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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

Deliverable reference number: D3.1

Deliverable title: Different exhibitions

Different interactive exhibitions on Responsible Research and Innovation (related with cutting edge scientific and technological issues), written in each partners language

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Executive summary

During the IRRESISTIBLE Project, more specifically, under its Work Package 3, groups of teachers and students will be 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. Through the process of exhibition development, 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 task of interactive exhibition development poses a novelty for many teachers (and, consequentely, their students) in many different levels: a) what is an *interactive exhibition*?, b) what are the potentialities of having students developing their own exhibitions?, c) what are the steps for building an exhibition?, d) how can the objects produced estimulate the interaction between visitors?, e) how can teachers and students evaluate the process of exhibition development?

In order to help science teachers from each CoL and answer these questions, we have developed a Guide aimed at helping in the process of interactive exhibition development. The development of this Guide followed a Design-Based Research approach, with several iterations, which allowed the refinement of its content in order to better suit the purpose of being an helpful tool throughout the process of IRRESISTIBLE exhibit development.

Deliverable 3.1 has the purpose of:

a) Describe the process of Guide development;
b) Present, and reflect on, the final results from the evaluation made by IRRESISTIBLE partners regarding the usefulness of the Guide, its potentialities and limitations, and, from there, suggestions of improvement;
c) Present the Guide, on its latest version;
d) Describe and characterize, globally, the set of exhibitions developed within the first phase of the Project;
e) Present and reflect on the evaluation made by IRRESISTIBLE partners regarding the positive and negative aspects of their exhibitions and regarding the integration of RRI in them.
f) Present improvement suggestions regarding the process of exhibition development.

The Guide has proven to be useful to all partners, being an helpful tool for both science educators, in the process of CoL teachers' guidance, and for science teachers, that work in

the ground and face the direct challenges of guiding students in developing interactive scientific exhibitions.

The exhibitions developed within the Phase 1 of the Project, and the feedback from the partners, have revealed the potentialities and also the limitations inherent to the process of having students developing interactive exhibitions on Responsible Research and Innovation.

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1. INTRODUCTION

The goal of the project IRRESISTIBLE is to design activities that foster the involvement of students and the public in the process of Responsible Research and Innovation (RRI). Each partner CoL develops one teaching module that implies the development of exhibitions addressing the concept of Responsible Research and Innovation. The process of exhibition development falls under the Exchange phase of the IBSE 6E model approach followed by the Project. Through this phase it is intended that students communicate and *exchange* to a wider audience the knowledge they have built during the previous phases of the model (Engage, Explore, Explain, Extend/Elaborate), hence, exchanging their fundamented-in-research opinions regarding the specific scientific issue under study. Although the IRRESISTIBLE approach relies on the extended 5E model, adding the extra step of Exchange, which makes it in fact a 6E model, for the Portuguese partner the Exchange phase is in close relation to another extra *E*, the *Empowerment* phase. Indeed, we believe that the opportunity of having students *speaking out loud* their fundamented-in-research thoughts through the development of an exhibition aimed at the general public is in close relation to their active citizenship rights and duties. In fact, most young students do not see themselves as *citizens* by the simple fact that they cannot vote. Their participation in the IRRESISTIBLE Project constitutes an excellent opportunity to develop their empowerment and their active citizenship skills, aiming also at developing the notion that their action can be as valid as another social actor action as long as it is research-based.

One of the advantages of both producing and presenting an exhibition is that it draws upon the facets of IBSE: in producing an exhibition pupils can re-present 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 exhibition to raise questions they become learners with their visitors. Encouraging students to research their own interests under the guidance of a teacher develops skills of formulating questions, collaboration and observation (Sleeper and Sterling, 2004).

During these exhibitions' preparation, learners will ask questions, use logic and evidence in formulating and revising scientific explanations, recognizing and analyzing alternative explanations, and communicate scientific arguments. Through the construction and presentation of exhibits on Responsible Research and Innovation both teachers and students are introduced to a different type of science from the one that is usually presented in science classes. Most of the 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).

Having in mind the novelty of exhibition development for the majority of CoLs, we developed a Guide with the purpose of giving all partners a basis, within a theoretical framework, for working with each CoL the process of exhibition development. The effort to make available a prototype of the Guide as soon as May 2014 was to allow each partner to integrate its content in the first CoL phase, starting, for the majority, in September 2014.

For the Guide development, first we revised on the potential of having students developing scientific exhibitions on cutting-edge topics; next, the concept of interactivity within museums and science centres was revised in order to clarify the characteristics of an interactive exhibition and, also, of an interactive object. Next, we focused on how to achieve, within the context of an exhibition, a satisfactory level of interactivity (i.e., interaction between visitors and between visitors and objects), giving the reader some suggestions on how to design interactive objects. Next, our major concern was to give examples or scenarios of interactivity for partners and their CoL teachers to get inspired on; at the same time the scenarios allowed the demystification of what was intended with "an interactive exhibition" within the framework of IRRESISTIBLE.

The content of this Guide was explored in the Lisbon workshop (October 2014) and some real examples of scenarios were made available for the participants to experience and assess their potentialities and limitations. After the Lisbon Workshop, the Guide received the contributions of other IRRESISTIBLE partners, whom contributed to enrich the possibilities of scenarios and, also to alert for the importance of texts in exhibitions. From there, the Guide assumed its complete version and was ready to be shared and used by all partners and their CoL's.

Within the first phase of the Project, more precisely during the school year 2014/2015, there were developed a total of 32 exhibitions involving almost 2000 students. Given the fact that the Guide was created in order to act as a tool, helping within the process of exhibition development, and taking into account that each partner has developed at least one exhibition in the first round, we wanted to understand the type of use that each one has made of the Guide. Also, we wanted to receive feedback regarding its potentialities, limitations and suggestions of improvement. With those purposes, we developed a questionnaire that was sent to all partners after the first round, in January 2016. The results allowed us to conclude and reflect about the usefulness of the Guide, not only under the IRRESISTIBLE project, but in the future.

In order to collect data regarding the exhibitions that each partner developed within the Project Phase 1, we developed a questionnaire in which we asked each partner to characterize their exhibitions, and to reflect on the positive and negative aspects of them. The analysis of the answers to this questionnaire, sent to all partners in October 2015, allowed us to reflect on the potentialities and limitations of the developed IRRESISTIBLE exhibitions and, from there, to suggest some improvements regarding the Phase 2 of the Project.

2. IRRESISTIBLE EXHIBITIONS: A DEVELOPMENT GUIDE

2.1. The process of Guide development: following a Design-Based Research approach

Back in January 2014, when we started the process of Guide development, we had clear in our minds that we wanted to develop a tool that could help each partner in the task of developing an interactive scientific exhibition on cutting-edge topics. For some, if not for all, this task was a novelty. But it also was a major stepstone for the IRRESISTIBLE Project. Hence, the urgency of having a Guide that could help readers to (a) better understand the potentialities of having students planning and developing exhibitions on RRI, (b) to better understand the concept of interactive exhibit and how to operacionalize it, (c) see the possibilities of interactivity scenarios, and, finally (d) assess the impact of the exhibitions in students, teachers and visitors.

Within the task of developing the Guide, we followed a Design-Based Research approach given the fact that we used a methodology aimed at developing a tool that could, itself, help at improving educational practices, through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings (Wang & Hannafin, 2005). Along this process there were several iterations, which conducted, from a prototype, to the final version of the Guide (figure 1).

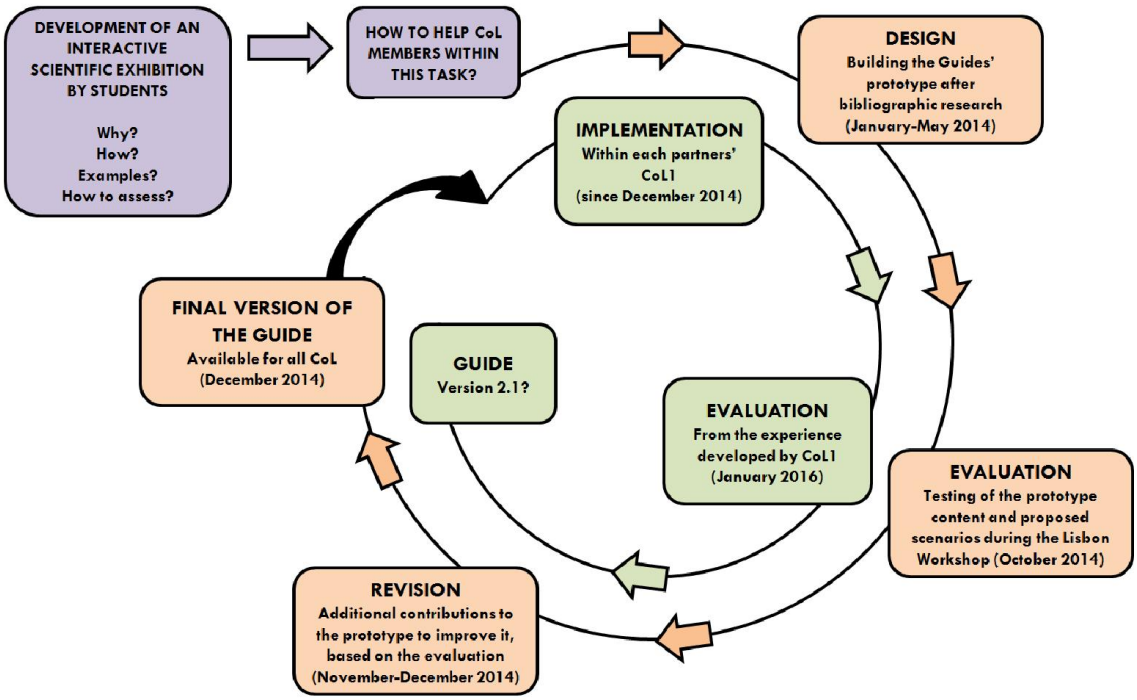


Figure 1 – The Design-Based Research approach in the process of Guide development.

2.1.1. Bibliographic research

When planning the Guides' content, it was clear to us that there should be two distinct parts: a) one, more theorethical, aimed at frameworking the concept of interactivity and interactive exhibition, and the potentialities of its development by students; b) and a second one, more practical, showing some different scenarios as a way to materialize the so desired "interactivity".

From January 2014 until March 2014 we dedicated at revising several publications from authors that develop their research in the field of informal science education, communication of science, museology and development of scientific exhibits in the context of science centres. The goal was to clarify the concept of *interactivity*, which we considered essential in the context of the development of IRRESISTIBLE exhibitions, and also the concept of *interactive exhibition*. The research brought to light a concept of interactivity that does not, necessarily, require the presence of technology, but, instead, does necessarily require the interaction between the visitors within the exhibit and between them and the objects that are being exposed. Neither this interaction require any physical movement – we can be in the presence of an interaction between the visitor and the object, even if the visitor is *only* thinking and reflecting on the stimulus from the object.

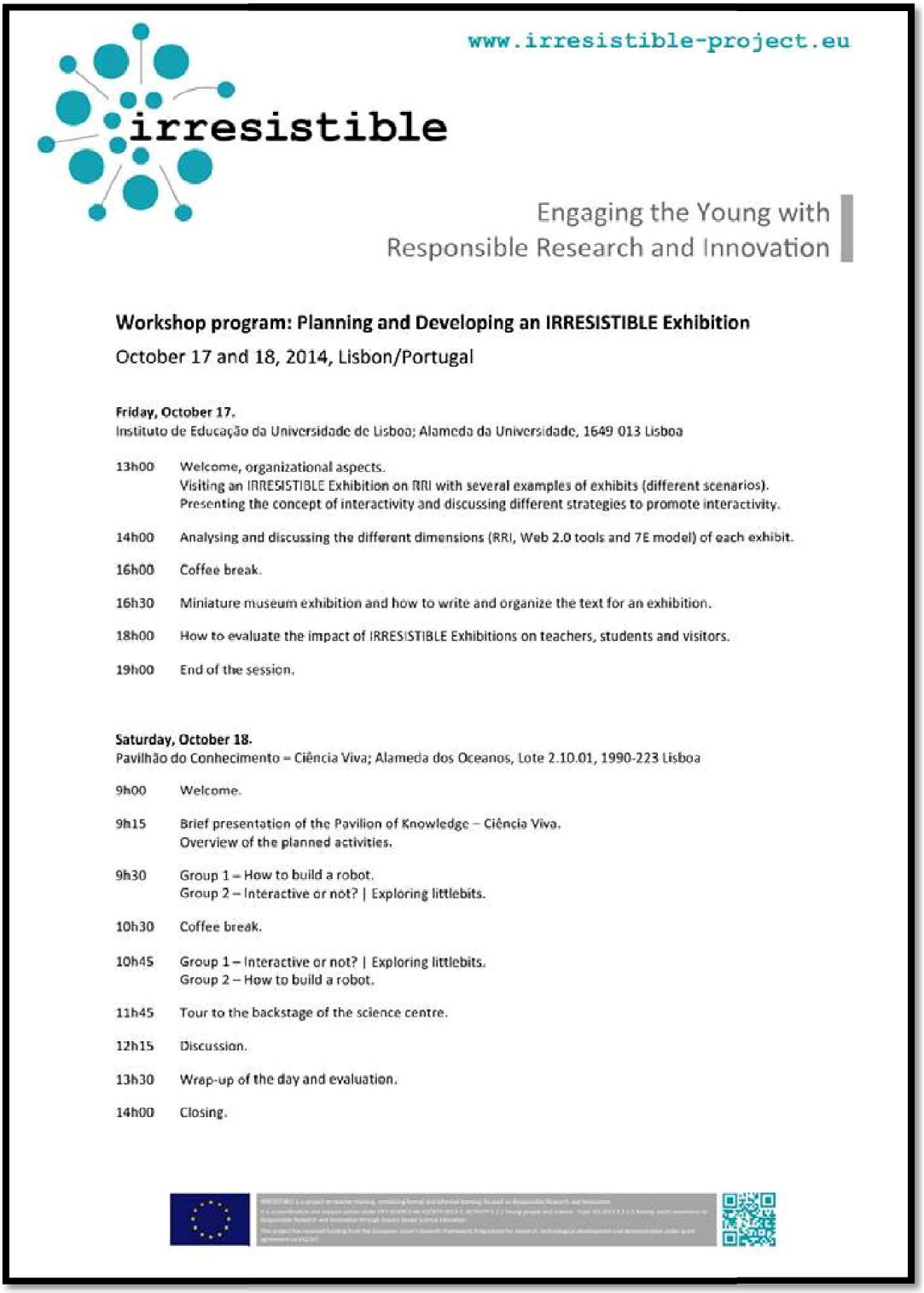
Along with the chapters on interactivity and interactive exhibitions, we added a chapter that already had served as framework for WP3, dedicated to explore and discuss the potentialities of having students planning and developing scientific exhibits on RRI topics. To us, this is also a crucial information that has the purpose of clarifying, not only but also, science teachers and give them the support to carry on with the decision of commitment to a project of this nature.

Along with the research, we started to write down the first version of the Guide – in its prototype format, which we finalized in May 2014. At that time, after uploading to the IRRESISTIBLE Dropbox folder, we shared with all IRRESISTIBLE partners – through an e-mail - in order to get their feedback and suggestions of improvement. After gathering all the feedback, we proceed to some changes of the initial Guide, adding to it a section on how to create an exhibition "Creating an Exhibit", focused on the three phases (D'Acquisto, 2006) of exhibit development.

2.1.2.The Lisbon Workshop: testing and evaluation of the prototype

The Lisbon Workshop "Planning and Developing an IRRESISTIBLE Exhibition" was hold in the Education Institute of Lisbon University, in the 17th and 18th of October 2014. This event had the purpose of gathering science educators, science teachers and experts from

science museums and presenting and discussing some ideas about how to plan, develop and evaluate an IRRESISTIBLE exhibition on Responsible Rserach and Innovation (figure 2). It also had the purpose of testing the content of the Guide, since the planning and concretization of the workshop was, also, based on it.



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Engaging the Young with
Responsible Research and Innovation

Workshop program: Planning and Developing an IRRESISTIBLE Exhibition

October 17 and 18, 2014, Lisbon/Portugal

Friday, October 17.
Instituto de Educação da Universidade de Lisboa; Alameda da Universidade, 1649 013 Lisboa

13h00 Welcome, organizational aspects.
Visiting an IRRESISTIBLE Exhibition on RRI with several examples of exhibits (different scenarios).
Presenting the concept of interactivity and discussing different strategies to promote interactivity.

14h00 Analysing and discussing the different dimensions (RRI, Web 2.0 tools and 7E model) of each exhibit.

16h00 Coffee break.

16h30 Miniature museum exhibition and how to write and organize the text for an exhibition.

18h00 How to evaluate the impact of IRRESISTIBLE Exhibitions on teachers, students and visitors.

19h00 End of the session.

Saturday, October 18.
Pavilhão do Conhecimento – Ciência Viva; Alameda dos Oceanos, Lote 2.10.01, 1990-223 Lisboa

9h00 Welcome.

9h15 Brief presentation of the Pavilion of Knowledge – Ciência Viva.
Overview of the planned activities.

9h30 Group 1 – How to build a robot.
Group 2 – Interactive or not? | Exploring littlebits.

10h30 Coffee break.

10h45 Group 1 – Interactive or not? | Exploring littlebits.
Group 2 – How to build a robot.

11h45 Tour to the backstage of the science centre.

12h15 Discussion.

13h30 Wrap-up of the day and evaluation.

14h00 Closing.

Figure 2 – The oficial program for the Lisbon workshop.

When planning this event it was clear to us that it was necessary to let the participants experience the more or less interactive scenarios proposed in the Guide. Therefore, we prepared different objects and, for the physical ones, placed them on the room of the Workshop, allowing the participants to place themselves in the role of visitors and also in the role of critics (figures 3-7). There were also digital versions of some of the objects that were tested by the participants. At the end of this testing session there was a moment of discussion on the positive and negative aspects of each object/scenario, and also its potentialities and limitations. The feedback from the participants was very positive, which indicated that the Guide was on the right path.

Figure 3 – The Lisbon Workshop participants.

Figure 4 – Testing of the interactivity scenarios at the workshop.

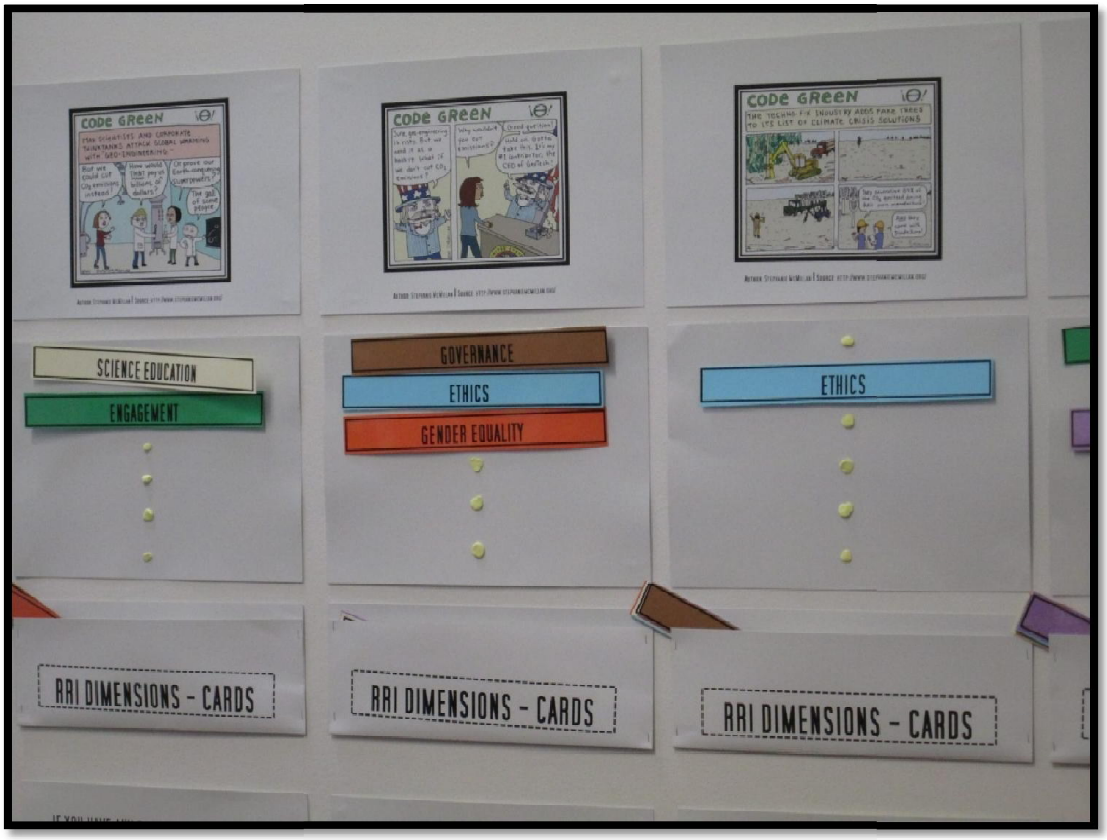


Figure 5 – The “Comics and RRI” scenario.

Figure 6 – The dices from the “Dice Game” scenario.

Figure 7 – Participants testing the digital objects.

Along with the practical part of the workshop, we prepared a presentation of the more theoretical aspects of the Guide (figure 8).

Figure 8 – Parts of the Lisbon Workshop presentation of the Guide content.

2.1.3.From prototype to a final version to be used by CoL teachers

After the Lisbon Workshop, and following the fedback given by the participants, and also following the contributions of some of the IRRESISTIBLE partners, the Guide grew up. And

its final 46 pages .pdf english version was oficial shared with every partner, and uploaded in the IRRESISTIBLE Dropbox folder. This was the version intended to be shared within each CoL and used by its science teachers when testing the IRRESISTIBLE teaching modules in Phase1 of the Project.

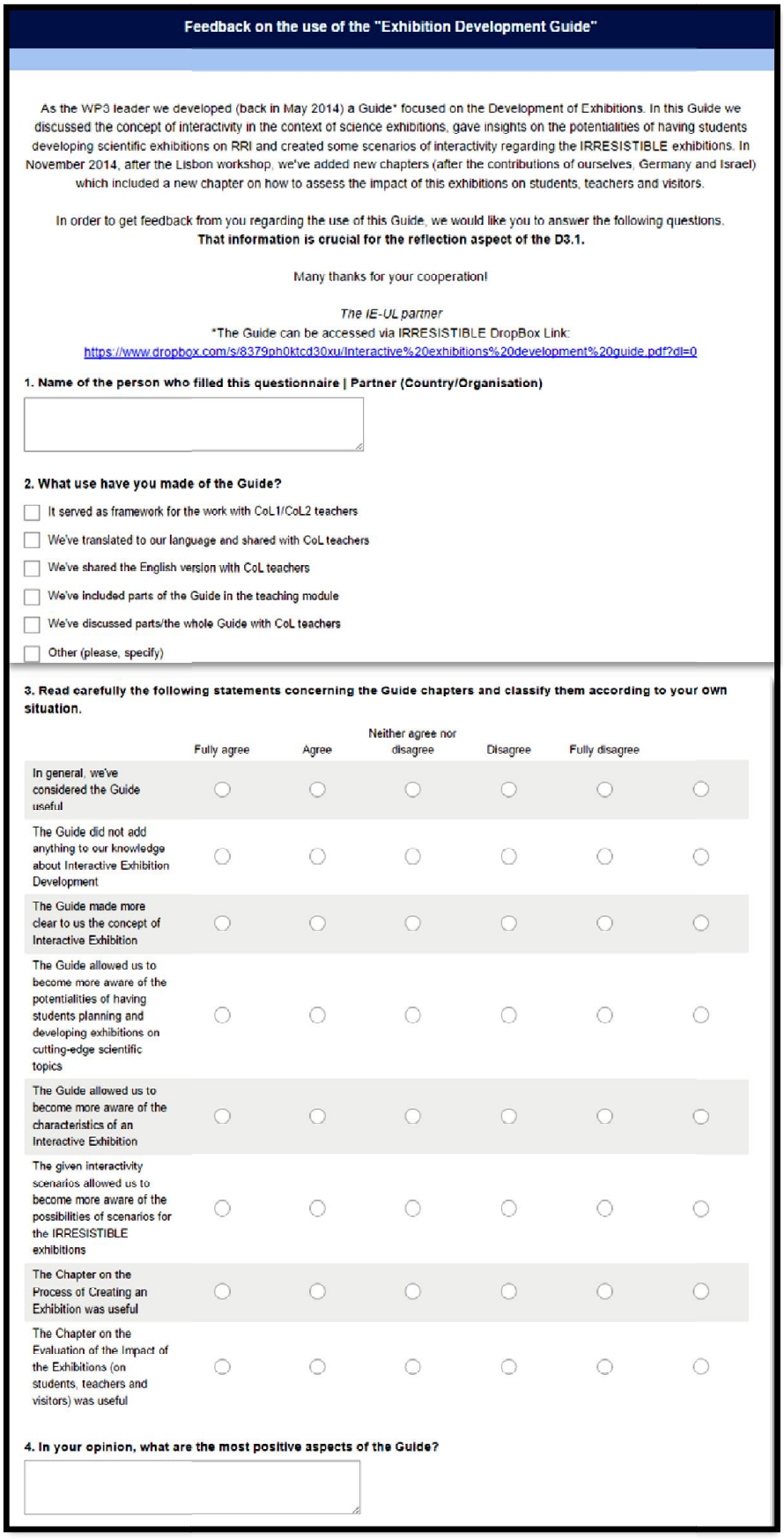
Figure 9 – Cover and first page of the final version of the Guide "IRRESISTIBLE Exhibitions: a Development Guide".

2.1.4. Assessment of Guides' usefulness: data collection after Phase1

After the first phase of the Project, it was time to reflect on the usefulness of the Guide according to each CoL1. In order to obtain the necessary data to perform that reflection, we created a non-anonimous online questionnaire composed of five questions: one in a multiple choice-type format, another in a Likert Scale-type format, and three open-ended questions. We then asked all partners to fill in.

With the developed questionnaire we aimed at getting feedback from partners concerning:

a) The use that each partner has made of the Guide (multiple choice question);
b) The appreciation of the distinct parts of the Guide and its usefulness (Likert-type scale question);
c) The most positive aspects of the Guide (open-ended question);
d) The most negative aspects of the Guide (open-ended question);
e) Improvement suggestions (open-ended question);



Feedback on the use of the "Exhibition Development Guide"

As the WP3 leader we developed (back in May 2014) a Guide* focused on the Development of Exhibitions. In this Guide we discussed the concept of interactivity in the context of science exhibitions, gave insights on the potentialities of having students developing scientific exhibitions on RRI and created some scenarios of interactivity regarding the IRRESISTIBLE exhibitions. In November 2014, after the Lisbon workshop, we've added new chapters (after the contributions of ourselves, Germany and Israel) which included a new chapter on how to assess the impact of this exhibitions on students, teachers and visitors.

In order to get feedback from you regarding the use of this Guide, we would like you to answer the following questions.
That information is crucial for the reflection aspect of the D3.1.

Many thanks for your cooperation!

The IE-UL partner
*The Guide can be accessed via IRRESISTIBLE DropBox Link:
https://www.dropbox.com/s/8379ph0ktcd30xu/Interactive%20exhibitions%20development%20guide.pdf?dl=0

1. Name of the person who filled this questionnaire | Partner (Country/Organisation)

2. What use have you made of the Guide?

- It served as framework for the work with CoL1/CoL2 teachers
- We've translated to our language and shared with CoL teachers
- We've shared the English version with CoL teachers
- We've included parts of the Guide in the teaching module
- We've discussed parts/the whole Guide with CoL teachers
- Other (please, specify)

3. Read carefully the following statements concerning the Guide chapters and classify them according to your own situation.

	Fully agree	Agree	Neither agree nor disagree	Disagree	Fully disagree	
In general, we've considered the Guide useful						
The Guide did not add anything to our knowledge about Interactive Exhibition Development						
The Guide made more clear to us the concept of Interactive Exhibition						
The Guide allowed us to become more aware of the potentialities of having students planning and developing exhibitions on cutting-edge scientific topics						
The Guide allowed us to become more aware of the characteristics of an Interactive Exhibition						
The given interactivity scenarios allowed us to become more aware of the possibilities of scenarios for the IRRESISTIBLE exhibitions						
The Chapter on the Process of Creating an Exhibition was useful						
The Chapter on the Evaluation of the Impact of the Exhibitions (on students, teachers and visitors) was useful						

4. In your opinion, what are the most positive aspects of the Guide?

Figure 10 – Screenshots of the questionnaire (https://pt.surveymonkey.com/r/PMD2MRK)

The data collected from the questionnaire was analised and the open-ended questions' answers followed a content-analysis, according to which there were created categories in which the several answers were grouped; then, a quantitive analysis was performed (calculus of absolute and relative frequencies). The answers obtained in multiple-choice and in the Likert-type-scale questions followed a quantitative analysis (calculus of absolute and relative frequencies). On the next section the results are showed.

2.2.Usefulness, potentialities and limitations: reflection on final results

2.2.1. What use have each partner made of the Guide

For the majority of the IRRESISTIBLE partners that answered the questionnaire (N=11), the Guide **served as framework for the work with CoL1 and CoL2 teachers** (64%; n=7). This was, indeed, one of the main purposes of this tool. Within this results, we can say that that one has been accomplished. Some of the partners (55%; n=6) also revealed that they have used the Guide (or, at least some of its parts) in **discussion sessions with CoL teachers**. We believe that is a very powerful strategy of allowing teachers to build knowledge on this particular process.

Although it was not mandatory to translate the Guide to local languages, some of the partners (19%; n=2) did **translated it (or at least, some of its parts) and shared with CoL teachers**. This extra task of translating this document is somewhat important when science teachers do have difficulties in reading English. Therefore, we see it as an important task in order to a more powerful and effective dissemination of this tool within science teachers. Nevertheless, some of the partners (36%; n=4) did **share the English version of the Guide with CoL teachers**.

Another of the purposes of the Guide was to contribute to the development of the teaching modules' phase, allowing the inclusion of parts of its content to better illustrate the Exchange step of the 5E extended model. As a matter of fact, some of the partners (27%; n=3) did **include part of the Guide in their modules**. That is, definitely, another powerful strategy of delivering this content to both teachers and students, in a more light manner.

Other partners (19%; n=2) did use the Guide as a **support for developing workshops and/or presentations**, during specially organised meetings, aimed at clarifying CoL teachers regarding the process of Exhibit Development. For one of the partners the Guide was also useful in terms of **supporting the development of workshops aimed at students**, focused on the process of exhibit construction. For other partner, the Guide also served as the **main guide for the development of the exhibits**.

2.2.2. On the usefulness of the different Guide chapters

In the second question of the questionnaire, we presented eight statements related to different Guide chapters and asked the respondents to classify them according to their own situation. We gave them five answer options: fully agree, agree, neither agree nor disagree, disagree and fully disagree. Table 1 summarizes the results.

Table 1 – Results on the usefulness of Guide' chapters, according to the partners answers.

	Fully Agree	**Agree**	**Neither Agree nor Disagree**	**Disagree**	**Fully Disagree**
In general, we've considered the Guide useful	54,55% 6	45,45% 5	0	0	0
The Guide did not add anything to our knowledge about Interactive Exhibition Development	0	0	0	45,45% 5	54,55% 6
The Guide made more clear to us the concept of Interactive Exhibition	36,36% 4	45,45% 5	18,18% 2	0	0
The Guide allowed us to become more aware of the potentialities of having students planning and developing exhibitions on cutting-edge scientific topics	27,27% 3	63,64% 7	9,09% 1	0	0
The Guide allowed us to become more aware of the characteristics of an Interactive Exhibition	54,55% 6	36,36% 4	9,09% 1	0	0
The given interactivity scenarios allowed us to become more aware of the possibilities of scenarios for the IRRESISTIBLE exhibitions	18,18% 2	54,55% 6	27,27% 3	0	0
The Chapter on the Process of Creating an Exhibition was useful.	36,36% 4	45,45% 5	18,18% 2	0	0
The Chapter on the Evaluation of the Impact of the Exhibitions (on students, teachers and visitors) was useful	54,55% 6	36,36% 4	0	9,09% 1	0

All of the partners have considered the Guide useful, revealing also that it add something to their knowledge about Interactive Exhibition Development. Those were, of course, two of the main goals of developing a document like this one; the answers reveal that they have been completely achieved.

For the majority, the Guide clarified the concept of Interactive Exhibition, with only two partners answering that they neither agree nor disagree. Also for the majority, the Guide allowed them to become more aware of the potentialities of having students planning and developing exhibitions on cutting-edge scientific topics.

When developing this tool, it was also our intention to clarify on the characteristics of an Interactive Exhibition. The answers of the partners revealed that this goal was almost fully achieved, with only one respondent answering that he neither agrees nor disagrees with this aspect.

Regarding the scenarios presented in the Guide, the majority of respondents agreed on the fact that they allowed for them to become more aware of the possibilities of scenarios for the IRRESISTIBLE exhibitions. However, the tendency of answers shows that this majority don't fully agree, but only agree with that statement. Adding this to the fact that three respondents answered that they neither agreed nor disagreed, it shows us that this chapter would benefit of some improvement, as the suggestions made by the respondents in the question #5 pointed out (see section 2.2.5).

The majority of respondents also agreed on the fact that both the Chapters "Creating an Exhibit" and "How to evaluate the impact of IRRESISTIBLE exhibitions on students, teachers and visitors" were useful.

2.2.3. The most positive aspects of the Guide

Regarding the positive aspects mentioned by the partners, there were seventeen mentions, in a total of eleven answers. After an initial content-analysis of the answers, the positive aspects were organised in six categories (table 2).

Table 2 – Positive aspects of the Guide, refered by the partners.

Category	N
Scenarios of Interactivity	6
Chapter on "Creating and Exhibit"	4
Clarity and organisation	2
Literature review	2
Comprehensiveness	1
References	1
TOTAL	**16**

As we can see from table 2, the **scenarios of Interactivity** presented in the Guide were the main aspect highlighted by the partners as a positive aspect, since they were specially useful for teachers and students, ilustrating and claryfying the possibilities of interactive exhibitions and supporting teachers in the process of students' guidance.

> *The most useful parts of the guide were i) the exhibit cenarios that you included and ii) the analytical steps for the exhibits development, as in that way the teachers got a more clear idea of how they could organize the class, support and guide their students to this process. (University of Crete, Greece)*

For us, the presence of the scenarios in the Guide was a priority, given the fact that the development of an interactive exhibition in a school context poses some challenges regarding the novelty of the task, both for students and teachers. Hence, the scenarios were created as exemples of what is intended. Our concern was, at the same time, to create scenarios that can have both a physical and a digital format, in order to deal with the constrains that are present at several schools regarding the use of ICT. If its true that this is not an issue in some school contexts, in others it is a real problem: the lack of computers for students work. Having that in mind, we tried to include options that can be achieved without a permanent availability of computers, hence the physical format options for the objetcts.

Another positive aspected mentioned by the partners was the **content regarding the steps necessary for creating an exhibit**, located in the Guides' chapter "Creating an Exhibit". According to the partners that highlighted this aspect, its relevance lies in the fact that it is particular useful for science educators in the process of guiding the CoL teachers, but also in supporting science teachers in the the process of guiding students during the task of exhibit development. This chapter was created after the feedback of one of the partners, and it improved the Guide, as we can attest by the results.

> *The ideas for different exhibit artifacts and the planning chart were useful. They gave us some ideas while guiding our teachers in this process. (Bogazici University, Turkey)*

> *The entire Guide is outstanding. The first part of the guide, based on Linda D'Acquisto's book, is especially good and useful. (Weizmann Institute, Israel)*

The **clarity and organisation** of the Guide was another aspect mentioned as being positive. As a matter of fact, our intention was always, from the beggining of the process of Guide development, to create a well organised and objective tool in order to facilitate the reading and, specially, the location of relevant information.

Another positive aspect highlighted by two of the partners was the **literature review** on the concept of interactivity and interactive exhibitions. For us, this was also a detrimental concern, since at the beggining of the Guide development, it was not clear in our minds what was *interactivity* nor *interactive exhibitions*. It was necessary to clarify and

operationalize this concepts in order to move forward and think about scenarios. And we felt the need to include this review on the Guide since it serves to theoretically framework the options of scenarios and interactive objetcs proposed, and also to point out, in a fundamented manner, to CoL members the most importante characteristic of an interactive exhibition, as the next answer illustrates.

> *Good literature review on the concept of interactivity. Pointing that interactive exhibit can be based on the interaction among people. (Jagiellonian University Museum, Poland)*

One partner did mentioned the **comprehensiveness** of the Guide as positive aspect.

> *The comprehensive approach, reaching from theoretical background over exh. project planning, a large diversity of tools (at different levels), to practical tipps and evaluation. (IPN, Germany)*

For one partner, the **references to literature** were useful, and this aspect was highlighted in his answer.

2.2.4. The most negative aspects of the Guide

For four of the partners that answered the questionnaire, there were no negative aspects in the Guide. Concerning the remaining partners, the highlighted aspects did not reunite consensus since every partner mentioned one diferent aspect, in a total of seven negative aspects mentioned. They were organised in seven categories, after the content-analysis of the partners' answers (table 3).

Table 3 – Negative aspects of the Guide, refered by the partners.

Category	N
Content on "Text in Exhibition"	1
Non-novelty of information	1
Extension	1
Presented concept of Interactivity	1
Inappropriateness of some content for younger students	1
Level of development of scenarios	1
Applicability to hard sciences	1
TOTAL	**7**

For one partner, the **chapter "Text in Exhibition"** was mentioned as a negative aspect of the Guide because, in his opinion, it was much more detailed than what is needed given the fact that students choose to use or develop illustrations in detriment of lenghty texts.

> *Probably the texts graphic design chapter was a little bit more detailed than needed, as (given the experience from the exhibits of the first phase) students, most of the times, prefered to use illustrations rather than lengthy texts, perhaps spontaneously thinking that images also capture their attention when visiting a museum. (University of Crete, Greece)*

The **non-novelty of the content** of the Guide was refered by one partner as a somewhat negative aspect. This is justified by the large experience of this partner in developing exhibits. However, in his opinion, for the non-experienced teachers, the information on the Guide is quite new.

> *As we (at Science LinX) are already quite experienced in exhibition development, most information for us was not new. But for the teachers it definitely was! (Science LinX, The Netherlands)*

The **extension of the Guide** was another aspected highlighted, given the fact that teachers may find the Guide a bit too long to read. To overcome this issue, and guarantee that the necessary information is passed to those teachers that may find it true, we believe it may be important to include some content of the Guide in the teaching modules, frameworking the Exchange phase.

For one partner, the **presented concept of Interactivity**, being, in his opinion, stronggly connected to ICT, is a negative aspect of the Guide. This was not our intention, neither our concept of Interactivity, given the fact that throught the Guide there are several mentions to the fact that interactivity does not require, necessary, the presence of ICT. And the fact that we have developed and presented scenarios that can be achieved by the development of physical (or non-digital) objects supports, in our opinion, this view.

The **inappropriateness of some content for younger students** was one aspect highlighted by one partner.

> *Some parts of it, e.g. drafting floor plans, text levels, or the evaluation rubric, was not appropriate for the age groups we had in the schools (11 or 12 year olds), but was too demanding. (JYU, Finland)*

The **level of development of scenarios** was another aspect poited out as negative. Some of the scenarios may be quite demanding for younger students.

> *Perhaps the level of development of each scenario is not quite enough in order to be fully aplied to the diversity of students (ages). (IE-UL, Portugal)*

Finaly, one other partner highlighted the fact that the Guide is **not completely applicable to hard scinces**, as Chemistry and Physics.

2.2.5. Improvement suggestions

Regarding this question, only two of the partners have not answered. The remain nine contributed whith sugestions, based, of course, on their own experience of using the Guide.

After analysing all the answers we came out with eight categories, summarized in table 4.

Table 4 – Improvement suggestions, refered by the partners.

Category	N
Illustrate the Guide with real IRRESISTIBLE exhibitions	4
Scenarios	2
Evaluation of Exhibitions	1
Levels of Interactivity	1
Vary difficulty of tasks	1
Guidelines on exhibit instalation and presentation	1
Extension of the Guide	1
Structure of the Guide	1
TOTAL	**12**

As we can see from table 3, four partners would like to see included in the Guide real **examples of exhibits developed within the IRRESISTIBLE Project**. That is definetely a possibility, given the fact that each partner has developed, at least, one case-study in Phase 1, aimed at evaluating the process of exhibition developement based in the data collected from both teachers, students and experts.

> *You could have enriched the guide with indicative exhibits on each topic, developed by the students who participated in the first IRRESISTIBLE phase, just to give a hint on what really student-developed exhibits could look like. (University of Crete, Greece)*

> *Add other scenarios and ilustrate with the exhibitions developed in Phase1 of the Project. (IE-UL, Portugal)*

Still in this category another partner has pointed out the relevance of indicating specific exhibit examples in which the RRI aspect has been included. We consider this suggestion

extremely relevant given the fact that one major difficulty felt by teachers from CoL1 during the process of exhibition development was, precisely, help students (and themselves) to think about ways to effectively integrate the RRI aspect in their exhibitions.

Two partners pointed out the fact that they would like to see more **scenarios** of interactivity in the Guide.

> *Give more examples of interactive exhibits. In presented scenarios could be more examples e.g.: poster - parts of the poster are hidden (for example with post-it notes), board or card games. (Jagiellonian University Museum, Poland)*

One partner has highlighted the importance of having a better conceptualization of the **levels of Interactivity** that are presented in the Guide, suggesting the use of a figure or graphic to sumarize it. This partner would have liked to see these levels consistently applied to the various scenarios presented in the Guide.

> *(…) I also think that, in the first part of the manual, the notion of different levels of interactivity could have been better conceptualized and mapped out (perhaps with a figure or graphic to summarize these levels) and applied consistently to the various tools and scenarios presented in the latter parts of the manual. (Weizmann Institute, Israel)*

The same partner points out another improvement suggestion, related to the **evaluation of the exhibitions**.

> *However, I would have liked to see practical examples of specific exhibit evaluation, including specific rubrics, in the last section or Appendix. (How did the members of IRRESISTIBLE actually evaluate their student-designed exhibits? I think we need to answer this question before the end of the project.) (Weizmann Institute, Israel)*

From here we can conclude that the given rubric suggestion in the last chapter of the Guide (Science Project Rubric), is, perhaps, not enough. The aspect pointed out by this partner is very much relevant. It is well known that the evaluation process is critical and, unfortunately, for some teachers, the *Aquiles's heel* of the teaching process. Therefore, we agree that the more resources and practical examples on how to evaluate the exhibitions given, the easier it gets for teachers to feel safe on embark on the (first) journey of helping students developing interactive scientific exhibits on cutting-edge themes. We would like to point out that some of the teaching modules developed in Phase 1 have, indeed, suggestions of rubrics aimed at evaluating not only the exhibition itself, but also the objects developed by the students, and also the process that lead to their construction. See, for exemples, the Portuguese Modules "Evaluate Earth's health trough Polar Regions" or "An Ocean of Resources", or even "Geoengineering: Climate Control".

One other partner has pointed out some **structural** improvement suggestions for the Guide.

> *I definitely like the layout, but at some points it is a bit unclear... e.g. on page 29 a new section of the book begins right below the table - hard to find when searching for it. Same on page 8. In the later part the grey EU-Project bar is missing at the bottom of the page - that looks much nicer. Probably only put it to the first page of the guide? (IPN, Germany)*

The **extension** of the Guide was also pointed out, and for one partner it could be useful to have a more concise version of this document.

Other partner highlighted the addition of **guidelines** on the installation of an exhibit by students in the museum.

> *It could be added some guidelines on the installation of an exhibition by the students in the museum e.g. presentation methods etc. (Eugenides Foundation, Greece)*

Finnaly, for one partner it would have been important to have in the Guide ideas on how to **vary difficulty of tasks** for different age groups.

2.3. One Guide, two formats

Since May 2014 the .pdf version of the Guide was made available to all partners. After the feedback gathered along the process of Guide development, the first version was improved and new chapters/sub-chapters were added, three of them following the direct contribution of two partners.

After the suggestions made by the partners, gathered through the questionnaire delivered in January 2016, the second version of the Guide was improved to a 2.1 version. This version will continue to exist in the .pdf format but also in the format of an electronic magazine. The .pdf version will be placed as an appendix to this report; the electronic magazine version is still in the phase of conclusion, and will be ready in the beginning of March 2016. The electronic magazine version will include photographs from the exhibitions developed in each partner country.

3. DIFFERENT EXHIBITIONS ON RRI: RESULTS FROM THE FIRST PHASE

In order to receive feedback from all partners concerning the exhibitions developed within the first phase of the project, we developed a questionnaire asking for each partner to characterize each exhibition regarding: a) the scientific topic, b) the group of students involved (total number, age and grade), c) the place where the exhibition was held, and d) the type of exhibition. We also asked them to include any special remarks concerning each exhibition. After this characterization, we requested for an overall balance regarding the positive and negative aspects of the set of developed exhibitions and the integration of the Responsible Research and Innovation aspect in them. This questionnaire was sent in October 2015.

On the next sub-chapters we present and discuss the results of the analysis of the answers to the questionnaire. This analysis followed both a quantitative and qualitative approach. In order to illustrate the exhibitions and some of their particular aspects, we will use photographs of the different exhibitions that each partner made available. Also, whenever it is justified and with the purpose of illustrating the ideas of the partners, we will present exceperts of their answers.

3.1. One year, thirty-two exhibitions

Within the first phase of the Project, more precisely during the school year 2014/2015, and following the implementation of the several teaching modules, there were developed a total of 32 exhibitions. Table 5 presents a synthesis of their global characterization.

Table 5 – The 32 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)
The Netherlands	4	Carbohydrates in breastmilk	139	School
Finland	1	Adaptation to climate change	87	Museum
Germany (IPN)	2	Plastic – Bane of the Ocean	39	School
Germany (DM)	1	Oceanography	60	School
Portugal	4	Polar Science (3)	169	School
		Climate Geonegineering (1)	43	School
Romania	1	The World of Nanomaterials and Solar Energy	1000	Museum
Turkey	4	Nanotechnology Applications in Health Sciences	97	School (3) University (1)
Poland	6	Nanotechnology	134	School (5) Conference room (1)
Greece	2	Nanoscience and Nanotechnology applications	108	Eugenides Foundation (1) Museum (1)
Italy (UNIBO)	2	Nanotechnology and solar energy	55	School
Italy (UNIPA)	1	Nanoscience for solar energy conversion	73	University
Israel	4	Perovskite-based photovoltaic cells	65	School (3) Science Museum (1)
	32		**2069**	

Regarding the type of exhibition, and taking into account also the interactivity scenarios presented in the IRRESISTIBLE Exhibition Development Guide that was used by all partners, there were produced a great variety of artifacts. Some exhibitions were more homogeneous concerning the type of artifacts; others more eclectic. Table 6 presents the results with respect to the type of artifacts produced within the 32 developed exhibitions.

Table 6 – Occurrences of types of artifacts within the 32 exhibitions.

Type of Artifact		**Number of exhibitions with this type of artifact**
Game	Physical (e.g., cardboard, soccertable)	17
	Digital (e.g., quizzes)	3
Poster	Physical	16
	Digital	3
Multimedia presentations (e.g., videos, audio)		10
Cartoons (digital or printed)		6
Models		6
Experiments/demonstrations		5
Digital application		3
Newspaper		1
Book		1
IKEA bookshelf (EXPOneer system)		8

As we can see from table 6, the prevalence of games, posters and multimedia presentations as the main types of artifacts presented within the exhibitions is clear. The option for developing **games**, either physical or digital, was taken into account for the majority of students and teachers involved in the development of the interactive exhibitions. Indeed, games (figures 11-17) 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.

Figure 11 – The “Ecolopoly” game, a cardboard game developed by students from Italy.

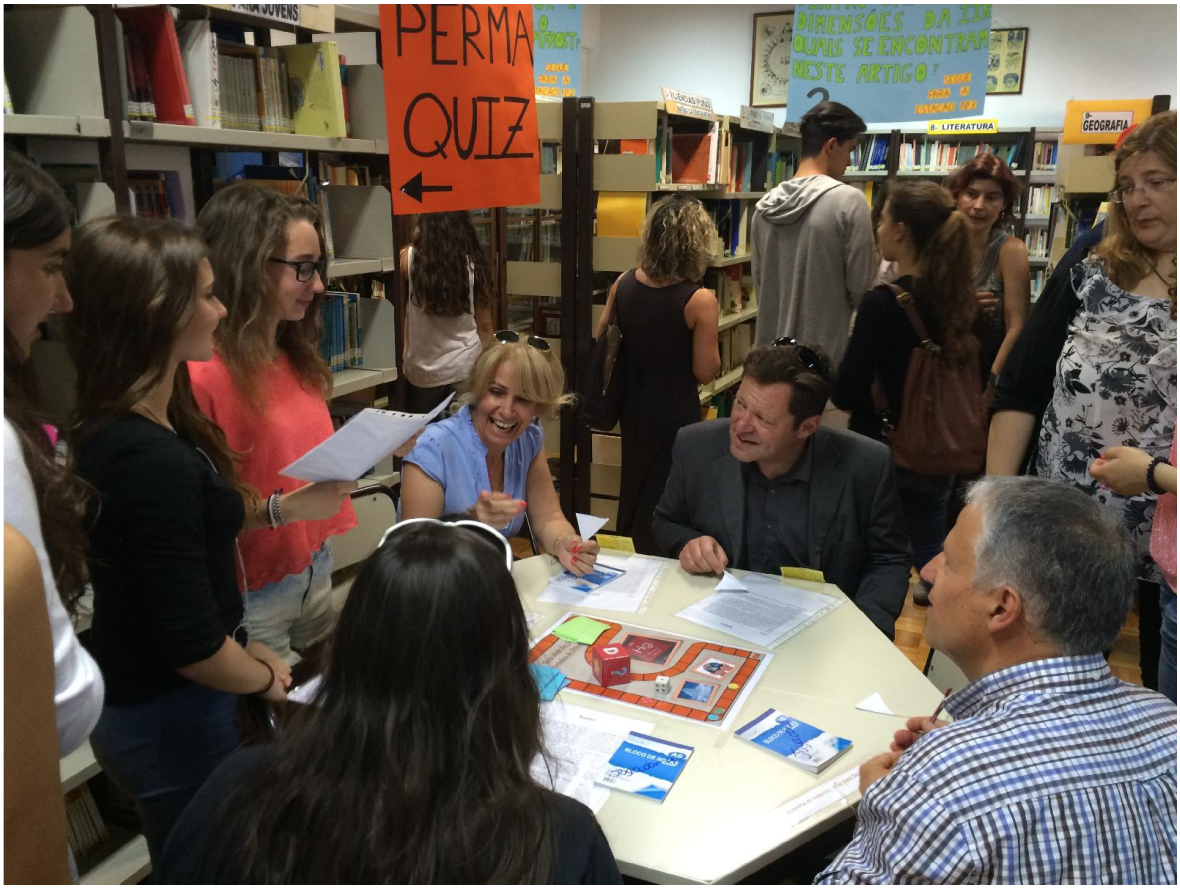


Figure 12 – The cardboard game developed by Portuguese students.

Figure 13 – A Turkish student explaining the developed game to the audience.

Figure 14 – One of the games developed by Polish students.

Figure 15 – A cardboard game developed by Portuguese students.

Figure 16 – The “Nano City” game, developed by Greek students.

Figure 17 – The "Who wants to be a Geoengineer" game, a digital game developed by Portuguese students.

The second most frequent type of artifact produced within the IRRESISTIBLE exhibitions was the **poster** (figures 18-21). Having in mind the goal of interactivity, a poster can assume several formats and require from the visitor different responses.

Figure 18 – Posters produced by Italian students.

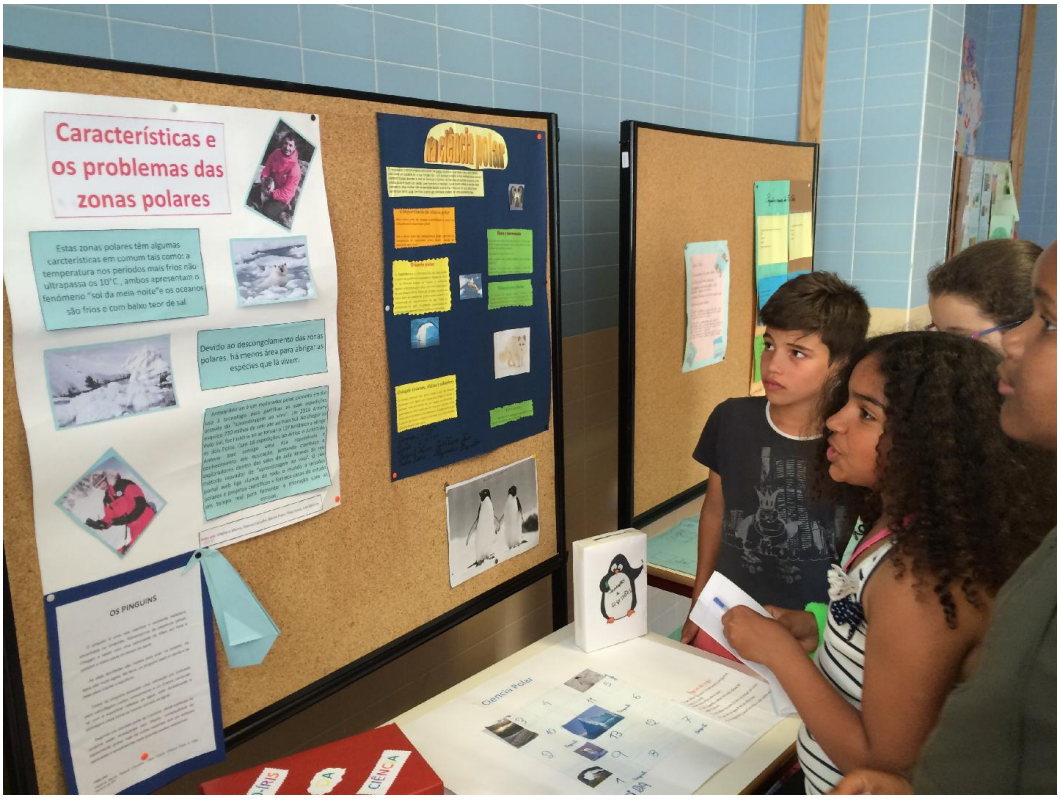


Figure 19 – Posters developed by Portuguese students.

Figure 20 – Posters hanging from the wings of an albatross model, developed by Portuguese students.

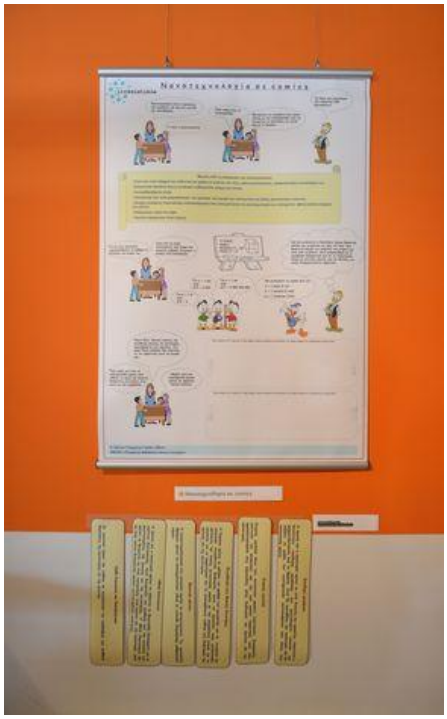


Figure 21 – A poster developed by Greek students; the bottom panels can be placed in the poster by the visitor, allowing him to co-construct the artifact.

The option for developing **multimedia presentations**, such as videos or audiofiles, was also taken into account by the students and teachers involved in the Project (figures 22-23). Although this type of artifacts require for a dispositive (PC screen, tablet or other) for their 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 for their motivation towards the exhibition production.

Figure 22 – Finnish students developed videos with the purpose of creating awareness on climate change.

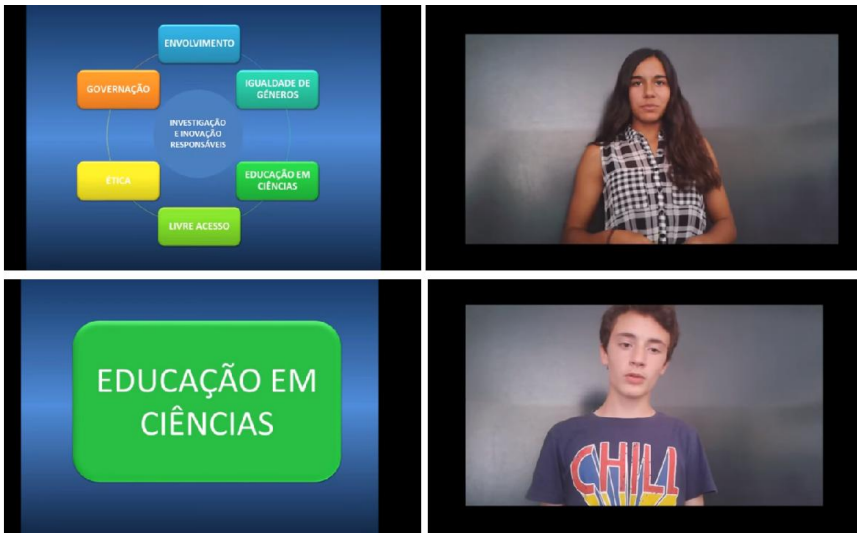


Figure 23 – Portuguese students developed a video with the purpose of clarifying the 6 dimmensions of RRI.

The development of **cartoons** was another option taken into account. Indeed, whether in a prited format or in a digital one, six exhibitions presented this type of artifact as a way to engage visitors with the scientific theme researched by students (figures 24-26).

Figure 24 – A display model combined with interactive cartoons, developed by Turkish students.

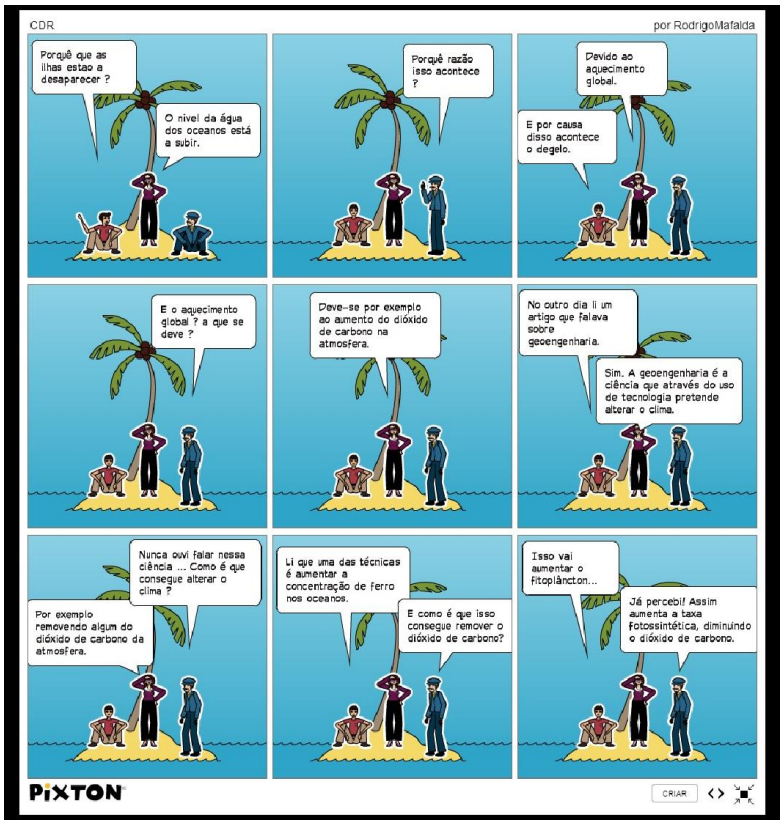


Figure 25 – A digital cartoon created by Portuguese students.

Figure 26 – Printed cartoons, arranged in a book format, developed by Portuguese students.

The development of **models** was another viable option for some students and teachers speacially when their exhibitions supports on physical and chemical concepts and phenomena (figures 27-30).

Figure 27 – A Turkish student explaining the produced models to visitors.

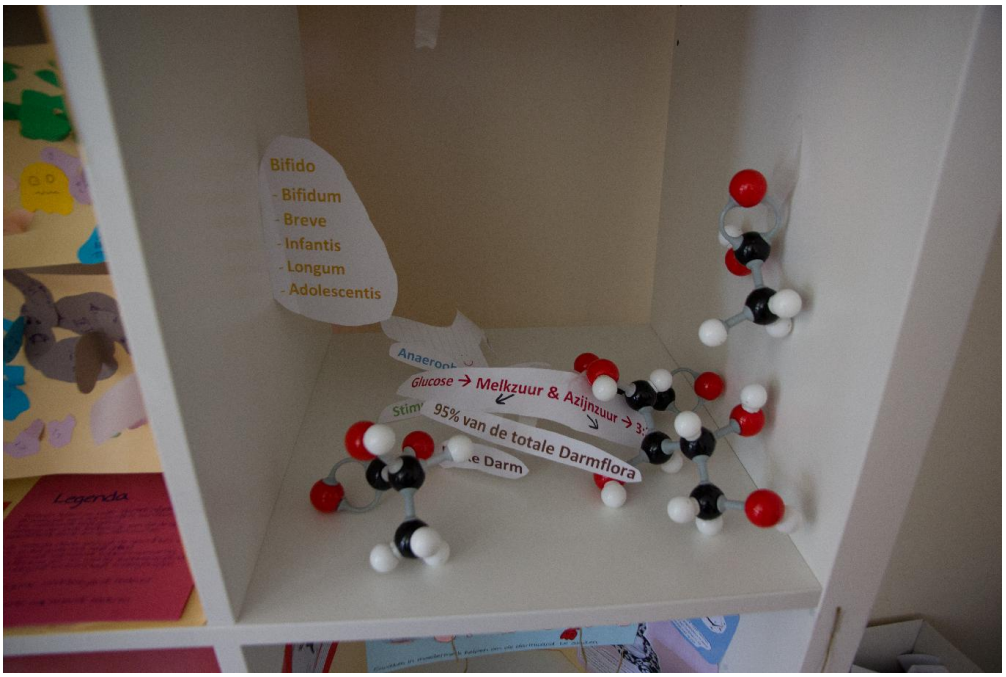


Figure 28 – A model related to the module of Carbohydrates in breastmilk, developed by Dutch students. This artefact was an integral part of the IKEA bookshelf system chosen by the Ducth CoL to support their exhibitions.

Figure 29 – A model for the adsorption phenomenon developed by Polish students.

Figure 30 – Visitors at the Romanian exhibition, manipulating some of the developed models.

Another artifact, chosen for some IRRESISTIBLE exhibitions, capable of stimulating the interaction between visitors and the exhibition was the **experiment/demonstration** (figures 31-35).

Figure 31 – An experiment developed by Greek students.

Figure 32 – A demonstration, developed by Polish students.

Figure 33 – An experiment, developed by Italian students.

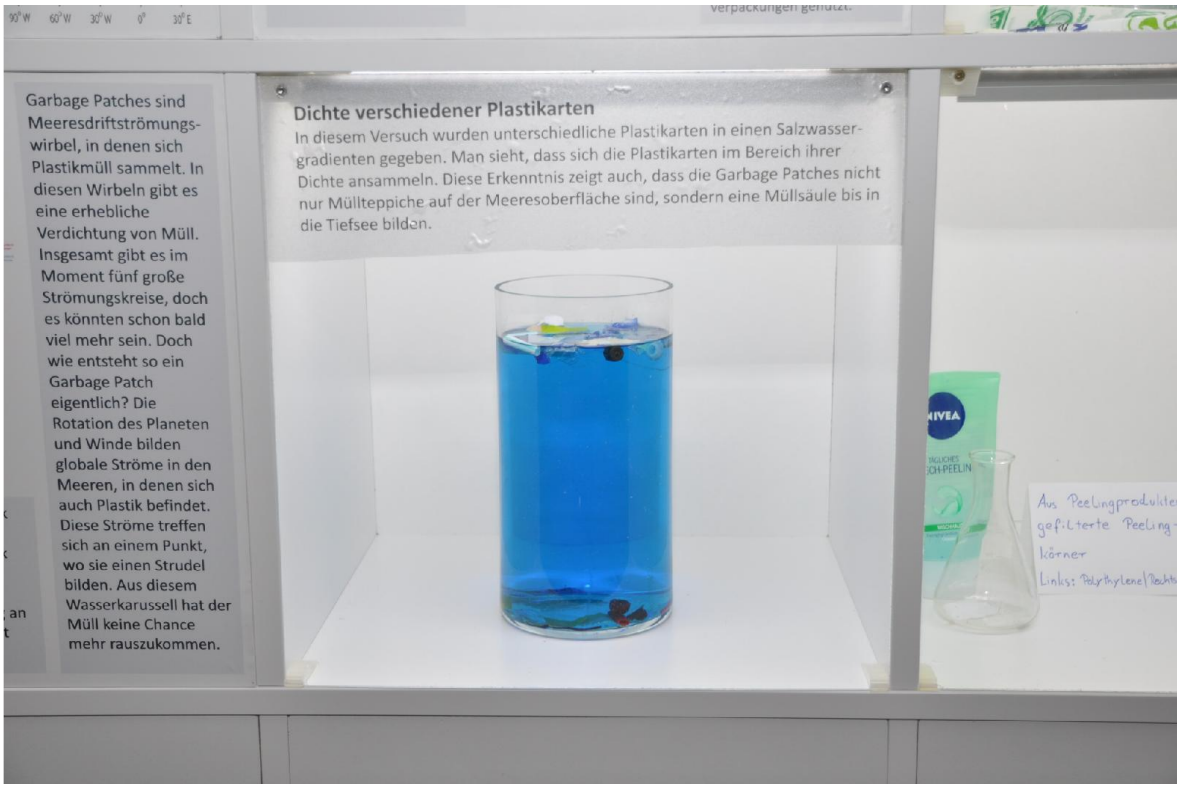


Figure 34 – A demonstration on the density of different plastics and their behavior in salt water, developed by German students. This artifact was an integral part of the IKEA bookshelf system (EXPOneer) chosen by the German CoL to support their exhibitions.

Figure 35 – A demonstration developed by Israeli students.

Other artifacts presented in the IRRESISTIBLE exhibitions were a digital application, a newspaper and a book.

A special remark must be done to the EXPOneer system that has been chosen to support 8 exhibitions. It is a modular exhibition system, based the furniture of the Expedit/Kallax-series of IKEA. Each case of the shelf can allocate different types of artifacts, depending on the desire of students and teachers developing the exhibition (figures 36-39).

Figure 36 – The EXPOneer system supported exhibition developed by German students; as artifacts, this exhibition held posters, demonstration and models.

Figure 37 – Two of the EXPOneer system supported exhibitions developed by Dutch students, and a close-up of one of the produced artifacts.

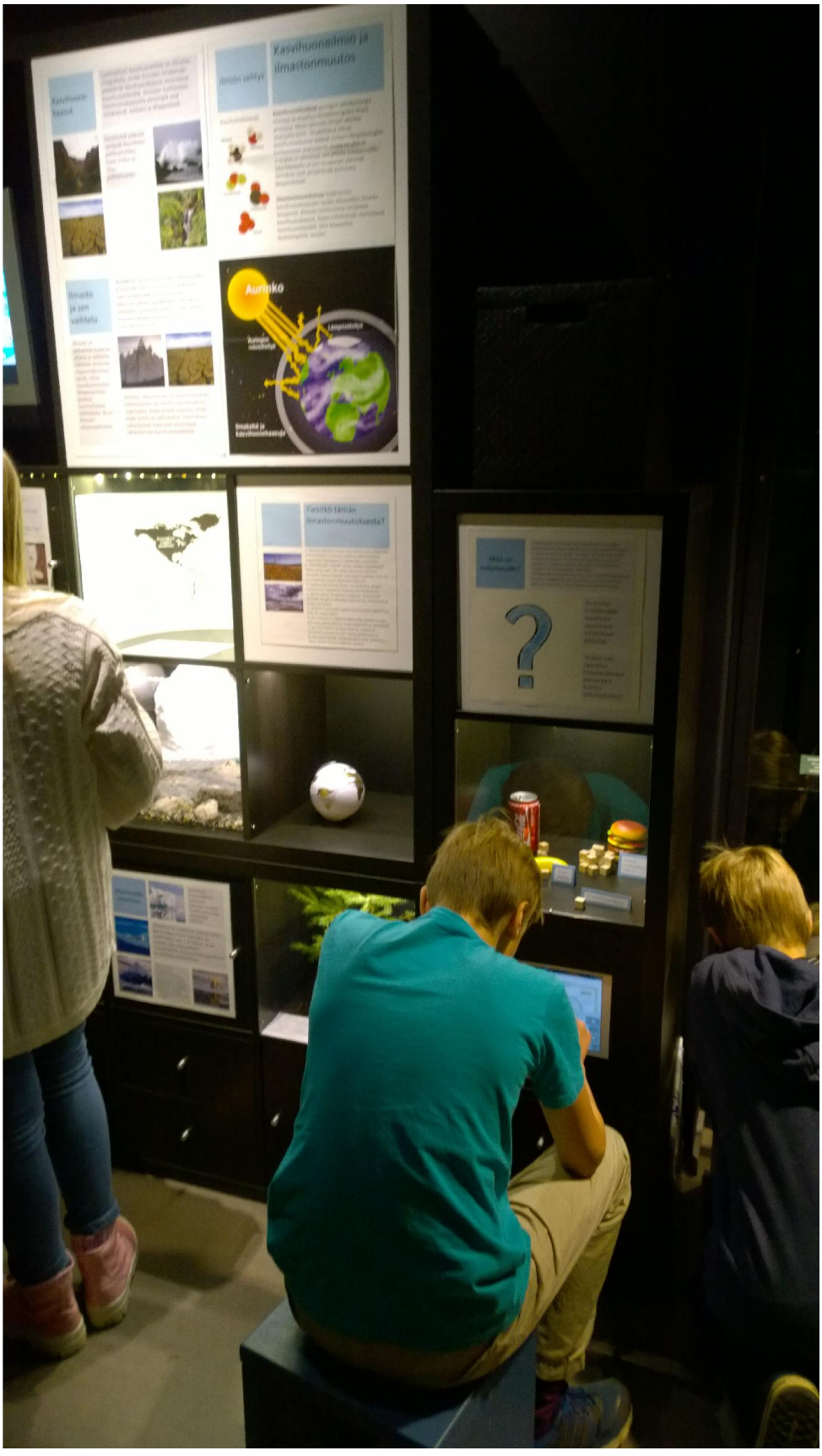


Figure 38 - The EXPOneer system supported exhibition developd by Finnish student teachers and their pupils.

Figure 39 - The EXPOneer system supported exhibition developd by German students, and a close-up of some of the produced artifacts.

3.2. Evaluation of the exhibitions

On the questionnaire sent to partners in October 2015, we asked them, having in mind the global of exhibitions developen within their CoL and the integration of RRI in them, to indicate the most positive and negative aspects. The analysis of their answers followed a content analysis approach, through which emerged categories of both positive and negative aspects. The occurrence of each categorie was quantified; excerpts of the answers will be included in order to better illustrate them.

3.2.1. Positive aspects

After an initial content-analysis of the partners answers, the positive aspects were organised in nine categories (table 7).

Table 7 – Positive aspects of the exhibitions developed within Phase 1 of the IRRESISTIBLE Project.

Category	N
Learning of scientific content	**8**
Meaningful learning	**7**
Development of skills	**7**
Students engagement	**5**
Expression of criativity	**5**
RRI integration	**4**
Learning about science	**4**
Exchange of knowledge	**3**
Implication of schools, museums and universities	**2**
TOTAL	**44**

As we can see from table 7 almost all parners mentioned as a positive aspect the fact that the students involved in the development of the exhibitions **learned about the scientific content** of their exhibition. Some teachers value the fact that students had the opportunity of learning by doing, and that was an enriching experience.

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

The involvement of both teachers and students in the process of exhibition development created the opportunity for them to expand their scientific knowledge, even if at the beginning some might be a little reluctant on the potentialities of this strategy.

Students increased their scientific knowledge. (Romania)

Participation in the project and construction of exhibits allowed the students and their teachers to expand their knowledge on the issues related to nanotechnology, especially in terms of its application in environmental protection. (Poland)

After sometimes a bit of reluctance from both teachers and students, in the end everybody like making the exhibitions. It took some students a while to realize how they can learn something by cutting pieces of paper, but in the end, most students said they really know their topic very well because of the exhibition. (The Netherlands)

For some partners, the involvement of students in this project and, more specifically, in the process of having to develop an exhibition about a particular scientific topic, allowed them to develop a more autonomous learning, and that is a positive aspect.

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

The development of scientific exhibits by students may be an incentive and a means for more autonomous learning. (Greece)

One partner did mentioned that the strategy of having students developing their own research with the goal of creating their own exhibition has shown to be a valid strategy of learning science.

The exhibitions have proven that the strategy of having students developing a research with the goal of developing an exhibition in order to explain to other what they have learned, and also their concerns regarding the scientific content related to RRI, is another valid strategy of learning science. (Portugal)

One other aspect mentioned as positive was the fact that because of the goal of exhibition development, students did attributed another meaning, importance and usefulness to their learnings, hence developing a more **meaningful learning**. Indeed, the need to develop an exhibition able to clarify the general public on the scientific content and controversies of important topics, allowed some students to establish a different relation with knowledge: more than having to know something just for the sake of it, they needed to know something because of the important task of having to explain it to others.

This project allowed students to feel that what they had learned was useful and it is valorised by others, because they understood that their learnings were fundamental since with them they were better able to develop a good exhibition and explain to other what they had learned. (Portugal)

Indeed, both the teacher and the students expressed the importance of the museum involvement and the exhibit design, because they represented (...) a moment of contact with the real world, triggered by the request to explain nanotechnology to a general public. (Italy)

We had fun learning by experimenting and also by explaining to other students all the difficult things that we studied; in this way we also had to consolidate our knowledge and I was very proud to be capable of explaining difficult concepts even to young students. (Student, Italy)

It was very useful to learn new things that we had to explain to others and, at the same time, learning what other students had to say. (Student, Italy)

Besides the aspects related to learning of scientific content, for some partners another positive aspect which resulted from the involvement of students in the process of exhibition development was the opportunity for them to **develop important skills**: a) communication, b) collaboration and teamwork, c) accountability for results, d) problem-solving, e) organisation and planning, f) researching.

It was a good opportunity to present their exhibit item to parents, teachers, peers, university students, and instructors i.e.; people they don't know. So the exhibit helped them improve their presentation and communication skills. (Turkey)

An important aspect of the project participation was the development of soft skills (including social competences) of its participants. The development of skills such as teamwork, accountability for results, communication, team problem-solving was indicated both by students and teachers involved as an important result of the project implementation. (Poland)

Students increased their scientific knowledge, but also they learned how to work in teams and organized their own work. (Romania)

Within this project, students not only were able to learn science (scientific content) but also did developed important skills, like working in teams, collaborating, planning in advance, researching, and communicating their learnings. (Portugal)

From the point of view of teachers and other CoL members, the most positive aspect was how the students developed of a strong sense of agency, or personal responsibility, both as citizens and as future scientists, due to the emphasis on the RRI dimensions and RRI-based thinking. (Israel)

For some partners, another positive aspect of this experience was the high **engagement of students** in the process of exhibition development, even those that are less active or less familiar with scientific contents.

> *Even usually less active students were positively involved. (Teacher, Italy)*

> *Moreover, this kind of practical and informal activities particularly involved students who were usually less familiar with scientific matters. (Italy)*

> *Students were more engaged and felt more motivated to learn, since they had to develop the exhibition. (Portugal)*

One other positive aspect mentioned by some partners was the opportunity that students had to **express their creativity** in a not so creative context, as it is for science classes and scientific subjects. The opportunity created by the need of developing and interactive exhibition, capable of engaging visitors and attract them, allowed for students to express their creativity when developing their artifacts and when planning the exhibition, motivating them for the tasks.

> *Students had an opportunity to use their creativity in normally not so creative science classes. Some students really liked that. (The Netherlands)*
> *Indeed, both the teacher and the students expressed the importance of the museum involvement and the exhibit design, because they represented a moment of freedom in which creativity can be expressed. (Italy)*

> *According to the projected activity (as foreseen in the Module activities), the teacher had the opportunity to involve students in the process of making exhibits, and develop his/her student's creativity, becoming so a facilitator in learning and a motivator. (Romania)*

> *Through this experience, students were able to develop their creativity within science classes, where normally they don't have that kind of opportunities, and they appreciated it very much. (Portugal)*

The fact that the development of the exhibition facilitated the **integration of the Responsible Research and Innovation** aspects in the scientific subjects was mentioned by some partners as a positive aspect. Indeed, one of the requirements for the exhibition development was the integration of the RRI dimensions on the exhibition/on the artifacts produced by students. And for that, during the module implementation, more specifically, during the Extend/Elaborate phase of the 6E IBSE model, students contacted more formally with the RRI concept and its dimensions, with the purpose of linking them with the scientific contents learned so far.

High school students acknowledged that through their involvement in the exhibits' development, they reviewed or changed their STEM orientation and field while at the same time showed adhering to the practical values embedded in RRI. (Greece)

RRI aspects in terms of ethical production of goods or transportation are addressed in the exhibit. (Finland)

The production of the exhibit facilitated the integration between disciplinary aspects and RRI. (Italy)

It was a good challenge for students because they tried to integrate RRI to a scientific content. It was the first time for them, and they tried really hard to come up with creative, interactive and interesting exhibit items, and they succeeded. (Turkey)

The opportunity for students (and teachers) to **exchange knowledge** through interaction with their peers, teachers, students, museum staff and university staff was another positive aspect highlighted by some partners. Indeed, the opportunity to contact with other actors during the process of exhibition development, allowed for students and teachers to gain other insights on their plan for the exhibition.

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

The interaction with other teachers from different types of schools and university staff was particularly fruitful. (Teacher, Italy)

It was an excellent experience for them, because they got a chance to see what the other students (in other schools) did. They interacted with their peer's exhibit items and discussed with each other. (Turkey)

By contacting with cutting-edge scientific topics, and by having the need to develop the exhibition, some students did develop another way to see and think about science, hence the categorie **learning about science** (different from the categorie *learning of scientific content*). The approach to RRI and the integration of their dimensions on the scientific topic explored by students contributed to this aspect, mentioned by some partners as positive.

The development of scientific exhibits by students may be an incentive (…) to capture the science not only as cognitive content but also as a creative process. (Greece)

Participation in the project and construction of exhibits allowed the students and their teachers (…) to understand that science development is not linear, in opposite to that, what arises quite often from school textbooks. Thanks to the meetings with scientists,

> *students and teachers could see that in the process of knowledge development in fact there is a place for failed experiments, erroneous hypotheses or theories that do not stand the test of time, and the investigations and their results implementation are associated both with opportunities and threats. That is why it is so important to consider the potential risks and submit the investigations for social control/evaluation, in which the students can participate themselves as members of civic society. (Poland)*

For some partners, the **implication of school, museum and university staff** was highlighted as a positive aspect, contributing to enhance and help the exhibitions and to valorize the effort of teachers involved in its development.

> *In most case, the exhibitions made were important events for the school and/or local communities. School officials and the representatives of the university took part in the exhibition openings, which also contributed to strengthening the position of teachers participating in the project. (Poland)*

> *The implication of museums on promoting and supporting the transfer of knowledge to young generation, but also to general public.(…) In this respect, the support offered by the museum was real helpful, also on the exploiting phase of the exhibition, more consistently on several events which were held in the period August - November 2015. (Romania)*

3.2.2. Negative aspects

After an initial content-analysis of the partners answers, the negative aspects were organised in nine categories (table 8).

Table 8 – Negative aspects of the exhibitions developed within Phase 1 of the IRRESISTIBLE Project.

Category	N
RRI integration	**9**
Time management	**9**
Novelty of subject/tasks/strategy	**5**
Limited resources	**2**
Moment of school-year	**2**
Students engagement/contribution	**2**
Evaluate the impact on visitors	**1**
Museum experts' contribution	**1**
TOTAL	**32**

As we can see from table 8 the two more frequently aspects mentioned as negative ones were the RRI integration and the time management. Regarding the **RRI integration**, the

majority of partners did conclude that the RRI dimensions were poorly integrated in the exhibitions. This happened, in part, due to the difficulty of deeply engaging students in the RRI theme, and also due to the complexity of some dimmensions. As a result, students tended to give more importance to the scientific content development than the integration of the RRI dimmensions in it.

> *In general, it is hard to deeply engage 9th graders - like the one we worked with - in the RRI topics. When discussing this, one has to differentiate between the pure presentation of RRI aspects in the final exhibition, and pupils experiencing and working on RRI during the process of exhibition development. One can clearly see that pupils in the presentation are focusing on the scientific content and some few RRI aspects like Ethics and sometimes Governance. The other aspects seem to be either too complex to pupils (like Public Engagement) or too marginal for an exhibition (like Open Access, Gender). (Germany)*
>
> *Other RRI aspects [apart from Ethics] were poorly covered (Finland)*
>
> *A shortfall was observed in the degree of integration of RRI aspects in the design of the exhibits, which indicates that further enhancement of the concept is necessary. The most obvious RRI aspects were Science Education and Ethics. The less obvious RRI aspects were gender equality, open access, governance and engagement. Many students gave more importance in the scientific content development than the integration of the RRI aspects into the content and thus, in the design process. RRI was addressed as an external or additional feature. (Greece)*
>
> *We did not make explicit enough that also the RRI-aspects had to be taken into account in the exhibitions, so these were not always very visible (or sometimes not at all). (The Netherlands)*
>
> *Students also faced a problem of presenting the six pillars of the RRI concept in the form of interactive exhibits, despite the fact that the vast majority were exhibits concerning cutting edge science issues. And although each exhibition included the exhibits referring to RRI, those exhibits were not very numerous. (Poland)*

Another aspect highlighted by many partners as being negative was the **time management**, mostly because it was underestimated. Taking into account the novelty of tasks, the process of exhibition development took more time than it was initially predicted, and that end up resulting, in some cases, in exhibitions with less quality.

> *The quality of the exhibitions is really dependent on the time that was put in by the students. Some schools had more time for this than others. (The Netherlands)*
>
> *Limited time dedicated to teachers' and students' extra-school activities, in general. (Romania)*

Concerning the difficulties experienced during the development and the building process of the exhibit, both the students and the teacher emphasized the little time available, even though such difficulties have not limited their creativity and the level of their performance. (Italy)

Other important issue was that the time spent for the construction of exhibits was underestimated. (Greece)

On the negative side, the teachers pointed out that the time management was not always ideal. In particular, the preliminary phase when the students had to gather information in preparation for the exhibit was very limited and time constrains did not allow to manage properly critical points that arose. (Italy)

In most groups, a significant problem was the limited time available for making the exhibits. (Poland)

The time allocated in the module for the exhibit development took longer than it was initially estimated. Because it took them longer to find an idea for constructing an interactive exhibit item and incorporate the nanotechnology applications into RRI. (Turkey)

The **novelty of subject/tasks/strategy** was another aspect mentioned as being negative, since it conditioned the developed exhibition. The novelty of having to develop an interactive exhibition focusing on scientific topics that are somewhat new to both teachers and students, and having to integrate another new topic that is the RRI, was felt by some partners as a limitation of both students and teachers performance. But we cannot forget that this is precisely the goal of IRRESISTIBLE, hence its groundbreaking character.

Limitations related to the various level of understanding of the exhibition main theme, by different teachers and students, taking into account the great input of subject novelty. (Romania)

In general, the more problematic phase was only the beginning of the process when they did not have any idea of what an exhibit is and how to design it. (Italy)

In some cases students had some difficulty adapting their behavior to the IBSE approach. (Italy)

It was a high level task for students to incorporate two new topics (nanotechnology and RRI) to a novel activity, namely developing an exhibit item. They had difficulties in understanding what they were supposed to do. At the end, getting exhibit items with less or no integration of RRI or less integrated content was not surprising. (Turkey)

Teachers had no experience in guiding students to develop exhibit items. So, teachers had difficulties in guiding students during the process. (Turkey)

Difficulties relating to the novel exhibit format (how to design the exhibit, how to make it interactive, how to build it) technical difficulties, and difficulties in the exhibition phase (lack of time and the need to translate the material to a different language and to younger students, etc.). (Israel)

Some partners faced the constraints of having **limited resources** for developing the exhibition, highlighting this as a negative aspect.

Limitations related to the budget allocated for preparing the exhibits. (Romania)

ICT was used in exhibitions to a limited extent only, which is due, among other things, to the limited equipment available in schools. (Poland)

The bad choice of the **moment of school-year** to present the exhibition was mentioned by two partners as a negative aspect. Indeed, this is important since it will constrain the time available for developing the exhibition, the effort that students and teachers can put tinto this task and, overall, the quality of the final product.

In most groups, a significant problem was the limited time available for making the exhibits and the deadline which fell at the end of the semester (school year), i.e. in the period of significant effort associated with the final evaluation of students' achivements. (Poland)

One very important aspect was the moment of the school-year chosen to conclude and present the exhibition to the public. All exhibitions were presented in the last period of the school-year, at the last week. Students were mainly foccused on other tasks, like their performance at exams and tests; and so were teachers. Hence, the quality of the final products was compromised. (Portugal)

The limited **students' engagement or contributtion** to the task of developing the exhibition was another aspects highlighted by some partners as being negative.

Pupil contribution was limited. (Finland)

Some schools had more time for this than others, and within classes there was a large variation in effort and enthusiasm put in by the different groups. (The Netherlands)

The lack of **evaluation of the impact of the exhibition** on visitors was one aspect highlighted as being negative.

> *If students put such an effort on developing this exhibitions as a means to allert and educate the community, they need to have feedback from visitors. This was a negative point of our exhibitions: in some of them, students did not even developed no instrument for collecting feedback; in others, they did but then they did not analyse the data. How can they evaluate the impact of their action on others without having their feedcback and discussing it? (Portugal)*

Finnaly, the limited museum experts' contribution to the process of exhibition development was another aspect mentioned as being negative.

> *Museum exhibit expert did not participate to the extent expected. (Finland)*

RRI integration on the process of exhibition development: the German partner analysis

A more detailed analysis and reflection of the RRI integration on the process of exhibition development was made by the German partner. We organized their observations on table 9.

Table 9 – Evaluation of the integration of the 6 RRI dimmensions within the process of exhibition development by the German partner.

RRI dimmension	Observations regarding the process of exhibition development	
	Positive	**Negative**
Public Engagement	Pupils gained insights into interaction processes between society and research. Pupils were confronted by open questions addressing connections between personal behaviour and policy decisions.	Complete process of interaction between society and research and science is too complex for pupils to comprehend. No direct feedback to policy system introduced or implemented.
Open Acess	Pupils had to learn to research and find data and determine its reliability (different approach to that in normal school lessons). Pupils gained understanding of how important free access to reliable data is. When developing the exhibition and searching for legal images to use (in terms of copyright) in the exhibition, pupils realized how Open Access can improve science (and science communication).	
Gender Equality	Boys and girls complemented each other well in the curation process. Due to the wide scope of the subject matter of oceanography, both sexes were able to choose sub-topics and elements of interest to them.	Usually gender issues relating to career perspectives were not a big topic in the classes.
Ethics	Pupils became acquainted with ethical views on various sub-topics of oceanography. Pupils had to make informed decisions whether to accept and present these views.	
Science	Pupils generated strong interest in topic of	Interdisciplinary approach / work is difficult to

Education	oceanography. Multi-faceted approach (lessons, simulation games, museum visit, field trip,…) was very effective.	implement in schools.
Governance		Very hard to integrate and virtually not present in the development process.

3.3. Suggestions of improvement

RRI integration

Given the results, and taking into account the importance of developing an exhibition that can truly address the RRI issues of the scientific cutting-edge topic studied by students, one might suggest the need to adress more frequently and in a more intricated manner the RRI issue during the whole module implementation, and not only during the Extend/Elaborate phase. It might be important to introduce the RRI aspects of the topic at the very beggining of its exploration. That implies from the teacher an effort to previously identify the *loose ends* on the topic that might relate to RRI and bring them to frequent discussions with students.

Time management and moment of school-year for the exhibition presentation

Having in mind the fact that the majority of partners mentioned the time available for the exhibition development as a constrain, one might suggest that this process should be taken care of since the beggining of the module implementation. In fact, students must be aware, since the Engage phase, that all their work and effort will result in the development of one exhibition, so it is important to allocate time to think about it during the several weeks/months of Project implementation, not just at the end of it (on the Exchange phase). Also, students and teachers must understand that, although the importance of this Project and of the task of exhibition development, they have another commitments at school (other classes to attend to, tests, exams, other schoolworks), so they need to focus on developing good, simple and effective ideias. It is also important to chose the best moment of school-year to develop the exhibition, specially the construction phase, preferably a moment when students don't get ovearload with exames or tests.

Students engagement and contribution to the task of exhibition development

We cannot forget that students must play a central role in the planning and development of exhibitions, hence their active participation is crucial. Despite that, if they're not motivated to collaborate or if they don't see the purpose of developing the exhibition,

their commitment to this task will decrease. Here the role of the teacher in motivating them and helping them to see how important their work is in order to alert the community for the scientific issues, is very important. Students must feel and understand that they play a very important role in society, and they can contribute to solving some of its problems. Presenting an exhibition, based on their own research, with the purpose of inform and allert to important scientific issues that concern us all is a very valid way to play an active citizenship.

4. CONCLUSIONS

The analysis of the different exhibitions developed in the first phase of the Project allowed us to conclude that all partners, despite the various novelties within the IRRESISTIBLE (cutting-edge scientific issues linked to RRI, interactive exhibitions and interactive artifacts) did made an excellent effort of developing interactive exhibitions, developing several artifacts capable of promoting the interaction between visitors and between them and the objects. The IRRESISTIBLE Exhibition Development Guide has contributed to this results. Indeed, according to the data gathered from the questionnaire applied to all partners after Phase 1 of the Project, concerning the usability of the Guide, and also their opinion regarding the positive and negative aspects, as well as improvement suggestions, we can conclude that this tool has great potential in supporting teachers (and, consequentely, their students) in the process of exhibit development. We can also conclude that this tool can be used in the context of teacher professional development. In fact, we've developed a tool that allowed, for each partners' CoL, the built of very important knowledge concerning the implementation and development of the didatic strategy of interactive exhibition development as a means to students Exchange, with visitors, their knowledge and concerns regarding cutting-edge scientific themes with a focus on RRI. Ideed, the developed tool not only allowed for the clarification of the concepts of interactivity and interactive exhibitions – foundational concepts within the abovementioned didatic strategy – but also allowed for the enlightening on the more practical aspects related to exhibition development. Aspects such as the three phases (and sub-phases) of exhibition construction, the care that must be taken into account when elaborating texts for exhibitions, and the importance of assessing (and how to assess) the impact of the exhibition on teachers, students and visitors. Finaly, the given set of interactivity scenarios contributed to exemplify and operationalize the concepts of interactivity and interactive exhibitions.

The analysis of the feedback of the partners regarding the positive and negative aspects of the exhibitions developed by their CoL's, allowed us to perform important learnings that can and should be taken into account by all during the Phase 2 of the Project. Although the novelty of the tasks implied in this Project, one cannot forget its main purpose: to design activities that foster the involvement of students and the public in the process of Responsible Research and Innovation (RRI). And for that, the phase of exhibition development plays an important role, since the exhibition acts as a platform for students to reach the public and speak out their own thoughts on important social issues, as RRI is.

The road of exhibition development presented many obstacles to all of us: the fully integration of the six RRI dimensions and the management of time for developing the necessary tasks, given their novelty, were two of the principle. Therefore, it is important to treat RRI not as an extra subject of the module, but as another way to see and analyse

the scientific topic of the module. Students (and teachers) need to put on the lenses of RRI when researching, analyzing and critically discussing on their scientific issue. This implies an effort for some teachers, that need to move away from a non-controversial, well established and consensual notion of science, and accept that science is uncertain, controversial and under debate. Having that in mind, it would become more easier to approach Responsible Research and Innovation and discuss its dimensions with students. As for time management, we believe that the more familiar with this approach the teachers and students are, the lesser problems they will have in managing all the tasks that are implicit to the development of an exhibition. And for that we believe that the developed Guide will give a good help, specially the chapter on how to build an exhibition, which clarifies the steps needed to take into account when embarking on a process like that.

The developed exhibitions have proven to be able to fulfill the Exchange phase of the 6E model (and, for other partners, also the Empowerment phase of the 7E model), acting as a platform for students to share their learnings and concerns about the scientific topic, and by doing that, promoting their contribution to help solving some problems related to science-technology-society-enviroment.

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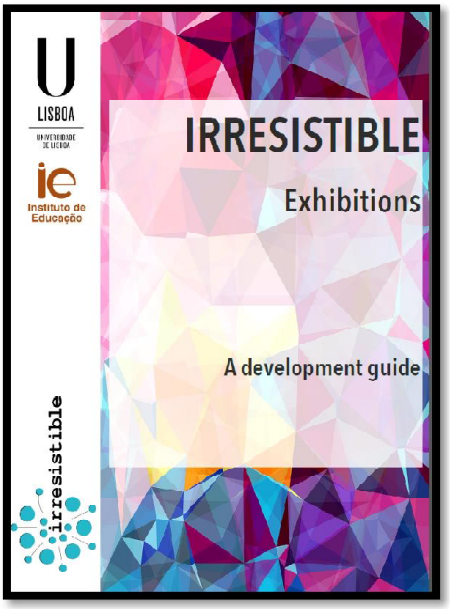
APPENDICES

"IRRESISTIBLE Exhibition Development Guide" (~12Mb)

https://www.dropbox.com/s/wbjhcs5lv0o03pc/Interactive%20exhibitions%20development%20guide_last_version%28january2016%29.pdf?dl=0



"IRRESISTIBLE Exhibition Development Guide" (~89Mb) – digital magazine version with photos from Phase1 exhibitions

https://issuu.com/institutodeeducacao-universidadedel/docs/development_guide_-_v2.2_web

https://www.dropbox.com/s/i5ainq1f5agovwj/Development%20Guide%20-%20v2.2.pdf?dl=0