topics and the RRI in close relation to it. We wanted to know if students attributed importance to what they learn, and if they recognized it as relevant for their daily lives. That could show us if they attributed personal meaning and a sense of relatedness to the scientific topics and also to the theme of Responsible Research and Innovation.

In all the exhibitions that were analysed trough the development of the case studies (26), the range of scientific topics was diverse – although all represented cutting-edge topics, some were more challenging for students to learn than others. There were a total of 14 topics addressed in the exhibitions (**table 12**). Not all exhibitions focused RRI with the same extent – and not all teachers developed their teaching on RRI with the same depth/success during the process of module implementation, what was naturally reflected on their students' opportunity to learn about RRI.

Table 12 – Number of case studies per topic.

Topic	Number of case studies
Carbohydrates in breast milk	4
Climate Geoengineering	3
Ocean Plastic Pollution	2
Climate Change	2
Perovskite-based photovoltaic cells	2
Catalytic properties of nanomaterials	2
Nano in Health Science	2
Polar Science	2
Application of nanomaterials in Energy area	2
Nanotechnology for Solar Energy	1
Nanoscience for Solar Energy conversion	1
Oceanography	1
Nanoscience and Nanotechnology applications	1
Super hydrophobic properties of nanomaterials and their applications	1

From the 26 case-studies, only 20 reported aspects concerning the relative importance of the topic for students' life. **Table 13** illustrates these results.

Table 13 – Categories of importance of the topic for students' lives x number of case studies

Category	Number of case-studies
Important for the present	**13**
Important only for the future	**6**
More or less important	**1**

The majority of interviewed students mentioned that the topics researched throughout the module and during the process of exhibition development were **important for their present lives**. While some students only mentioned the importance attributed to the scientific topic, others, also mentioned the relevance of RRI.

In general, students consider the topic as 'very important', since it not only affects the global society, but their personal life as well. They stated that it is highly important that "people learn more about this topic; then they probably watch out for not disposing plastics carelessly into the environment". (Germany – Kiel; Ocean Plastic Pollution)

Pupils considered climate change as an important issue, and they were able to define it quite specifically during the interview. (…) We saw evidence that pupils understood how their own consumption of goods and energy impacts climate change. (Finland, Geoengineering)

I will use RRI aspects in my daily life, especially the open access. It is important, beside the scientific research to take into consideration its ethical issues. (Student, Israel; Perovskite-based photovoltaic cells)

If the product is totally against the RRI issues I will not use it, and it will be my choice to decide. (Student, Israel; Perovskite-based photovoltaic cells)

As a matter of fact, my students kept using and mentioning the RRI dimensions and the ethical issues in different contexts – in their chemistry lessons and in their junior entrepreneur worldwide projects that made them be directly involved and practice part of the RRI dimensions. (Teacher, Israel; Perovskite-based photovoltaic cells)

The dimensions of RRI – especially the dimensions of Gender, Open Access and Ethics – were also viewed as important by the students, as illustrated by the results of the pre/post questionnaires. (Israel; Carbohydrates in breast milk)

Students highlighted that both the actuality of the topic and the RRI issues were very important for the perception of how science matches with their life. (Italy – UNIBO; Nanotechnology for solar energy)

Students suggested that the topics (Nanoscience and RRI) are important to their daily lives because maintaining a clean environment contributes to human well-being: "Of course, it is important since it promotes well-being for all. RRI is important because it aims at *reducing the waste of resources and it has important implications in the economy". (Italy – UNIPA; Nanoscience for solar energy conversion)*

The topics are very important in our daily lives. The fate of the whole planet depends on our actions. If we want to do something useful we can be close to the destruction of the environment. Thus research should be conducted in a very responsible way. (Student, Poland; Catalytic properties of nanomaterials)

They are important. Because we face the issue of gender equality often at school work or in scientific research. (Student, Poland; Nano in health science)

It gives us, perhaps, a greater sense of the importance of preserving the environment and the importance of investigating and study all the techniques, and of moving increasingly towards ... we can make the techniques possible. (Student, Portugal; Climate Geoengineering)

Regarding the RRI, students also consider that the learning achieved is important, particularly because in society it matters to make decisions having in mind also the possible consequences of those decisions. And when addressing scientific matters as controversial and current as Geoengineering, it is important to reflect on the implications of the research in this field and on implementation of technologies for the society and its various sectors. (Portugal; Climate Geoengineering)

In my opinion, this topic awakens our attention because it shows us that it is not necessary to be anyone special, no need to have a great job or being a scientist to have, in a way, an important role in what is happening on our planet, and that they are not the only ones that have to deal with the present problems, we do too! (Student, Portugal; Polar Science)

I consider that these are problems ... That these are important issues if we are people who concern ourselves with the environment, because in our day to day life we often harm the environment, without realizing it, such as sometimes prefer the cars, oil to electric cars and this is an example where emissions can harm everything that happens at the poles, and in fact will be reflected in the rest of the world ...has to do with our choices day-to-day, some things. (Student, Portugal; Polar Science)

Some topics, because of their specific gender relatedness, are more relevant for some students than others. That was the case of the module on Carbohydrates in breast milk when applied in a class of Israeli students.

The topic of milk – especially the issues regarding a comparison of mother's milk and infant formula – were very relevant and important for the predominantly female students. (Israel; Carbohydrates in breast milk)

Sometimes, even though having considered the topic important for their lives, students aren't able to justify their relevance or provide specific examples.

Pupil: I think it was quite important. [Interviewer asks how or why it was important, but pupils cannot answer] (Finland; Climate Change)

In their opinions, students generally recognized the topics discussed as important, but they could not convincingly justify that statement. It may evidence that students treated the mere participation in the project as important to themselves and the feeling/impression *was also transferred to the subject matter of the project. (Poland; Catalytic properties of nanomaterials)*

Some students consider the importance of the topic more for their **future** than in their present lives.

On the other hand, they think it will be a very important and problematic issue when they achieve adulthood, so, the more information they have, the better. (Portugal; Climate Geoengineering)

For our daily life they are not, but for our future maybe they are likely to be, because, for example, if these ecosystems were to be destroyed or damaged, then the consequences will be suffered by us or by future generations and then yes we will ... If no one discuss these matters these ecosystems will end up being destroyed or damaged and the consequences will come in future times. And then yes it will affect us. (Student, Portugal; Polar Science)

I think it's important for us to be aware of the RRI because future researchers and scientists will pass through this course and some of us will be those people that in the future will be scientists... The sooner we are aware about these ideas, the better use we will make of this information in the future, to be able to be better persons, and better researchers. (Student, Portugal; Polar Science)

I didn't know that nanotechnology was used in so many areas and in so many products. I learned that, and also I learned that I need to search when I buy a product (as a consumer). So, I will consider this in my future life. (Student, Turkey; Nano in health science)

These might be topics that come back later at school, or at university, so it was useful to learn. (Student, The Netherlands; Carbohydrates in breast milk)

It is not (yet) very important for my daily life, but it is interesting to know that formula is different from mother's milk; and that certain things are added to formula that are also healthy. (Student, The Netherlands; Carbohydrates in breast milk)

Although the majority of students found relevance on the topics to their lives, some students, however, only found them **partly important**.

Compared to students in other projects, the relevance for their own life was not that highly present. This might be in part due to the complex and abstract topic (with a focus on the impact of increased CO_2 levels in the oceans). Another reason could be that – since the development of the exhibition content was finished three months prior to talking to the teacher and students – it might be that the topic wasn't that present to the students any more. (Germany – Kiel; Ocean Plastic Pollution)

3.5. Overall balance

Just like any other process, there were positive and negative aspects related to the implementations of the teaching modules and the planning and construction of the exhibits. The CoL1 and CoL2 Irresistible Project partners recorded positive and negative aspects related to the different stages of the project. The data presented next was organized by the type of participants in the project, respectively, students, teachers and, finally, two participant experts.

3.5.1. Students

Positive aspects

Positive aspects referred by students that participated in the Project, were organized in the following categories: a) active learning and action promotion; b) knowledge about cutting-edge science topics/RRI; c) contact with experts; d) interpersonal relationships; e) self-guided work; f) skills development; g) students' confidence and value; h) resources; i) Science and work of scientists; j) awareness and j) dissemination (**table 14**).

Table 14 - Positive aspects of the project referred by the students

Active learning	**14**
Knowledge about cutting-edge science topics/RRI	**11**
Contact with experts	**6**
Interpersonal relationships	**4**
Skills development	**4**
Students' confidence and value	**3**
Science and work of scientists	**3**
Awareness	**1**
Dissemination/Action	**2**
Total of cases	**26**

The possibility of learning through **active learning** was the positive aspect most highlighted by students. Students emphasized not only the fact they were involved in the planning, construction and presentation of exhibitions, seeing their own ideas coming to life, but also the freedom to develop their own learning during the module tasks.

> *It was a very positive experience to be responsible of our own learning and not just listening to the teacher lecturing. (Student, Italy Unipa*)

> *It was the first time that we were called to build something on our own. Without someone telling us exactly what we should to. We felt free to design what we wanted and then construct it. (Student, Greece)*

I liked the freedom we had during the lessons (in the whole project), "Get to work, by then it should be finished", it was your own responsibility, I liked that. (Student, The Netherlands)

Selecting the variables to be investigated about the interaction between matter and radiation and having to report to others the findings, opens up the mind in the effort of understanding and elaborating. (Student, Italy - UNIPA)

The best was that we saw our idea taking shape. Some things weren't as we imagined but never mind. At first we did not understand exactly what we would make but then it was very nice. We loved that we went and worked at the university and we presented our exhibits in the museum. (Student, Greece)

Entering the lab to discover rather than to verify represents a reverse-approach which allowed me to experience a mental effort which left its mark. (Student, Italy -UNIPA)

Another motivating factor for students was related to the innovative characteristics of the topics researched. **knowledge about cutting-edge science topics and RRI** was considered a positive aspect developed during the project modules, as they focused on new unfamiliar issues. This situation fostered the learning of new contents as well as the consolidation of existing knowledge.

[The most positive thing] was what we've learned, because basically we are the future and we have to became informed in order to produce a better future. We need to have this knowledge because this phenomenon also can hurt ourselves and so, it is important for people to know, in order to not to have problems. (Student, Portugal)

I only knew the benefits of nanotechnology. During this process I learned the risks of its applications (...). (Student, Turkey)

We have learned that it is important to make responsible decisions because nanosilver can have both positive and negative effect. (Student, Poland)

As far as the positive aspects are concerned, students appreciated the innovative feature of the topic of nanotechnology, the very new issue of RRI (Italy - UNIBO)

The construction of the exhibition was good fun, it integrated the members of the group and allowed them to find out a great number of things about nanosilver and RRI. (Student, Poland)

Contact with experts from scientific institutions and science centres was considered as being a plus for the students, giving them the possibility to learn and have access to primary information, and working as an inspiration source for some, while arousing their interest in the work carried out in these institutions.

I learned a lot of new things, and I saw a new place that I want to learn in one day. (Student, Israel)

I think a very good thing was that we had access to information not only of people working directly in the field, as the scientists who came here and who were available, but also the researchers of which we had access to their articles, and the fact that we can do something different and creative in the end! (Student, Portugal)

The fact that specialists from the museum supported us in our endeavour to exhibit in a very popular location motivated us even more on achieving qualitative exhibits. We wanted to show visitors how much solar energy we can harness and its benefits for our planet." (Student, Romania)

As far as the positive aspects are concerned (…) and the engaging interaction with a science centre. (Italy - UNIBO)

The work developed contributed to establish positive **interpersonal relationships** among students. During the different project phases, students learned how to cooperate, to know themselves better and to help each other.

The work on the exhibition strengthens the bonds between the persons preparing it. Thanks to that, we grew closer together and we practised group work, which will be useful in the future. (Student, Poland)

When I was doing internet search, I had difficulties in finding what I was looking for. However, my friends helped me with that, so I was able to find sufficient information (Student, The Netherlands).

We've learned so much how to work together, not to be closed only to what I think, what I like, but also how to open to the ideas of other persons. (Student, Poland)

What is important is cooperation and careful planning of everything, because spontaneous making important decisions may have serious consequences. (Student, Poland)

From my point of view, the most important outcome of the procedure was the fact that students worked with team spirit, bonded with each other and improved their relations with me and the other teachers they cooperated with. (Teacher, Greece)

Students' confidence and value in/of themselves was another positive aspect pointed out by students. At the beginning of the process several students had low expectations considering the exhibition planning and construction and some modules tasks that were too complicated. But at the end of the process and taking into account the work they had developed, students felt proud and aware of their capabilities.

[The exhibition had] much more [impact] than our expectations! We had low expectations ... but *at the end of the day it was very good! (Student, Portugal)*

It was nice presenting our work to others. We never imagined we could know more about something so innovative and explain it to others. (Student, Greece).

I was impressed with how we can design and create a photovoltaic panel. And I understood how to do it. This was possible because we worked as a team. (Student, Romania)

For some students, the participation in the project enabled them to **develop skills** related to a) working with the "media" – audio and videos; b) building interactive objects for the exhibition; and c) analysing articles.

(...)They liked (...) "working with media" (audios, videos) was highlighted as benefit of the project. (Case Study, Germany - IPN)

The most positive thing was the experience that we have won! To learn to work in groups, how to present an exhibition to the people, know how to analyse scientific articles. (Student, Portugal)

In the students' opinion, the work developed around the project favoured the understanding of science, enabling them to have a greater familiarity with the work that is done in **Science**, in particular learning how the **work of the scientists** is done and what is the role of the scientific research.

Through the construction of the exhibition we learned about many of the issues associated with nanotechnology as well as the issues related to the work of a scientist. (Student, Poland)

I think the best thing is that I learned about the need to exploit solar energy. I discovered that science is concerned related to giving us a cleaner environment. (Student, Romania)

Addressing cutting edge topics and RRI also raised students' **awareness** to the existence of both negative and positive issues related to the researched topics, as well as to current scientific research related to these issues trying to mitigate their adverse effects, such as in the case of global warming.

Even though they recognised their limited character, as it was mainly focused in schools, **the dissemination** of the project was still referred as having been very positive.

The students were very much involved in the exhibition, excited with their role in the audience, they demonstrated a very strong relationship with their exhibits, they identified themselves with the message that the exhibits expressed. All the members of the project groups instructed the visitors on how to handle their exhibits. (Teacher, Poland)

Negative aspects

Regarding the **negative aspects** of the project, the main references presented by students were organized in the following categories: a) planning the exhibition; b) building the exhibition; c) duration of the exhibition process; d) team work management; e) lack of experiments in the module; f) RRI/scientific topic; f) financial support for materials; h) evaluation; and i) without negative aspects (**table 15**).

Table 15 - Negative aspects of the project referred by the students

Planning the exhibition - Time management - Information management - Interactive format	 **8** **2** **1**
Building the exhibition - Technical problems - Space - Format	 **2** **2** **2**
Duration of the Exhibit process	**3**
Team work management	**3**
Lack of experiments in the module	**1**
RRI/ scientific topic	**1**
Financial support for materials	**1**
Evaluation	**1**
Without negative aspects	**2**
Total of cases	**26**

The process of **planning the exhibition** was the negative aspect most highlighted by students related to the project. Among the aspects mentioned by students that negatively impact this process are: a) **time management** of the planning tasks; b) **information management** about the topics presented in the exhibition; and c) the **interactive format** of the exhibition. The difficulties in the organization of a large quantity of information seem to have negatively conditioned the students who highlighted the novelty of the topics and the additional workload required by the project as negative factors. The project turned out to require from students an additional effort when compared to traditional classes.

The negative aspects: it was the short time to accomplish the tasks. Not only the final task but even the individual tasks were all very short notice and then also very coincident with the tests. So it was complicated! (Student, Portugal)

Of the student-designed exhibit experience were mentioned above: difficulties in organizing a great deal of different knowledge (relating to new science content and RRI dimensions) into an exhibit format (also new for the students) (...). (Israel).

It was the time. The time, was not the fault of the teacher who gave us little time, no, it was our fault for not knowing how to manage time. We didn't have the notion that we had to get things going so early, that's maybe why we did not. (Student, Portugal)

More time was spent on planning the exhibit and purchase of other materials. (Student, Poland)

[The negative aspects] the overlap between the subtopics. (Germany - IPN)

Beautiful but very challenging. It was interesting and it was a great opportunity. The negative aspect was perhaps the time, it lasted a lot and we worked hard despite the other school commitments (Student, Italy - UNIBO).

In my opinion, the biggest problem was finding time for everything. Because, however, meetings we had every week, they demanded at least willingness to come there and not to sit and think about something else, because it would not have brought in anything. (Student, Poland)

Some aspects of the process of **building the exhibition** were also presented by students as negative. These aspects were related to a) **technical problems** that appeared during the building process; b) the lack of **space** for displaying the exhibition and c) the **format** and adjustments made to the objects presented in the exhibition – due to the need to translate them into a different language and to adapt them for the younger students.

The negative aspects of the work on the construction of the exhibition were technical difficulties. We had to realize what we can do and what we cannot do. (Student, Poland)

The negative aspect of the project was the short amount of time we had to correct the exhibit. (Student, Italy UNIBO).

As my colleagues have mentioned the time and space, because our school had not only our exhibition that day, but other exhibitions… i.e. the space they gave us somehow was not ideal and the fact that there were other exhibits scattered those who came to see our show, in a way. But despite all this, I think we had a good impact. (Student, Portugal)

(...) and difficulties in the exhibition phase (lack of time, lack of space, the need to translate the material to a different language and to younger students (...). (Germany, IIPN)

The **duration of the exhibit process** was not the most adequate, often considered as being too long and, in other cases, as being too short, taking into account all the work that it implied. Other references pointed out to the short project duration arguing that the time available to do all tasks was not enough.

The students did not indicate any specific negative aspects except one student who thought that the project lasted too long and another that, on the contrary, thought that it did not lasted long enough. (Italy - UNIPA)

Since much of our time was invested in this project, we should have had more time to accomplish the last task and another space that had more room to expose our work! (Student, Portugal)

Ensure greater involvement of all members of the group. Start planning early in order not to do this at the last moment. (Student, Poland)

For some students, there were some issues with **team work management**, being regarded as one of the negative aspects of the project. These issues resulted from the number of students in the groups, the distribution of tasks among the group members, and also their commitment to its fulfilment.

In the beginning, it was pretty hard to distribute the tasks. Each of us wanted to fulfil the objective, but the only thing we had to do was to harmonize our time. Then we grouped according to each other's availability and have clarified the problems we had to solve. Our teacher helped us with clarifying tasks. We took part in activities organized as a project management model. (Student, Romania)

More even number of people in the groups. (Student, Poland)

Some people "bash out" more tasks than others. (Student, Poland)

They [the students] mentioned the problems arising from teamwork when less productive members are part of the team. (Germany - Kiel)

Other less favourable dimensions, from the perspective of the students, where the **lack of experiments in the module, the novelty of the topics, the funding for materials** and **assessment** that often took place during the project with large time requirements.

As negative experience, they mentioned the evaluation: "too often, too long. (Germany - IPN)

We did not have funds available for the prototype. (Student, Poland)

However, it should also be emphasized that there are two case studies, within the project, where students considered that there were no negative aspects:

The students themselves didn't bring up anything negative about the process. (Case study, Greece)

Suggestions for improvement

As for what they would change, students' suggestions were organised in the following categories: a) design of the exhibition; b) work done; c) duration of the Project; d) group work; e) evaluation; f) place of exhibition; g) dissemination; and h) collaboration within teachers (**table 16**)

Table 16 - Suggestions of change presented by the students

Design of the exhibition	**3**
Work done	**3**
Duration of the project	**3**
Group work	**2**
Evaluation	**1**
Place of the exhibition	**1**
Dissemination	**1**
Collaboration between teachers	**1**
Total of cases	**26**

Regarding the **design of the exhibition**, students considered that this domain could be improved, particularly, in terms of interactivity, as they would like to integrate more aspects of RRI in the exhibition and, thus, provide more interesting information for visitors.

> *We would build the exhibit in a different way we would change the layout of our exhibit and we would construct it so that it would be more interactive. (Student, Greece)*

> *In our exhibit we would change somethings... As we see it now we could have integrated more RRI in it, but not too much cause the visitors might get tired. There are things that we would change at the appearance and we would like the information to impress most visitors. But we are generally pleased with it! (Student, Poland)*

If they had the opportunity to do so, they would devote themselves more during the project, thus, an aspect to be changed would be the **work done**. They would have liked to be able to better plan their work, including for example the search for information and the choice of resources, in order to arrive at a better final product.

> *I would put a bit more effort in what I make. What we did now was too simple. (Student, The Netherlands)*

> *I would plan more in advance which information is going where, more discussion about that in the group and I would have a better look in advance about which materials we need. (Students, The Netherlands)*

The **duration of the project** should be different, so that they have time to complete all the module tasks and build the necessary objects for the exhibition as well as having the time for its construction. They also consider that the place of the exhibition could be bigger or a different space, in order to give greater visibility to the exhibition and become more accessible to a larger audience.

> *In my opinion, due to the time that we invest in the project, I think we should set up our project in a more public space, where even people outside school were able to see the project or see it displayed in the street! (Student, Portugal)*

> *Next time I would think a bit more about how much time it will cost (Student, The Netherlands)*

> *Also had more time ... more organization ... Because, if we had this notion, we had started early on; and no, we let it drag because: "Oh no, it'll be just a simple thing, it's easy!" ... Maybe we even had time but did not know, perhaps, to use it. (Student, Portugal)*

A change to be made, for some students, would be in **group work**. Some students would prefer to have been integrated in a more motivated group, or at least to work better in a group.

> *I would like to have been in a different, more motivated group. (The Netherlands)*

> *(...) if they could go back and do anything differently, they would have been more committed to the research and would try to work better in group. (Portugal)*

Other suggestions of change would be a better **dissemination** of the exhibition so that their project had a larger impact and a more efficient **collaboration among teachers** of different subjects so that the project was constituted as an effective commitment at the school level.

> *I think we could have tried to pass the word to more people. For example, say "Look, do not forget, in the library - either there or here - there will be an exhibition that we did, you have this and that." Just try because not everyone looks at the posters, there are many people who simply do not look! (Student, Portugal)*
>
> *Maybe the project could include also teachers of other subjects and maybe not only use the time on scientific issues ... because it is a scientific work but not only ... the goal is not only to learn science or to make a laboratory activity but is strongly intertwined with social issues (Student, Italy - UNIBO).*

The **evaluation** was reported by a student that would change the criteria associated with the creativity that, in his opinion, should not integrate the evaluation parameters in a science course.

> *I think it is a bit weird to be graded on creativity. I chose sciences because I am not creative, so I don't like that. (Student, The Netherlands)*

3.5.2. Teachers

Positive aspects

In the balance held by the participating teachers, they highlighted some positive features that were also referred by students, constituting, in this way, categories of common analysis, such as: a) active learning; b) knowledge about cutting-edge science topics/RRI; c) interpersonal relationships; d) science and scientists work; e) students' confidence and value; and f) contact with experts. Teachers also mentioned other positive features that were organized in the following categories: a) outcomes/conclusion of the work; b) commitment with the exhibition and the active role of the students; c) feedback received; d) motivation; e) students' creativity; and f) relationship with other schools (**table 17**).

Table 17 - Positive aspects of the project referred by the teachers

Active learning	**6**
Outcomes/conclusion of the project	**6**
Knowledge about cutting-edge science topics/RRI	**5**
Interpersonal relationships	**3**
Science and work of scientists	**3**
Students confidence and value	**2**
Commitment to the exhibition and the active role of students	**2**
Contact with experts	**2**
Feedback received	**1**
Motivation	**1**
Students' creativity	**1**
Relationship with other schools	**1**
Total of cases	**26**

The **active learning** methodologies used in this project, centred in Inquiry Based Science Education for the construction of interactive exhibitions, was one of the positive aspects most highlighted by teachers. This learning strategy promoted the contribution of students, even those who are generally less participatory, verifying a positive immersion of all due to the motivation provided by the activities, leading to better results and outcomes.

The student teachers were happy to be able to work with pupils during their Science education class and saw this as the most positive outcome of the project – a concrete opportunity to apply inquiry-based science education with real pupils. (Case Study, Finland)

Students have learned by doing and for them this was a positive experience. (Teacher, Italy UNIPA)

Pupils' active role on the learning process helped to make exhibitions more meaningful e.g. from the issues that are interesting for them, but also from the perspective of RRI issues (Finland)

The exhibits development motivated students that aren't usually very active in class and that helped them improve their self-image. They felt useful, students that given their educational background don't have this opportunity very often. (Teacher, Greece)

Even usually less active students were positively involved. (Teacher, UNIPA)

"If they [students] discover themselves, if they themselves were looking, they would produce things much more fantastic; we teachers would learn much more, they would be much happier and have more success, than just to memorize things; I still find it an interesting super methodology let them go ... " (Teacher, Portugal)

> *A path following this methodology should be activated every year thus becoming a standard teaching method. (Teacher, Italy - UNIPA)*

There were also positive references from teachers about the **outcomes** of the Project and **conclusion of the project**. The perceived satisfaction and pride of both students and teachers at the end of the project was quite clear as they concluded and presented their exhibits.

> *For the teacher, the project overall was a success. She achieved the goal of developing the class and the outcome of the project was broadly appreciated. (Germany - Kiel)*

> *Finally, it was shown at the local community that students from the vocational school are also capable of developing such interesting exhibits. (Teacher, Greece)*

> *The satisfaction of students from the completion and presentation of their own work (Case study, Greece)*

Some participating teachers have ideas that coincide with the students' in terms of the **knowledge about cutting-edge science topics/RRI** that has been developed, recognizing that this experience is the source of significant learning, not only for students but also for themselves.

> *We become aware – not of the problem itself [global warming], because that we already knew! – But we now are more aware that someone cares about it, and that are being created strategies to solve the problem! (Teacher, Portugal)*

> *According to the second year experience of exhibitions, it seems to be evident that primary school pupils learn about climate change as a scientific process by this method. (Case study, Finland)*

Another dimension highlighted by teachers is related with the **interpersonal relationships**, especially the relationship that was established within the whole team, involving not only the students, but also the teacher.

> *Students who were actively engaged in the procedure said that they liked collaborating with each other and with me outside school. (Teacher, Greece)*

> *The most important outcome of the procedure was the fact that students worked with team spirit, bonded with each other and improved their relations with me and the other teachers they cooperated with too. (Teacher, Greece)*

For teachers, participating with their classes in the project, gave students the opportunity to **contact with experts** from universities, science museums and research centres and collaborate with them.

> *Furthermore, it was very useful for children the fact that they met, talked and cooperated with researchers of the FORTH, the EF and the University during the development of their exhibits. (Teacher, Greece)*

> *Collaboration with the university staff for the students was constructive experience. (Teacher, Italy - UNIPA)*

In the teachers' opinion, students also learned things related to **science and the work of scientists** and regarding the role of scientific research. Teachers also highlighted, that students started to understand the importance of the participation of different actors in the process of responsible research and innovation.

> *Another positive outcome is that they [the students] understood that the scientific community are not just people closed on themselves... They have learned that the work of scientists crosses the barrier of the scientific research and becomes known by society, and also their research has a practical application. Or might have a practical application! So I think they understood better what is the role of a researcher... a scientist! I think that at this age, they only know a few scientists, like Einstein! (...) And also for them it seems that Science is something that has passed and it seems that now no one is working or are working on Science, with this module they realized that there is a scientific community and therefore, scientists are working for the good of all. (...) The governments, who have a very important role; the people themselves, society itself and students themselves, which may also participate. This is one of the positive aspects of what was more significant for students. (Teacher, Portugal)*

> *They learned about nanoscience through inquiry. In other words, they learned how an experimental research was conducted, how a product was developed. So they improved their skills in that sense... (Teacher, Turkey).*

Students' confidence and value in themselves, and their **commitment to the exhibition and to an active role** were also pointed out by teachers as positive aspects resulting from the project development.

> *Preparing the introductory material to the exhibit presentation stimulated them to think it over and elaborate new concepts on the basis of what they already knew. This made them confident and more autonomous in building their own knowledge. (Teacher, Italy - UNIPA)*

> *The students were very much involved in the exhibition, excited with their role in the audience, they demonstrated a very strong relationship with their exhibits, they identified themselves with the message that the exhibits expressed. All the members of the project groups instructed the visitors on how to interact with their exhibits. (Teacher, Poland)*

Other aspects referred by teachers as being positive were a) the **feedback received** from their colleagues, parents and other students, taking into account the interactive characteristics of the exhibition, recognizing that this public recognition makes it worthwhile to invest in a project of this nature; b) the **motivation** in doing the tasks; c) the **students' creativity** demonstrated in the exhibition and, d) the **relationship with other schools**, promoting a beneficial exchange of knowledge and skills between students.

> *The exhibition received excellent feedback from colleagues, parents and other students, thus overall it was worth doing the work. Especially the media included (3 student-created videos, 7 audio stations) created a lot of extra work, but gave the exhibition an interactive and professional touch that was well received by the audience. (Germany - IPN)*

> *There was a mutually beneficial exchange of knowledge and competence among students from different types of schools (Teacher, Italy UNIPA).*

Negative aspects

The **negative aspects** mentioned by teachers were organised in the following categories: a) time management; b) group work; c) exhibition related issues; d) workload; e) student lack of skills to construct the objects; and f) collaboration with other teachers (**table 18**).

Table 18 - *Negative aspects of the project referred by the teachers*

Time management	**6**
Group work	**4**
Exhibition	
- **Materials**	**1**
- **Time to build**	**2**
- **Place**	**2**
- **Size**	**1**
- **Date**	**1**
- **Length**	**2**
Workload	**2**
Student lack of skills to construct the objects	**1**
Collaboration with other teachers	**1**
None	**1**
Total of cases	**26**

As we can see in **table 18**, **time management** was considered, by teachers, as the most negative aspect of the project. In their opinion, more time would be needed to develop the project. In some cases, teachers needed more time to make choices about the topics or tasks in the project. Many times, that lack of time seems to be related to the necessary time to prepare the exhibition that turned out to take longer than was initially expected.

> *We did not really follow the six steps in the module, we had to make choices, we did not have the time to do it all. Next year, we can make the planning better, and already add it to the PTA (program of evaluation), that would make it easier. (Teacher, The Netherlands)*

> *Well, it took us 4 weeks to develop the exhibit. Initially, we thought it would take 2 weeks, but it took more than what we thought (Teacher, Turkey).*

Among the teachers, **group work** is also a sensitive dimension, due to the fact that some elements of the group do not involve themselves actively, having harmful consequences for the other members who could end up with more work. In their opinion, the dynamics of some groups were not the most appropriate.

> *In one group (Group A) although all were good students, there was an unequal distribution of workload, and one student (who had undertaken the programming part of the android*

application) took almost all the work and was overwhelmed with technical work, and did not profit in terms of nanoscience or RRI knowledge. (Teacher, Italy UNIPA)

Also, some aspects related to the **exhibition** represented negative issues for the participating teachers. Among these aspects they pointed out a) the materials need to build the exhibition; b) the place; c) the size; d) the date; and e) the duration, allowing more people to visit the exhibition.

The exhibit provoked a small upheaval at the school, as there wasn't much time and students were leaving their normal classes to work on the exhibit. Maybe it was due to my lack of experience in organizing such procedures better, or to some other teachers' intolerance. But I believe that even them, when they saw the exhibit complete, they felt proud for their students (Teacher, Greece).

I would make sure to give more time to the presentation day. I'd give more time to plan and organize the exhibit. And I'd advertise it more widely, so that there would be a larger audience, including the parents. (Teacher, Israel)

Really, the room was small and we had the games of the groups a bit on top of one another. (Student, Portugal)

Too much time spent in the building enclosed in four walls without the access to fresh air. (Student, Poland)

As my colleagues mentioned the fact that time and space, was that our school had not only our exhibit that day, but other exhibitions, i.e. the space they gave us somehow was not ideal and the fact that there were other exhibits scattered those who came to see our show, in a way. But despite all this, I think we had a good impact. (Student, Portugal)

Almost year-round work on the project finished with a several-hour-long exhibition. Maybe it would be worthwhile to consolidate the effects of several months of work? (Teacher, Poland)

The amount of **additional work** related to the development of the module constituted a negative aspect of the project, according to some teachers. However, in some other cases, this was considered worthwhile.

The teacher argued, that it was far too much work to do parallel to regular school lessons. Developing the module from scratch, introducing it in class and building an exhibition was for her, way over budget. (Case study, Germany IPN)

She mentioned that surly it was quite a lot of extra work, but worth doing it. (Case study, Germany, IPN)

The **students lack of skills to construct the objects** and the **lack of collaboration among teachers** had also negative consequences for the project, as the collaboration with other teachers would have been a benefit in order to exchange experiences and to achieve better time management.

If one could have the involvement of other colleagues we could better divide the commitment of the project (both in terms of time and expertise), otherwise we have to *separate what to do in the school timetable and what to do in an extra- school time (Teacher, Italy UNIBO).*

Suggestions for improvement

The suggestions for improvement presented by the teachers were organized in the following categories: a) time management; b) scope of the project/exhibition; c) duration of the project; d) dissemination; e) information given; f) place of exhibition; g) communication with teachers; g) orientation of the teacher; h) evaluation; and i) organization of the project (**table 19**).

Table 19 - Suggestions of change presented by teachers.

Time management	**5**
Scope of the project/exhibition	**3**
Duration of the project	**2**
Dissemination	**2**
Information given	**1**
Place of exhibition	**1**
Communication with teachers	**1**
Guidance by the teacher	**1**
Evaluation	**1**
Organization of the project	**1**
Total of cases	**26**

Teachers considered that in future projects they will improve the **time management** of all tasks during the process, having in mind the exhibition as a final assignment. This first experience with the module implementation gave them knowledge on how to better plan it in the future, and better allocate the time needed for the different tasks.

Next time I would organize the lessons a bit different: after the presentations of the expert-groups I would come back to the science and then make the exhibitions. (Teacher, The Netherlands)

I would start the exhibits procedure earlier in the module. Maybe even before the completion of the activities phase. Students should reflect more actively about their exhibit from the beginning of the module. (Teacher, Greece).

Next year, we can make the planning better, and already add it to the PTA (program of evaluation), that would make it easier. (Teacher, The Netherlands)

… I'd give more time to plan and organize the exhibit. (Teacher, Israel)

Some teachers would reduce the **scope of the project and of the exhibition**. For them, it would be beneficial to develop a project with only one class, in order to better monitor the project. Limiting the scope of the exhibition, eliminating the RRI dimension, was pondered by some who considered it difficult to integrate in the exhibition.

> *(...) the exhibition would be planned on a smaller scale (however, if it is too small, there is a risk that it would become insignificant; a certain minimum size would need to be determined). (...) they would refrain from curating an exhibition with two classes. Many of the difficulties describes above could be reduced by involving less pupils in the process (i.e. a single class of approx. 30 pupils). (Germany - DM)*

It is also worth mentioning the suggestions made regarding the **duration of the project** proposing more time to the development of the module and to organize the exhibition, taking into account the time necessary some for its construction.

Moreover, the **dissemination** is an aspect that could be improved, doing it earlier and reaching a wider audience. This way, students could have a better perception of the impact of their work on larger scale.

> *I would make sure to give more time to the presentation day…And I'd advertise it more widely, so that there would be a larger audience, including the parents. (Teacher, Israel)*

> *Well, the only suggestion I can give is, in the next school year, when students return to school, the PC teacher (since I'm not here anymore) make students look at their blog and think of feasible ways for disseminating it... Then, yes. I believe if students find good ways to disseminate, their work would be much more complete. (Teacher, Portugal)*

Reflecting upon this process, teachers also pointed out some suggestions for a) the selection of **information** sources to be provided to students, choosing less but better sources; the place of the exhibition in order to find a location that provides more visibility to the project developed by the students; c) **guidance given by the teacher** that should be more active in order to effectively involve all students; d) the **communication with teachers**; e) the **evaluation** criteria, that should be improved in order to get a bigger involvement from the students in the construction of the exhibition; and f) the **organization of the project** - the project could benefit if it started with the contribution of experts prompting a discussion about what is science, then followed by the assignment requiring the construction of the exhibition.

> *I would reduce a little the given information, because our students, they are not prepared to read texts with that dimension and complexity. The texts are too big! Ourselves, in class, always give smaller texts so that they can read and interpret. But ... I think it's essentially it. (Teacher, Portugal)*

> *We should have had more time to prepare and a place should be chosen so the exhibition could have greater visibility. (Teacher, Portugal)*

> *I would start the exhibits procedure earlier in the module. The process should be more condensed. (Teacher, Greece)*

Furthermore, one of them would improve the communication tools used by the teachers to talk about RRI topics. (Teacher, Italy UNIPA)

We should have a better 'goal' like showcasing the bookcase somewhere, or make more clear what the meaning of the exhibition is. (Teacher, The Netherlands)

3.5.3. Experts

Two records enabled to obtain more evidences about the opinion of two experts related to the project developed. According to the participating experts, this project helped the development of students' skills, in particular, the ones related to a) scientific processes as they learned how to search, analyse and select relevant information and b) curated exhibitions, as they learned how to organise information and communicate with visitors. The experts also highlighted the relationship that was established between the school and the scientific community due to the collaboration that existed, and the great challenge that was to work with the students.

The process of exhibits development put children in an unusual role for them. It was first time they hadn't been simply asked to understand a subject but through the construction of a scientific exhibit to explain and communicate the points considered as essential to a visitor who may not know very much about the issue and persuade him that It is important for the (current or future) everyday life to know them. For students to be able to correspond to this process, they had to make further inquiry about the theme chosen to communicate, to learn as much as they could and then, analyzing their material, to choose that information considered as critical to pass the message they wanted to the visitors through their exhibit (...). the process had positive repercussions to us who work in science museums. We had the opportunity to work closely with highly qualified teachers, to impart knowledge and experience from fields in which there may not have great fluency – those of non-formal education and science communication. (Expert, Greece, CoL1)

Through the focused field visits, students understood that designing an exhibit is not so easy process. They realised that further research is needed in order to communicate the subject matter to the general public, before to get to the hands-on phase of the process. However, they succeeded to complete their research and to deliver exhibits, on time. In addition, the installation of the students-curated exhibition in the museum as part of the exhibits development procedure was a big challenge and asset for us as it was the 1st time that we have been involved in such a task. (Expert, Greece, CoL2)

4. STUDENTS' PERCEPTIONS ON THE DEVELOPMENT OF EXHIBITIONS IN SCIENCE CLASSES: IMPACT OF THE PARTICIPATION IN THE IRRESISTIBLE PROJECT

We contributed to the questionnaire developed within WP5 which was to be applied to all CoL2 students that participated in the IRRESISTIBLE Project. This online pre and post-questionnaire comprised several sections. We contributed to Sections 3 and 4 with the following 16 items, to be evaluated by students through a five point Likert-scale:

a) I'm capable of planning and constructing a science exhibit about a current and relevant scientific theme
b) Planning and constructing a science exhibit is motivating
c) The development of a science exhibit about a given subject allows me to learn more about that subject
d) The construction of science exhibits improves the relationships amongst students
e) The construction of science exhibits improves the relationship between students and teacher
f) ICTs are great tools to support the development of science exhibits
g) I'm capable of creating science exhibits as a way to raise awareness in the community for current and relevant scientific issues
h) Through the development of science exhibits I can influence the decisions and behaviours of other citizen's related to social issues concerning science, technology and environment
i) In my science classes I discuss about current problems and how they affect my life
j) In my science classes I develop competencies that allow me to have a more active role in society
k) In my science classes I'm encouraged to ask questions
l) In my science classes I carry out projects that I consider important and socially relevant
m) In my science classes I learn to act in a socially responsible way
n) In my science classes I learn to respect my colleagues' opinions
o) In my science classes I learn about ways to influence other people's decisions about social issues related to science, technology and society
p) In my science classes I'm responsible for initiatives that allow me to influence other people's decisions about social issues related to science, technology and society

Participants

The questionnaire was answered by a total of 3368 students on the pre-test application and 2433 on the post-test application, from a total of 10 different countries (see **table 20**). Turkey, Poland and Greece were the most represented countries, but Italy and Portugal also had more than 500 respondents each.

Table 20 - Number of questionnaires answered from each participating country.

Country	Pre-test	Post-test	Total per country
Israel	153	59	212
Netherlands	36	85	121
Finland	277	90	367
Romania	47	43	90
Portugal	269	276	545
Italy	513	185	698
Greece	617	483	1100
Turkey	623	505	1128
Germany	226	206	432
Poland	607	501	1108
Total	**3368**	**2433**	**5801**

Participants were distributed across all age groups as is illustrated by **table 21**, with the majority being 15 or 16 years old, but also with very large numbers from ages 11, 12, 13 and 14; and also from the 17 year old age group.

Table 21- Participants distribution per country/age group.

Country	Age										
	-8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18+**
Israel	0	0	0	0	0	10	2	30	118	31	0
Netherlands	0	0	0	0	0	0	23	47	14	26	5
Finland	0	0	20	121	173	34	0	0	0	2	4
Romania	0	0	0	0	0	0	0	3	39	16	28
Portugal	41	7	30	14	3	104	83	142	93	12	1
Italy	0	0	0	0	0	0	19	211	120	137	196
Greece	0	0	1	256	176	76	95	203	156	100	8
Turkey	0	0	8	116	310	217	132	150	124	64	7
Germany	0	0	0	0	0	15	67	57	110	106	75
Poland	0	0	0	0	7	88	199	183	230	234	100
Total	**41**	**7**	**59**	**507**	**669**	**544**	**620**	**1026**	**1007**	**728**	**424**

The instrument

The questionnaire was composed of 5 sections with a total of 33 questions. Section 1 included 3 characterization questions (country, age, gender); section 2 included 12 closed questions focused on RRI issues in education (where the participants had to rate statements on a 5 point Likert scale ranging from *totally agree* to *totally disagree*); section 3 included 3 open questions about the ethical issues tackled by the students in their projects; section 4 included 8 closed questions about the student developed exhibits (where the participants had to rate statements on a 5 point Likert scale ranging from *totally agree* to *totally disagree*); and finally section 5 included 8 closed questions about the students science classroom environments (where the participants had to rate statements on a 5 point Likert scale ranging from totally agree to totally disagree).

Here we will focus our analysis on the participants' answers to sections 4 and 5. In order to validate the developed sections, for this new population, the Cronbach's alpha index was calculated for both. The attained values for Cronbach's Alpha on these sections was respectively .853 and .876, indicating that the internal consistency of both topics was high (Cronbach's Alpha larger than .8), illustrating the reliability of the proposed topics.

Next, we calculated the overall progression of our sample. For this, in **table 22** we can observe the average mean score and standard deviation for each of the analysed questions (both pre and post-test), as well as the ANOVA results indicating if there is a significant difference between pre and post-test results. As can be illustrated by this table almost all questions (with the exception of questions number 17 and 20) showed a significant raise in their scores favouring the post-test results (considering $p < ,05$).

Table 22 - Pre and post-test results for the whole sample with ANOVA.

Questions	Pre-test			Post-test			F	Sig.
	N	Mean	Std. Deviation	N	Mean	Std. Deviation		
15. I can plan and develop a scientific exhibit about a current and relevant science topic	3117	3,41	1,128	2283	3,90	1,020	269,261	,000*
16. To plan and develop a scientific exhibit is something that motivates me	3128	3,824	1,0980	2281	3,952	1,0762	18,208	,000*
17. Developing a scientific exhibit about a given topic allows me to learn more about it	3110	4,225	,9714	2270	4,254	,9806	1,129	,282
18. Developing a scientific exhibit improves the relationships among students	3120	3,874	1,0693	2272	4,015	1,0631	23,196	,000*
19. Developing a scientific exhibit improves the relationship between students and teacher	3119	3,916	1,0428	2272	4,033	1,0560	16,464	,000*
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	3106	4,101	,9583	2268	4,116	,9508	,351	,554
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	3105	3,455	1,1143	2268	3,784	1,0510	119,516	,000*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	3112	3,545	1,0697	2267	3,732	1,0468	40,732	,000*
23. In my science classes I discuss current issues and how they impact my life	3100	3,345	1,1853	2259	3,534	1,1504	34,343	,000*
24. In my science classes I develop competencies that allow me to have a more active role in society	3106	3,496	1,1282	2264	3,652	1,0830	25,790	,000*
25. In my science classes I am encouraged to ask questions	3097	3,628	1,1600	2264	3,738	1,1238	12,059	,001*
26. In my science classes I develop important and socially relevant projects	3097	3,265	1,1768	2258	3,561	1,1281	85,368	,000*
27. In my science classes I learn how to act in a socially responsible manner	3089	3,604	1,1470	2259	3,796	1,0756	38,639	,000*
28. In my science classes I learn how to respect my colleagues' opinions	3097	3,931	1,1201	2256	4,015	1,0414	7,877	,005*
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	3093	3,405	1,1073	2261	3,632	1,0717	56,354	,000*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	3089	3,340	1,1462	2260	3,565	1,0854	52,798	,000*

* Significant difference between pre and post-test results

We have also conducted an analysis per country to identify possible differences.

Israel

In **table 23** we can observe the results concerning the participants from Israel. In this case there was a significant increase in all questions, except in the cases of questions 17, 20, and 25.

Table 23 - Israel pre and post-test results ANOVA.

Questions	F	Sig
15. I can plan and develop a scientific exhibit about a current and relevant science topic	25,582	,000*
16. To plan and develop a scientific exhibit is something that motivates me	15,458	,000*
17. Developing a scientific exhibit about a given topic allows me to learn more about it	3,567	,060
18. Developing a scientific exhibit improves the relationships among students	8,663	,004*
19. Developing a scientific exhibit improves the relationship between students and teacher	11,184	,001*
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	,966	,327
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	9,701	,002*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	9,088	,003*
23. In my science classes I discuss current issues and how they impact my life	6,670	,011*
24. In my science classes I develop competencies that allow me to have a more active role in society	24,889	,000*
25. In my science classes I am encouraged to ask questions	2,754	,099
26. In my science classes I develop important and socially relevant projects	9,387	,002*
27. In my science classes I learn how to act in a socially responsible manner	26,295	,000*
28. In my science classes I learn how to respect my colleagues' opinions	16,549	,000*
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	14,237	,000*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	15,077	,000*

* Significant difference between pre and post-test results

The Netherlands

In **table 24** we can observe the results concerning the participants from the Netherlands. In this case there was only a significant difference between pre and post-test results in question 27. It should be noted that The Netherlands was one of the countries with the least participants, including only 36 pre-test answers, making it harder to identify significant differences.

Table 24 - The Netherlands pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	2,284	,134
16. To plan and develop a scientific exhibit is something that motivates me	,333	,565
17. Developing a scientific exhibit about a given topic allows me to learn more about it	,045	,832
18. Developing a scientific exhibit improves the relationships among students	,509	,477
19. Developing a scientific exhibit improves the relationship between students and teacher	,036	,850
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	,349	,556
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	,343	,559
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	,556	,458
23. In my science classes I discuss current issues and how they impact my life	,106	,746
24. In my science classes I develop competencies that allow me to have a more active role in society	2,346	,129
25. In my science classes I am encouraged to ask questions	,980	,325
26. In my science classes I develop important and socially relevant projects	1,932	,168
27. In my science classes I learn how to act in a socially responsible manner	8,087	,005*
28. In my science classes I learn how to respect my colleagues' opinions	,041	,840
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	,909	,343
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	,075	,784

* Significant difference between pre and post-test results

Finland

In **table 25** we can observe the results concerning the participants from Finland. In this case, there was a significant increase only in questions 15, 17, 23, and 28.

Table 25 - Finland pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	11,449	,001*
16. To plan and develop a scientific exhibit is something that motivates me	,016	,900
17. Developing a scientific exhibit about a given topic allows me to learn more about it	9,348	,002*
18. Developing a scientific exhibit improves the relationships among students	,738	,391
19. Developing a scientific exhibit improves the relationship between students and teacher	,106	,745
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	,007	,933
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	,548	,460
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	,004	,947
23. In my science classes I discuss current issues and how they impact my life	6,220	,013*
24. In my science classes I develop competencies that allow me to have a more active role in society	3,530	,061
25. In my science classes I am encouraged to ask questions	,707	,401
26. In my science classes I develop important and socially relevant projects	,494	,482
27. In my science classes I learn how to act in a socially responsible manner	,120	,730
28. In my science classes I learn how to respect my colleagues' opinions	5,141	,024*
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	2,283	,132
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	,565	,453

* Significant difference between pre and post-test results

Romania

In **table 26** we can observe the results concerning the participants from Romania. In this case, there was a significant increase in every question. It should be noted that Romania was the country with the smaller number of answered questionnaires (47 + 43) making it even harder to achieve significant differences, emphasizing the relevance of the achieved progress.

Table 26 - Romania pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	81,642	,000*
16. To plan and develop a scientific exhibit is something that motivates me	58,267	,000*
17. Developing a scientific exhibit about a given topic allows me to learn more about it	23,039	,000*
18. Developing a scientific exhibit improves the relationships among students	36,166	,000*
19. Developing a scientific exhibit improves the relationship between students and teacher	9,186	,003*
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	6,408	,013*
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	41,492	,000*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	57,707	,000*
23. In my science classes I discuss current issues and how they impact my life	18,132	,000*
24. In my science classes I develop competencies that allow me to have a more active role in society	36,296	,000*
25. In my science classes I am encouraged to ask questions	18,078	,000*
26. In my science classes I develop important and socially relevant projects	51,883	,000*
27. In my science classes I learn how to act in a socially responsible manner	22,639	,000*
28. In my science classes I learn how to respect my colleagues' opinions	23,928	,000*
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	46,323	,000*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	35,649	,000*

* Significant difference between pre and post-test results

Portugal

In **table 27** we can observe the results concerning the participants from Portugal. In this case, there was a significant increase in questions 15, 17, 21, 23, 26, 29 and 30.

Table 27 - Portugal pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	10,969	,001*
16. To plan and develop a scientific exhibit is something that motivates me	,541	,462
17. Developing a scientific exhibit about a given topic allows me to learn more about it	12,739	,000*
18. Developing a scientific exhibit improves the relationships among students	,157	,692
19. Developing a scientific exhibit improves the relationship between students and teacher	,948	,331
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	,267	,605
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	4,327	,038*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	,087	,768
23. In my science classes I discuss current issues and how they impact my life	26,514	,000*
24. In my science classes I develop competencies that allow me to have a more active role in society	3,473	,063
25. In my science classes I am encouraged to ask questions	1,131	,288
26. In my science classes I develop important and socially relevant projects	9,343	,002*
27. In my science classes I learn how to act in a socially responsible manner	2,096	,148
28. In my science classes I learn how to respect my colleagues' opinions	,075	,785
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	4,335	,038*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	14,245	,000*

* Significant difference between pre and post-test results

Italy

In **table 28** we can observe the results concerning the participants from Italy. In this case, there was a significant increase only in questions 15 and 21.

Table 28 - Italy pre and post-test results ANOVA.

Questions	F	Sig
15. I can plan and develop a scientific exhibit about a current and relevant science topic	4,094	,043*
16. To plan and develop a scientific exhibit is something that motivates me	,196	,658
17. Developing a scientific exhibit about a given topic allows me to learn more about it	2,267	,133
18. Developing a scientific exhibit improves the relationships among students	1,282	,258
19. Developing a scientific exhibit improves the relationship between students and teacher	1,641	,201
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	1,299	,255
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	8,677	,003*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	,536	,465
23. In my science classes I discuss current issues and how they impact my life	,565	,453
24. In my science classes I develop competencies that allow me to have a more active role in society	,824	,364
25. In my science classes I am encouraged to ask questions	2,654	,104
26. In my science classes I develop important and socially relevant projects	1,844	,175
27. In my science classes I learn how to act in a socially responsible manner	,300	,584
28. In my science classes I learn how to respect my colleagues' opinions	,588	,444
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	1,911	,167
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	,033	,857

* Significant difference between pre and post-test results

Greece

In **table 29** we can observe the results concerning the participants from Greece. In this case, there was a significant increase in questions 15, 18, 19, 20, 21, 23, 26, 29 and 30.

Table 29 - Greece pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	32,516	,000*
16. To plan and develop a scientific exhibit is something that motivates me	,541	,462
17. Developing a scientific exhibit about a given topic allows me to learn more about it	,107	,744
18. Developing a scientific exhibit improves the relationships among students	7,132	,008*
19. Developing a scientific exhibit improves the relationship between students and teacher	16,134	,000*
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	4,671	,031*
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	6,752	,010*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	3,413	,065
23. In my science classes I discuss current issues and how they impact my life	6,797	,009*
24. In my science classes I develop competencies that allow me to have a more active role in society	,468	,494
25. In my science classes I am encouraged to ask questions	1,139	,286
26. In my science classes I develop important and socially relevant projects	9,354	,002*
27. In my science classes I learn how to act in a socially responsible manner	3,604	,058
28. In my science classes I learn how to respect my colleagues' opinions	1,178	,278
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	4,904	,027*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	5,446	,020*

* Significant difference between pre and post-test results

Turkey

In **table 30** we can observe the results concerning the participants from Turkey. In this case, there was a significant increase in every question, except in questions 17 and 20.

Table 30 - Turkey pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	51,573	,000*
16. To plan and develop a scientific exhibit is something that motivates me	19,221	,000*
17. Developing a scientific exhibit about a given topic allows me to learn more about it	,942	,332
18. Developing a scientific exhibit improves the relationships among students	15,371	,000*
19. Developing a scientific exhibit improves the relationship between students and teacher	6,384	,012*
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	1,657	,198
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	17,701	,000*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	9,395	,002*
23. In my science classes I discuss current issues and how they impact my life	14,792	,000*
24. In my science classes I develop competencies that allow me to have a more active role in society	28,686	,000*
25. In my science classes I am encouraged to ask questions	8,516	,004*
26. In my science classes I develop important and socially relevant projects	47,199	,000*
27. In my science classes I learn how to act in a socially responsible manner	32,790	,000*
28. In my science classes I learn how to respect my colleagues' opinions	14,576	,000*
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	26,029	,000*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	27,863	,000*

* Significant difference between pre and post-test results

Germany

In **table 31** we can observe the results concerning the participants from Germany. In this case, there was a significant increase in questions 15, 16, 19, 21, 22, 23, 26, and 29.

Table 31 - Germany pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	43,915	,000*
16. To plan and develop a scientific exhibit is something that motivates me	18,649	,000*
17. Developing a scientific exhibit about a given topic allows me to learn more about it	1,715	,191
18. Developing a scientific exhibit improves the relationships among students	3,064	,081
19. Developing a scientific exhibit improves the relationship between students and teacher	10,292	,001*
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	,013	,908
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	12,832	,000*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	5,619	,018*
23. In my science classes I discuss current issues and how they impact my life	4,578	,033*
24. In my science classes I develop competencies that allow me to have a more active role in society	5,737	,017*
25. In my science classes I am encouraged to ask questions	,858	,355
26. In my science classes I develop important and socially relevant projects	2,334	,127
27. In my science classes I learn how to act in a socially responsible manner	,600	,439
28. In my science classes I learn how to respect my colleagues' opinions	,366	,546
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	,379	,539
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	1,178	,278

* Significant difference between pre and post-test results

Poland

In **table 32** we can observe the results concerning the participants from Poland. In this case, there was a significant increase in questions 15, 17, 21, 23, and 24.

Table 32 - Poland pre and post-test results ANOVA.

Questions	F	Sig.
15. I can plan and develop a scientific exhibit about a current and relevant science topic	39,459	,000*
16. To plan and develop a scientific exhibit is something that motivates me	,196	,658
17. Developing a scientific exhibit about a given topic allows me to learn more about it	6,714	,010*
18. Developing a scientific exhibit improves the relationships among students	,776	,379
19. Developing a scientific exhibit improves the relationship between students and teacher	2,643	,104
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits	,984	,322
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	24,760	,000*
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	3,456	,063
23. In my science classes I discuss current issues and how they impact my life	5,375	,021*
24. In my science classes I develop competencies that allow me to have a more active role in society	,209	,648
25. In my science classes I am encouraged to ask questions	,512	,474
26. In my science classes I develop important and socially relevant projects	7,910	,005*
27. In my science classes I learn how to act in a socially responsible manner	,647	,421
28. In my science classes I learn how to respect my colleagues' opinions	,078	,780
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	10,712	,001*
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	1,687	,194

* Significant difference between pre and post-test results

It becomes clear from this analysis by country that participants' from different contexts had diverse perceptions regarding the topics covered by the questionnaire. **Table 33** summarizes the ANOVA results for every country identifying the questions where there was a significant difference between pre and post-test (p < ,05)

Table 33 - ANOVA significant results for all participating countries (only significant results are reported).

Questions	Israel	Netherlands	Finland	Romania	Portugal	Italy	Greece	Turkey	Germany	Poland	Total
15. I can plan and develop a scientific exhibit about a current and relevant science topic	,000*		,001*	,000*	,001*	,043*	,000*	,000*	,000*	,000*	**9**
16. To plan and develop a scientific exhibit is something that motivates me	,000*			,000*				,000*	,000*		**4**
17. Developing a scientific exhibit about a given topic allows me to learn more about it			,002*	,000*	,000*					,010*	**4**
18. Developing a scientific exhibit improves the relationships among students	,004*			,000*			,008*	,000*			**4**
19. Developing a scientific exhibit improves the relationship between students and teacher	,001*			,003*			,000*	,012*	,001*		**5**
20. ICT (Information and Communication Technologies) are a good tool to support the development of scientific exhibits				,013*			,031*				**2**
21. I am able to develop scientific exhibit that raise awareness in the community to current and relevant scientific issues	,002*			,000*	,038*	,003*	,010*	,000*	,000*	,000*	**8**
22. Through the development of scientific exhibits I am able to influence other citizens decisions and behaviours about issues related to science, technology and the environment	,003*			,000*				,002*	,018*		**4**
23. In my science classes I discuss current issues and how they impact my life	,011*	,	,013*	,000*	,000*	,	,009*	,000*	,033*	,021*	**8**
24. In my science classes I develop competencies that allow me to have a more active role in society	,000*			,000*	,			,000*	,017*		**4**
25. In my science classes I am encouraged to ask questions				,000*				,004*			**2**
26. In my science classes I develop important and socially relevant projects	,002*			,000*	,002*		,002*	,000*		,005*	**6**
27. In my science classes I learn how to act in a socially responsible manner	,000*	,005*	,	,000*				,000*			**4**
28. In my science classes I learn how to respect my colleagues' opinions	,000*		,024*	,000*				,000*			**4**
29. In my science classes I learn how to influence other citizens' decisions about social issues related to science, technology and the environment	,000*			,000*	,038*		,027*	,000*		,001*	**6**
30. In my science classes I am responsible for initiatives that allow me to impact other citizens' decisions about social issues related to science, technology and the environment	,000*			,000*	,000*		,020*	,000*			**5**
Total	**14**	**1**	**4**	**16**	**7**	**2**	**9**	**14**	**7**	**6**	

From the analysis of **table 33** the differences between countries become clear. Romania, Israel and Turkey were noticeably the ones were more significant differences were observed (16-14 out of possible 16). Greece, Portugal, Germany and Poland also had several questions with significant differences (9-6). With The Netherlands, Italy and Finland being the countries with the least significant differences (1-4).

Concerning the posed questions, from this analysis it also becomes clear that questions 15, 21 and 23 were the ones where more differences are observed (9-8 out of possible 10). Questions 19, 26, 29 and 30 were also questions were differences are important to mention (5-6 out of possible 10). With questions 20 and 25 being the ones were the least amount of differences were observed (only 2 countries each).

Attending at the results we can conclude that students improved their perceptions in what regards their competences for developing exhibitions in science classes as a way of creating awareness on topics relating science-technology-society-environment: at the end of the project, they felt capable of attaining this goal. Also they realized that this sort of project improves the relationship between students and teachers. Concerning their classroom environments, the Project contributed to students' improved perceptions that in their science classes: a) they discuss current issues and how they impact their lives; b) they develop socially and relevant projects; and c) they learn how to influence other citizens' decisions about social issues related to science, technology and environment.

5. THREE YEARS: 218 IRRESISTIBLE EXHIBITIONS

During the three years of the Project, more precisely during the school years 2014/2015 and 2015/2016, and following the implementation of the several teaching modules, a total of 218 exhibitions were developed. **Table 34** presents a synthesis of their global characterization.

Table 34 – IRRESISTIBLE Exhibitions: a synthesis.

	Partner	Total of exhibitions	Theme (number of exhibitions per theme)	Total number of students involved	Place of exhibition (number of exhibitions per place)	Total number of teachers involved (Science and Non-Science – ST and NST)
CoL1 (2014/2015)	The Netherlands	4	Carbohydrates in breastmilk	139	School	6 ST
	Finland	1	Climate change	87	Museum	30 ST
	Germany (IPN)	2	Plastic Pollution in Oceans	39	School	2 ST
	Germany (DM)	1	Oceanography	60	School	2 ST
	Portugal	4	Polar Science (3) Climate Geoengineering (1)	212	School (3) Online (1)	7 ST
	Romania	1	Nanotechnology	1000	Museum	30 ST
	Turkey	4	Nanotechnology	97	School (3) University (1)	10 ST
	Poland	6	Nanotechnology	134	School (5) Conference room (1)	8 ST
	Greece	2	Nanotechnology	108	Eugenides Foundation (1) Museum (1)	5ST
	Italy (UNIBO)	2	Nanotechnology	55	School	2 ST
	Italy (UNIPA)	1	Nanotechnology	73	University	4 ST
	Israel	4	Nanotechnology	65	School (3) Science Museum (1)	2 ST
CoL2 (2015/2016)	The Netherlands	13	Carbohydrates in breastmilk (9) Polar Science (2) Nanotechnology (2)	411	School (12) Church (1)	29 ST
	Finland	14	Nanotechnology (5) Climate change (6) Climate Geoengineering (3)	311	School (12) Online (2)	56 ST (41 in teacher training)
	Germany (IPN)	12	Oceanography (6) Nanotechnology (4) Plastic Pollution in Oceans (2)	264	School	14 ST
	Germany (DM)	2	Nanotechnology	45	School	2 ST
	Portugal	15	Plastic Pollution in Oceans (7) Climate Change (3) Polar Science (2) Climate Geoengineering (2) Extension of Portuguese Continental Shelf (1)	483	School (13) City Sports Park (1) University (1)	18 ST
	Romania	11	Nanotechnology	1000	Science Museum (1) School (10)	30 ST
	Turkey	14	Nanotechnology (7) Plastic Pollution in Oceans (4) Climate Change (3)	596	School (9) Science Centre (5)	65 ST 1 NST
	Poland	26	Nanotechnology	884	School (25) Science Museum (1)	41 ST 8 NST
	Greece	46	Nanotechnology (23) + Plastic Pollution in Oceans (16) + Carbohydrates in breastmilk (7)	646	Science Center	35 ST
	Italy (UNIBO)	20	Nanotechnology	233	School (10) Science Museum (10)	22 ST 12NST
	Italy (UNIPA)	3	Nanotechnology	133	School	12 ST
	Israel	10	Nanotechnology (8) Carbohydrates in breastmilk (1) Plastic Pollution in Oceans (1)	265	School (8) Science Museum (2)	9 ST
		218	**Nanotechnology (131) Plastic Pollution in Oceans (32) Carbohydrates in breast milk (21) Climate change (13) Oceanography (7) Polar Science (7) Climate Geoengineering (6) Extension of Portuguese Continental Shelf (1)**	**7340**	**School (139) Science Centre/Museum (70) University (3) Other (5)**	**439 ST || 21 NST**

Regarding the type of exhibition, and also taking into account the interactivity scenarios presented in the IRRESISTIBLE Exhibition Development Guide that was used by all partners, a great variety of artefacts were produced. Some exhibitions were more homogeneous concerning the type of artefacts; others more eclectic. **Table 35** presents the results regarding the type of artefacts produced in the 218 exhibitions, and **table 36** indicates the top 5.

Table 35 – Occurrences of types of artefacts within the 218 exhibitions.

Type of Artifact		Number of exhibitions with this type of artefact	% of exhibitions with this type of artefact
Game	Physical (e.g., cardboard, soccertable)	66	38
	Digital (e.g., quizzes)	14	8
Poster	Physical	67	39
	Physical but 3D (cubes, objects...)	37	22
	Digital	13	8
Multimedia presentations (e.g., videos, audio)		37	22
Web-integrated exhibit /website/Blog		10	6
Cartoons (digital or printed)		6	3
Models		32	19
Experiments/demonstrations/simulations		32	19
Digital application		3	2
Newspaper		1	1
Book		6	3
Play		1	1
Hologram		1	1
Prototype		1	1
IKEA bookshelf (EXPOneer system)		31	18

Table 36 – The top 5 type of IRRESISTIBLE exhibitions' artefacts.

Type	% ocurrence
Poster (physical)	**39**
Game (physical)	**38**
Poster (physical but 3D)	**22**
Multimedia presentations	**22**
Models	**19**

As we can see in **table 36**, the prevalence of posters, games, multimedia presentations and models as the main types of artefacts presented within the exhibitions is clear. The most frequent type of artefact produced within the IRRESISTIBLE exhibitions was the

poster (on its physical format – 2D and also 3D). When we think of a poster, what comes into our minds is something static, that does not imply the manipulation by the reader, full of text, with some images – thinking of a poster as something *interactive* is, perhaps, a hard task. Nevertheless, with the help of the IRRESISTIBLE Exhibitions Development Guide in combination with students' remarkable creativity, the posters developed within the IRRESISTIBLE exhibitions were, indeed, interactive and fulfilled the goal of actively engaging the visitors. Indeed, these posters assumed several formats and required from the visitor different responses.

The option for developing **physical games** was chosen by many students and teachers involved in the development of the interactive exhibitions. Indeed, games can be a very powerful strategy for stimulating the participation of visitors, allowing for their interaction and creating an atmosphere where the discussion and reflection about important issues can be accomplished in a more playful manner.

The option for developing **multimedia presentations**, such as videos or other presentations was another option chosen by students and teachers involved in the Project. Although this type of artefacts requires a device (PC screen, tablet or other) for its visualization (and that may not be a valid option for some schools), their development is normally felt by students as a very enjoyable task, contributing to their motivation towards the exhibition production.

The development of **models** was another popular option for some students and teachers especially when their exhibitions concerned physical and chemical concepts and phenomena.

As seen from these results, the development of truly engaging and interactive scientific exhibitions can be successfully achieved with simple resources and everyday school materials. All it takes is some imagination!

6. INTEGRATING RESPONSIBILE RESEARCH AND INNOVATION IN THE PROCESS OF EXHIBITION DEVELOPMENT

These results are based on the answers to the questionnaire sent to all partners in September 2016 and also on the answers partners gave on the focus group during the final meeting of the project, in Kiel. In Kiel, we asked all partners to indicate 5 potentialities and 5 difficulties of the integration of RRI in the process of exhibition development. We also asked them to reflect on ways of improving that integration. We gathered answers from 11 partners.

6.1. Potentialities

One of the goals of the IRRESISTIBLE was to involve students, teachers and the public in the process of Responsible Research and Innovation. For this to happen, the exhibitions developed by students had to integrate the aspects of RRI that were more relevant to the researched scientific topic. Even though this integration was not an easy task, all partners found potentialities in it (**table 37**).

Table 37 - Potentialities in the integration of RRI on the process of exhibition development (N=11)

Opportunity for students and teachers to consider social and global problems not normally included in science classes	**10**
Promotes students' and teachers' engagement and motivation for learning about RRI	**5**
It allows for a better/deeper understanding of RRI	**5**
It represents an opportunity for students to develop an active role on exchanging information about RRI with visitors	**3**
It represents an assessment strategy of teaching and learning RRI	**3**
Opportunity to promote the public awareness on RRI	**3**
It represents an opportunity for students to consider and use new methods and techniques in order to engage the public with their exhibition	**2**
Helps students and teachers to change their attitudes towards RRI	**1**
The appeal of topics can promote the involvement of parents in the exhibition development process	**1**

The majority of partners agreed that the integration of RRI in the process of exhibition development creates an **opportunity for students, and also teachers, to take into account global problems that are not normally included in science classes**. The IRRESISTIBLE Project had as one of its premises that the topics of the teaching modules had to be featured in the science curriculums of the partner countries. However, by exploring them with the lenses of Responsible Research and Innovation, students and teachers were able to *rediscover* these, more or less familiar topics, from a new, more global and social perspective. This happens because RRI urges students and teachers to think and consider other features of the scientific problem being researched. By having the task of developing an exhibition that expresses the integration of RRI into a scientific topic, **students and teachers became more interested in learning about RRI**, and this happens also because of the central role that students take (and that is new for most of them) related to the task of **creating something that will be shared with others as a means to create awareness on a topic that has global implications for society**.

> *The students realized that physics and chemistry are not just studying and doing exercises but have also a vital role in society and this fascinated them. They were deeply involved in the construction of exhibits because it triggered their creativity and allowed them to go out and talk about science and RRI to a general public. For that reason the exhibits were important in emphasizing the social value of this project. (Italy, UNIBO)*

> *Integrating RRI contents and constructing an exhibition in the classes gave a social meaning to learning science. Discussing RRI in the context of exhibition development makes the students naturally think about public engagement in science & technology. (Finland)*

> *Made the teachers more excited about teaching the science class (the student teachers and teachers at elementary schools in Finland are "all-round" teachers i.e. they teach all subjects, not only science). The application of science in solving a big issue was seen as more interesting than their typical image of science class or exhibit, and this gave the project extra thrust. (Finland)*

As a result of having to integrate Responsible Research and Innovation into the exhibition – hence, creating something that expresses the interconnections of a particular theme of science and society – **students and teachers also improved their understanding of RRI**.

> *The most important outcome is that both teachers and students were able to increase the understanding of RRI aspects as a result of the project. (Greece)*

Some partners highlighted the fact that the task of having to create an exhibition that integrates RRI represented an **opportunity for the assessment of what students had learned about RRI and also the effectiveness of teaching RRI**.

> *Possibility to use the exhibits as formative assessment – how much RRI ideas did the students understand, what did they see as important points to be put on the posters / products? (Finland)*

By having to develop an interactive exhibition, students were forced to think about strategies that promote the engagement of the audience with the objects and also stimulates visitors' interactions between themselves. For some partners, **the inclusion of RRI helps students to develop more interactive exhibitions and stimulates their creativity in order to promote public engagement**.

> *[The integration of RRI] gave the exhibits more interactivity. Typically, the RRI ideas were posed as questions to the audience. The "fact content" was just telling things at the audience, but the audience was expected to participate in thinking about the RRI questions. This in turn made the students think about how others would view the exhibit and how they should*

present things to make it interesting to other people, what kind of ideas or questions to share. (Finland)

6.2. Limitations

Although the potentialities of the integration of RRI in the process of exhibition development were convincing, partners also found some limitations in this (**table 38**).

Table 38 - Difficulties on the integration of RRI in the process of exhibition development (N=11)

Integrating all RRI dimensions…	
…due to lack of knowledge about RRI	**7**
…due to the fact that some dimensions were more relevant for the topic/students	**5**
Novelty of topic and tasks makes it hard for teachers to support students	**8**
Express the knowledge on RRI through an exhibition since it's an abstract concept	**5**
Novelty of the concepts makes it hard to understand them	**4**
Understand the relevance of also exhibiting RRI, apart from the science	**3**
Lack of teachers' explicitly directions on the integration of RRI	**1**

One major aspect – understood as a difficulty when trying to integrate RRI in exhibitions – had to do with the support that teachers could give to their students. We cannot forget that not only the RRI topic was new to students, as also was the task of having to plan and develop an interactive exhibition to be presented to an audience. That is why the support of teachers is crucial – but also for them, these are novelties. Without proper support from teachers – in highlighting the relevance of RRI in connection with science, and in helping the development of the exhibition – students will certainly feel lost and run into problems in the more demanding tasks, **creating exhibitions more centred in science facts, and less in RRI features**.

However, the integration of RRI aspects into the exhibits was proved problematic again, even though it was much improved from the 1st round. The science education was the main aspect of RRI that was obvious in all exhibits. Generally, better uptake of the RRI approach is required in the exhibits development process. Other important constraint was that teachers were not familiar with RRI aspects in teaching; therefore, students faced difficulty in integrating all RRI aspects in their exhibits. (Greece)

Proper support from teachers begins with the work in the classroom – if teachers don't find any potentialities or relevance in bringing RRI into their science classes, or if their approach is merely superficial and brief, students will certainly not value RRI or make an effort to integrate it in their exhibition.

In terms of RRI we had some problems creating enough RRI relevance for the teacher so they would stress them when teaching and thus deeply anchor them in class – with the consequence that the six RRI dimensions are hardly visible in the exhibitions. Although the RRI issues were discussed in each class (to a different extent), only one class explicitly presented the aspects in the exhibition, several others at least described some of the RRI problems and named examples. (Germany, IPN)

Students often did not understand the finer points about RRI ideas or all RRI ideas (possibly in turn because the teachers did not have equally good grasp on all of them). At any rate some were fairly difficult concepts for 10-11 year olds. (Finland)

Teachers or students sometimes felt the RRI ideas should not appear on a SCIENTIFIC poster, and left them out of any visible products, even though they were discussed and contemplated in class. (Finland)

To most teachers, RRI did not seem that important and some of them 'just left out' the chapter about RRI. This was maybe partly caused by a lack of instruction about the importance of RRI for the modules. We tried to organize a number of sessions about that for teachers, but due to the voluntary nature of those sessions, almost no teachers signed up. (The Netherlands)

6.3. What changed between CoL1 and CoL2?

Taking into account the integration of RRI in the process of exhibition development, partners were asked to think about what had changed between the 1st and the 2nd CoLs. Answers were quite diverse. For some, the expertise of science educators on RRI in the 2nd round allowed (a) for more explicit instructions for teachers to implement the integration of RRI in the exhibitions, and (b) for better guidance when discussing RRI topics with teachers.

Due to the fact that the 1st CoL was especially focused on developing teaching materials, and the 2nd CoL on testing them, some partners considered that the 2nd CoL had more time to address and discuss RRI aspects. However, other partners considered that the module development task created better opportunities to discuss RRI. Therefore, for them, 1st CoL teachers were better able to guide students than 2nd CoL teachers, because they were able to spend more time discussing its integration in the topic.

Another major distinction between rounds was the greater diversity of topics/modules to be tested in the 2nd round. For some partners that made easier the integration of RRI in the exhibitions: a) the new topics were more suitable for exploring the several RRI dimensions, or b) the new modules had clearer instructions on the integration of RRI.

Finally, and considering teachers who tested modules on both rounds, some partners expressed that these *more experienced* teachers were, on the 2nd round, more confident on the potentialities of the strategy to enhance students' knowledge and motivation to learn science, and felt more confident on how to address RRI in their classes.

6.4. Strategies for improvement

Taking into account the difficulties of integrating RRI into the student-curated exhibitions, we asked partners to think about possible strategies for improving this integration.

For some, it might be important to clearly **define the target group** of the exhibition, in order to help students thinking about the best approach to engage the audience, and also in the cognitive complexity of the exhibited topics.

Another way to facilitate the integration of RRI in the exhibition involves **creating a positive attitude** towards learning about it. This can be fostered when students are supported to see the role of science and science exhibits in society. To achieve such goals, students could visit more exhibits, and/or think about everyday problems that science could solve.

For other partners, one way to overcome the difficulties inherent to the understanding of RRI may lie in the introduction of this topic **throughout the all project** – and not just in the end of the module – in order for students to better understand and get familiar with it.

It was suggested to create a **special activity** for students, during the initial phase of the exhibition development, consisting in a brainstorming discussion about all the RRI aspects that are connected to their exhibits' content, discussing possible ways to integrate them in the exhibition.

7. FINAL REMARKS

Students enjoyed, felt more motivated to learn and engaged more in the learning process

After the analysis of the 26 case studies, the first conclusion we can draw is that this didactic strategy is something that students appreciated and valued. They enjoyed the idea of developing an interactive exhibition in the context of science classes, they enjoyed the idea of having to be "creative", they faced problems throughout the process but in the end they felt happy. This happened because they played a central and active role in the process of exhibition development. They felt more motivated to learn, and more engaged in the process – because *learning* was recognized as *valuable* for them in order to develop the exhibition' objects, and also because they knew they would have to face an audience and their (unpredictable) questions! Consequently, for them, these science classes and this learning were meaningful – they needed them in order to produce a better exhibition in order to accurately inform their audience. Although students liked the experience, some of them liked it even more because of the opportunity to interact with visitors and seeing in their answers and comments that all their work was worthwhile. Developing an exhibition but not experiencing the contact with the public leads to a less enjoyable experience for students. Nevertheless, there were a few cases where students struggled with their motivation to develop the exhibition. Concerning this lack of motivation, the case studies analysis led us to conclude that it is extremely important to emphasize, from the very onset of the module: (a) the fact that the main goal is to produce a final exhibition, (b) the importance of the exhibition as a way to create awareness on a cutting-edge topic and its social implications, (c) the importance of students' central role in achieving this exhibition, and (d) the importance of developing a better understanding about the exhibition topic, supported by students research and scientific accepted knowledge (and not in common sense) – hence, allowing students to view the module tasks as crucial for building the knowledge necessary to develop their exhibition.

Students learned new scientific topics and RRI while developing important skills

All cases emphasized that with this strategy supported students learning. And what did they learn about? They learned about the scientific topics of the modules, but they also learned about Responsible Research and Innovation. This also happened because students had to create something that represented their knowledge.

However, students didn't just learn about the topics. This strategy also proved to enhance other students' skills. The exhibition development process is a project inside a bigger project. Hence, students were faced with many project management challenges, including those inherent to working in a group. That is why many cases reported that students developed their social skills, their autonomy, and also project management skills – planning, (re)planning, distributing tasks, respect deadlines, account for others opinions, and achieve a consensus, among others. This occurred because students played a very central and active role throughout the process. Students also developed their communication skills – they learned how to better communicate their ideas to their group colleagues, to their class colleagues, and even more importantly, to the public of their exhibitions. Moreover, when facing visitors' questions, students also developed their argumentation skills. Students also improved their critical thinking skills when faced with the need to understand an unknown topic – reading different information sources, selecting relevant information, and organizing that information into something coherent and usable for developing their exhibition. When performing their own scientific experiments and research with the goal of collecting primary data, crucial for a better understanding of the science behind the topic of each module, students also developed important reasoning and experimental skills.

Students overcome their own initial low expectations: they were capable!

There were many cases highlighting that students with lower academic performances – in the context of traditional science classes – participating in the project developed important skills. This came as a surprise for the teachers at the end of the process. There were many cases emphasizing that students felt anxious in the beginning of the project: concerned that they would not be able to accomplish this new challenge. For them – at least for the large majority – it was the first time they were faced with the task of having to develop an exhibition, with the special characteristic of being *interactive* and also focusing on cutting-edge topics on RRI. Students are not used to being on the stage and playing a central role in their (science) classes/in their academic lives. It is perhaps safer and convenient for them to delegate in the teacher the responsibility for their learning. On the other hand, when they feel responsible, they start to doubt their abilities. This happens also with teachers regarding their own students. Even the ones that embraced the project had their doubts – but in the end, and after seeing the results and students' performances, they recognized that it was worthy to take up this challenge and believe in students' abilities. This also happened with students. The feeling of accomplishment that some have reported during the interviews revealed that they were proud of their work and also that the required effort was worthwhile. *This is amazing!* Because of this experience, students learned a life-lesson: even when we don't feel capable, we have to try! But one thing is certain: teacher support was crucial. Although this strategy was new for the vast majority of teachers, they demonstrated their ability to support students during the process – even though some also doubted their own abilities. Therefore, not only students revealed being capable, but also teachers. All it took was the courage to try something different.

Students' difficulties…

The task of developing an interactive exhibition focused on cutting-edge scientific topics on RRI was a novelty for students. For some, this task was, in fact a four-in-one novelty: a) develop an exhibition; b) the exhibition had to be interactive; c) the exhibition had to focus on cutting-edge scientific topics; d) RRI had to be integrated with the scientific content. It comes with no surprise that students faced difficulties. It was difficult to plan the exhibition, it was a challenge to manage all the sub-tasks implied in its development, it was not easy to work in groups, and it was definitely not easy to integrate RRI features in the exhibition. As for the **project management tasks** – planning and constructing the exhibitions –teacher support was crucial. It was important to let students experience those difficulties in order for them to learn on how to overcome them – and if not in this project, in the next one! But one thing is certain: although many students highlighted group work and project management as their main difficulties, they also pointed out that those were important learning achievements. As for the **integration of RRI in the exhibition**, we can conclude that a better RRI-Science integration in the classroom leads to a better integration of RRI-Science in the exhibition. A better integration in the classroom depends, of course, on the module and its tasks, but also on the relevance attributed by teachers to this domain. Some modules expressed a better integration of RRI from the very beginning of the tasks; others left the RRI part to the end. But all included this topic. Of course we cannot force teachers to address RRI issues in their classes – there were, actually, cases, where due to the shortage of time, teachers chose not to include this topic in their classes. Perhaps if they saw it with more relevance, they wouldn't choose to leave it aside. Even more, if teachers don't see the relevance of teaching about RRI, and don't value this topic, neither will their students – hence, developing exhibitions where RRI is not present at all. Even when teachers address RRI in their classes, *how* they do it influences the way students manage to integrate it in the exhibition – if treated as a subject apart from the scientific topic, students will struggle to integrate RRI in their exhibition objects. The analysis of the cases allowed us to understand that there were different approaches when teaching RRI – some that included discussion sessions focused on the problems and connections between Science and RRI; and others on role-play activities where students enacted different actors with different agendas, leading to better results. One other important aspect has to do with the *implicit/explicit* way that RRI is approached in classroom. The best way is to include both approaches – approaching it only in an implicit way may let it pass unnoticed to students; and only in an explicit way may lead to situations where RRI is shown separated from Science. This last situation was, indeed, very frequently reported in the case studies: students were able to include RRI in the exhibition, but in a somewhat *artificial* manner, very much segregated from the "main" exhibition focused on the Science. Consequently, we believe that the way RRI was presented in the exhibitions has a lot to do with the way RRI was approached in the classroom, and this, in turn, has a lot to do with the way teachers see RRI and the relevance they give it in the context of Science Education.

It proved to be a great opportunity to involve (and educate) the community allowing students to understand (and develop) their active role as citizens

The goal of IRRESISTIBLE is to involve teachers, students and the public in the process of RRI. It's easy to see that the involvement of teachers and students happens when they use the modules and develop their tasks: all modules focus on cutting-edge scientific topics under the lenses of RRI. But what about public interest and participation? This happens when the exhibition developed by students (with the support of teachers) reached the communities. When other students, teachers, school staff, parents, friends and a wider audience visited the exhibitions and contacted – and interacted – with the objects that students developed. By visiting students' exhibitions, and by asking questions and listening to students' answers, and by playing students' games, visitors ended up learning (more) about cutting-edge scientific topics and RRI. We are pretty sure that by the end of this process, students know more about Climate Geoengineering, Nanotechnology and Carbohydrates in Breast Milk (just to mention a few topics) than the average citizen. And because they do so, they are in the right position to share with others what they have learned – with the aim of educating them. The development of the IRRESISTIBLE exhibitions had, for some of the partners, also the significance of allowing students to understand that they *can* and *must* have an important role in society. They are citizens – not just *future citizens* – and that means that they can act *now* (not just in the future), trying to understand some of our societal problems, and helping in solving them. The development of the IRRESISTIBLE exhibitions, understood under this perspective, is a more meaningful process to students: they feel useful, they feel that what they learn is useful, and they see School and Science Education as useful too. Therefore, the development of exhibitions – under these lenses – promotes active participation of the community and also for the development of students' active citizenship skills. These are key skills that they will need throughout their lives – the sooner they start developing them, the better.

Teachers enjoyed and saw great potential in this didactic strategy

Just like their students, teachers embraced this challenge with fears. "What if I cannot help my students?", "What if I don't know the answer to their questions?", "What is RRI?", "How to approach RRI?", "What is an interactive exhibition?", "What if I don't have time for other curricular topics and activities?", "What if students aren't capable?", "What if this is too much for me and for them?", "How can I evaluate their learning?". Those were, certainly, questions that popped up in teachers' minds at the onset and during the process of module testing and exhibition development. But by experiencing this didactic strategy, teachers reported not only their personal satisfaction – it was very enjoyable for them –, but also several potentialities after putting it to practice. Teachers realized that (a) students' motivation towards learning increases, (b) students learn the content better, (c) students develop important skills that would, otherwise, not have the opportunity to develop, (d) by using the process of exhibition development and the exhibition itself as a product of this process, it is possible to evaluate students learning achievements, and (d) the relational atmosphere between students, and between students and teachers improves.

Teachers overcome their initial lows expectations towards students' capabilities: all it took was to try it at least once!

Many teachers reported that, in the beginning, they were not very trustful of their students' abilities – specially those students with lower academic achievements. But when confronted with students' performance throughout the process, teachers realized they were wrong, and that it is quite productive to place students in a central and active role in Science Classes. What end up happening was that students revealed being able to learn and to plan, develop and build amazing exhibitions, using their extremely creative skills – which are usually set aside in the context of Science Classes. This detail is remarkably important. By having the opportunity for being creative and developing something on their own, students felt more motivated to achieve it successfully.

Teachers' difficulties…

Even though not all teachers reported difficulties, many did. That should be expected whenever trying to implement new didactic strategies in the classroom. Not only teachers have to deal with their students' struggles, but also with their own difficulties – inherent to teaching new topics and managing processes which they don't know how much time will take, what tasks are necessary and which ones are more time-consuming, how to support students and how to anticipate their difficulties when everything is new. Managing time was the greatest challenge. Indeed, the several tasks of developing the exhibition are very time consuming – planning was, perhaps, the task in which students spent more time. Additionally, as in any project, there were setbacks that forced students to think in alternative routes, and that takes up time. For this reason, several teachers chose to develop the objects building phase outside the classroom – that can be a good strategy as long as students regularly report on their progress.

Teachers grew as professionals

This project was a challenge to all – students, teachers, cooperating experts, and Science Education researchers. Nonetheless, as with many other challenges, it was a great opportunity to learn, develop new skills, and grow on a personal and professional level. Some teachers did report that the participation in the IRRESISTIBLE project made them rethink some characteristics of their practice – valuing inquiry based learning approaches; using the "less known and less comfortable" areas of the curriculum; encouraging students to develop projects in which they assume a central and active role, using exhibitions developed by students as a strategy for them to learn more about Science, Society and active Citizenship; and using innovative strategies to bridge the gap between School and Society.

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