Interactive Exhibition on Climate Geoengineering: Empowering Future Teachers for Sociopolitical Action

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ABSTRACT

The present case study, involving 19 pre-service teachers, intends to identify the potentialities and the limitations associated with the development of interactive exhibitions on socio-scientific issues as a strategy to empower future teachers for sociopolitical action. An interactive scientific exhibition developed accordingly to the IRRESISTIBLE project module "Geoengineering: Climate Control?" sought to create opportunities for students to work collaboratively, to take responsibility and to participate in activism initiatives. The results suggest positive impacts on students' scientific knowledge, exhibitions' development skills and empowerment for action. The main difficulties are focused on group work and time management. This pedagogical initiative allowed the development of competences considered important for citizens' scientific literacy and active involvement in sociopolitical action.

KEY WORDS

Interactive exhibit, IRRESISTIBLE, Activism, Teacher training.

Exposição Interativa sobre Geoengenharia Climática: Capacitação de Futuros Professores Para a Ação Sociopolítica

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RESUMO

O presente estudo de caso, envolvendo 19 estudantes da formação inicial de professores, pretende identificar as potencialidades e as limitações associadas ao desenvolvimento de exposições interativas sobre questões sociocientíficas como estratégia para capacitar as futuras professoras para a ação sociopolítica. Uma exposição científica interativa desenvolvida de acordo com o módulo "Geoengenharia: Controlo do Clima?" do projeto IRRESISTIBLE procurou criar oportunidades para as estudantes trabalharem de forma colaborativa, assumirem responsabilidades e participarem em iniciativas de ativismo. Os resultados sugerem impactos positivos no conhecimento científico, em competências para o desenvolvimento de exposições e de capacitação para ação das futuras professoras. As principais dificuldades centram-se no trabalho de grupo e na gestão do tempo. Esta iniciativa pedagógica permitiu o desenvolvimento de competências consideradas importantes para a literacia científica dos cidadãos e o envolvimento ativo em ação sociopolítica.

PALAVRAS-CHAVE

Exposição interativa, IRRESISTIBLE, Ativismo, Formação de professores.

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> Democracy is not only a political form, it is a way of life, characterized above all through the transitivity of consciousness in man's behaviour. Transitivity is neither born or developed, unless through certain conditions, when man is engaged in debate, examining his and societies problems. In which he participates.
>
> Freire, 1967, p. 81

INTRODUTION

In a world led by constant scientific and technological innovations, there are a number of emerging problems, at the local and global level, for which it is urgent to find sustainable and responsible solutions. To deal with these problems, it is not enough to gather scientific information and knowledge. Different points of view on the issues that are being analysed must also be considered (Colucci-Gray & Camino, 2014). As Colucci-Gray and Camino (2014) mention, humans are introducing greater and deeper transformations into natural systems, resulting in an increase in socio-scientific and socio-environmental issues. Besides natural occurring transformations, others are prompted by the network of social and ecological interrelationships, leading to unpredictable results requiring decision-making and research based accountability criteria.

In this context, interactive science exhibits, including the *Exchange* and *Empower* phases of the IRRESISTIBLE project teaching modules, are part of an approach promoting democratic participation. This is sustained by a learning path seeking to give sense to future teachers lives, relating new knowledge with real concerns. This type of interactive exhibit aims to educate future teachers, as well as visitors on social issues affecting all of us. It is also our purpose to develop the participants competence to plan concrete actions, that can contribute to protect the environment and strengthen democratic values.

The IRRESISTIBLE Project involved several European countries aiming to introduce Responsible Research and Innovation (RRI) in the different levels of basic and secondary science education, through *Inquiry Based Science Education* (IBSE). One of the expected impacts of the project, through teacher training and professional development, is contributing to society scientific literacies, responsibility, and creativity (Apotheker, Blonder, Akaygun, Reis, Kampschulte & Laherto, 2016).

By providing future teachers with this type of teaching-learning scenarios they will be better prepared to teach inquiry based science, and actively participate in solving social issues related to science, technology, and the environment, through initiatives such as interactive science exhibits. This study, intends to research the potentialities and limitations associated with the use of interactive science exhibits in the training of future teachers for sociopolitical action.

INQUIRY AND RESPONSIBLE RESEARCH AND INNOVATION

RRI plays a leading role in Europe, integrating one of the central concerns of the European Union (EU) Framework Program (Direcção-Geral da Investigação e da Inovação, 2014; Von Schomberg, 2013). In this program, investing in research is considered crucial for Europe's smart, sustainable and inclusive development (Direcção-Geral da Investigação e da Inovação, 2014, p.5). The responsible research and innovation is a transparent and interactive process, with various actors, from civil society and/or researchers, aiming for the acceptability, sustainability and social relevance of the innovation processes and its products. The purpose of its underlying principles and dimensions is to enable the scientific and technological advancement of our society to be properly incorporated (Von Schomberg, 2013), while finding solutions to a wide range of existing challenges. The European Commission (European Union, 2012) sought to answer these challenges through the creation of a society-driven research and innovation policy, and through an inclusive participatory approach for all social actors, implemented in six key elements: Involvement, Gender Equality, Science Education, Ethics, Free Access and Governance. Therefore, the IRRESISTIBLE project tried to involve teachers, students and the general public in the RRI process by raising awareness to the need for cooperation between scientific research and society, in order to promote truly responsible research and innovation (Reis & Marques, 2016a, p. 9). Each module is focused on a current and controversial science issue, promoting the participants learning about these topics, and their discussion, taking into account the six dimensions of RRI (Apotheker et al., 2016; Reis & Marques, 2016a). Each module was also developed taking into account an Inquiry Based Science Education (IBSE) approach integrating Rodger Bybee's (5E) teaching model: Engage, Explore, Explain, Elaborate and Evaluate. Another core characteristic of the project was the development of teachers and students' technological competences using digital resources. The Portuguese project team added to this model two new phases - *Exchange* and *Empower*, extending it to 7Es (Azinhaga, Marques & Reis, 2016; Reis & Marques, 2016a). The two added phases to the 5E model imply the design, implementation and evaluation of the interactive science exhibits, by the students, creating a strategy for school activism (Reis & Marques, 2016a). The construction and presentation of the exhibits create an opportunity for students to participate in collective action on the controversial issues being analysed, while also encouraging exhibit visitors to take action (Reis & Marques, 2016b).

The adoption of *Inquiry* in the IRRESISTIBLE project intended to react the recommendations of the European Commission report presented by Rocard (2007). One of the problems pointed out in this report, by the science education experts group led by

Rocard (2007), was the small number of young people interested in this area. According to Osborne and Dillon (2008), the introduction of the IBSE pedagogical model in science classes opposes this tendency allowing students to increase their interest in science. *Inquiry* is a teaching strategy that captures the spirit of science research, and the development of knowledge about the natural world, and should not be described or confused with practical activities such as hands-on (Bybee, 2006). In the published book about *Inquiry* (NRC, 2000), the National Research Council highlights some features that should be present in teaching and learning when using this pedagogical strategy. Bybee (2006), when analysing these characteristics, highlights the students as the central element of this approach, and their mental activity with a scientific orientation towards the goal of developing scientific explanations. Other features emphasized by Bybee (2006) are the relationship between the issues analysed with current scientific knowledge, and the existence of elements of rationalization and communication.

Recognizing the importance of the RRI approach and the use of *Inquiry* in the context science education, the scope of the IRRESISTIBLE project was extended, giving the opportunity to students of the Undergraduate Program in Basic Education, future teachers, to engage with the proposals of the project modules. If it is important to invest in current teacher's professional development, it is no less important to involve future teachers in training and learning experiences of this nature. This intervention can benefit students understanding, reasoning and attitudes towards the environment and a healthy life, as well as society through the dissemination of RRI principals, promoting each individual ability to make better informed choices.

ACTIVISM AND INTERACTIVE SCIENCE EXHIBITS

Interactive exhibits aim to empower future teachers for action, promoting a deeper understanding of the studied issues using *Inquiry* and RRI. This knowledge can stimulate and motivate future teachers to invest in issues that affect our society and encourage them to act (Hodson, 2003). The interactive dimension of the exhibits favour's the emergence of meaning, resulting from the interaction between the visitors and the facilitators present at the exhibit (Reis & Marques, 2016b). For Reis and Marques (2016b) the visitors' active participation is crucial for the emergence of clear conceptual knowledge built in the group. In order to promote meaningful learning, the artefact planned by the students must actively engage the visitor, prompting him to the application of new knowledge. The tasks and the reflection promoted during the exhibit are essential in the process of building knowledge and awareness. Interactivity can be promoted by using multimedia applications, by manipulating virtual objects on screens, simulating experiments, online tests with immediate *feedback*, *role-playing*, synchronous and asynchronous communications between groups, and sharing alternative points of view about a given issue. Another effective strategy to stimulate interaction is questioning. According to Marques (2016), questions raised in the beginning, middle or at the end of the exhibit/exploration of the artefact can direct the visitors' attention, raise doubts and encourage discussion.

Conducting interactive exhibits seeks to create opportunities for students to work collaboratively, take on responsibility, and participate in activities promoting change. This is a way for students to learn how to participate, by experiencing participation.

According to Hodson (2014), "to show students how to establish, support and sustain politically active communities" (p. 69). In this context, we adopted Hodson's (2003) definition of sociopolitical action as a form of participation, requiring the capacity and commitment to carry out appropriate, responsible, and affective actions regarding social, economic, environmental and ethical issues in society. Educating for sociopolitical action, as Hodson (2003) emphasizes, implies recognizing that the environment is a social construct on which we act, change and reconstruct through our actions. For this author, it is essential to empower students with scientific knowledge, in order to understand and deal with socio-scientific issues. By learning more about these issues, students will be better prepared to "to understand the underlying issues, evaluate different positions, make an informed decision on where they stand in relation to the issue, and argue their point of view" (Hodson, 2014, p. 70).

Although several authors defend the use of activities that promote sociopolitical action in educational contexts (Blatt, 2014; Hodson, 2003, 2014; Reis, 2014; Schusler & Krasny, 2015), its adoption by teachers is not an easy task. As illustrated by the results of the study developed by Reis (2014), with teachers from the *We Act* project community of practice (aimed at supporting teachers and students of different levels of education - from the first grade of basic education to higher education – taking informed and negotiated actions to address social and environmental issues), the adoption of practices oriented towards informed activism about socio-scientific and social-environmental issues faces several obstacles. Thus, the integration of activities that aim at sociopolitical action requires the teacher to have: knowledge about the interactions between science, technology, society and the environment; a strong belief in their educational potential to empower students as citizens; didactic knowledge to implement initiatives of this nature; willingness and ability to participate in social change (Reis, 2014). For sociopolitical action to be a reality in our classrooms, it is essential that future teachers experience it, in order to understand their potential and build knowledge about how to act in society. As advocated by Hodson (2014), action-oriented education helps students to be prepared and engage in responsible action by developing the competences, attitudes, and values necessary to control their lives. Teaching-learning situations that allow students to act (at school) considerably increases their likelihood of becoming active citizens in the present and in their adult life. For Blatt (2014), understanding current societal issues and preparing for intervention requires a different view of school's role, and of the purpose of education, moving away from standardized testing and adopting a new culture that seeks to create an "activist mentality" in students. This requires a pedagogical approach geared towards environmental action, favouring the development of youngsters' capacities to participate as scientifically literate citizens (Schusler & Krasny, 2015). Schusler and Krasny (2015) found that youngsters, between the ages of 9 and 18 (attending environmental education programs – in formal and non-formal educational contexts – in the United States), developed diverse knowledge, dispositions, and capacities related to science and civic participation, namely to understand problems, to be able to find alternative explanations and to critically debate within a community. Besides this, they also developed critical thinking, allowing them to draw their own conclusions about socio-scientific and socio-environmental issues. Another advantage

ELISABETE FERNANDES LINHARES | PEDRO REIS

related to action-oriented practices is developing the capacity to negotiate with others through democratic processes stemming from concerns centred on social, economic, environmental, moral, and ethical dimensions. According to these authors, environmental action, as a pedagogical approach, takes place in the intersection between youngster's civic engagement and *Inquiry* based science education (Figure 1).
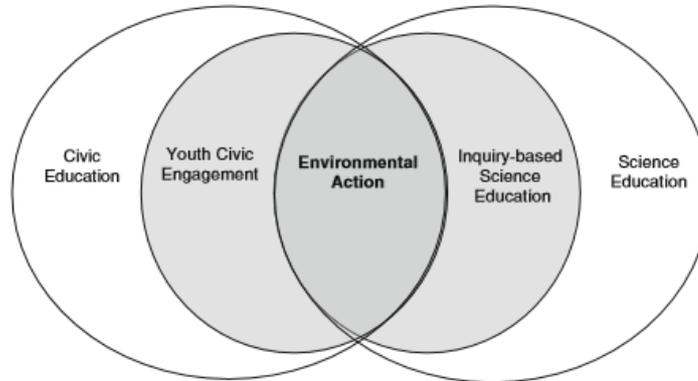
Figure 1. Representative scheme of environmental action occurring at the intersection between youngster's civic engagement and *Inquiry* based science education. Retrieved of Schusler and Krasny (2015).

The processes of doing science and engaging in participatory democracy share many characteristics, such as questioning, understanding systems, considering alternative explanations, and the need to critically discuss issues within a community. Youngsters civic engagement during public consultations and when integrating organizations, fosters their development, as well as stimulates change in society. As stated by Schusler and Krasny (2015), *Inquiry* activities allow students to describe objects, raise questions, construct and evaluate explanations, taking into account current scientific knowledge, and communicating their ideas to others. Thus, "environmental action provides context for learners to engage in scientific inquiry toward specific social purposes" (Schusler & Krasny 2015, p. 367). Students can become co-producers of scientific knowledge when engaged in a process of community action. Simovska (2008) further points out that when students have the opportunity to actively participate in improving the environment during their educational process, they become agents of their own learning and take responsibility in their lives and are able to cope with change.

ACTING IN DEMOCRATIC SOCIETIES

Action-oriented science education implies the transformation of attitudes, values, behaviours and beliefs that awaken the will, desire and ability to act (Ukpokodu, 2009). This study view of science education aims at the expansion of democracy and democratic citizenship. Democratic citizenship means that the actors are responsible and able to engage in social problems on scientific and technological issues.

In Dewey's view, school is an especially primed institution to ensure the principles of a democratic society. It is through schools that society is transformed, emphasizing its very important role in the production of social change (Dewey, 2005). This same author argues that such a function is only possible if a transformation occurs in what is the essence of the school purpose. A society with these characteristics should offer a type of education that provides individuals with personal interest in social relationships, and reasoning competences that ensure social change (Paraskeva, 2005).

Carter, Rodriguez and Jones (2014) argue that transformative learning theory provides a relevant framework for students to raise their awareness about current science issues, enabling them to take informed decisions necessary for sociopolitical action. Transformative learning requires the direct intervention of the individual, enabling him to develop the competences and dispositions for critical reflection. These premises are essential components for democratic citizenship (Mezirow, 2003). In this sense, it is a process where the acquired problematic reference frameworks (assumptions and expectations) are transformed in order to become more reflective. This change in reference frameworks guides the learners action (Mezirow, 2000).

Carter et al. (2014) identify four fundamental characteristics in the interpretation of transformative learning theory - critical reflection, disorientation and conflict, emotional self-learning and focus on action. Reflection developed in this process stems from a dilemma, or confrontation, that encourage students to identify and critically review their ideas. Beliefs, emotions, and knowledge about a particular issue are questioned. Reflection and construction of new knowledge allow for the emergence of alternative viewpoints. Thus, the authors conclude that "where personal framework, beliefs and values are changed, action and activism is much more likely" (p. 537).

For Freire (1967), education for democracy should offer the learner the necessary tools to engage in discussions about the issues affecting society. In this perspective, it is important to educate the student about existing dangers, and to enable him to intervene instead of submitting himself to other's guidelines. It is an education for dialogue, focused on the constant critical reflection about the reality we live in, and guided towards change. This same author argues that education must lead man to engage in changing society, in his context, emphasizing the power of transformation of reality by man, which can only occur in a society where relations between subjects are not of domination. In a problematizing education, the way each actor in the educational process perceives the world around him dictates his way of acting (Freire, 1987).

METHOD

The qualitative nature of this case study means that its direct data source is the natural environment in which it takes place, during which a rich and detailed description of the context and data are obtained, in order to generate meaning (Bogdan & Biklen, 1994). Ponte (2006) characterizes a case study as a well-defined entity (in this case, a class from the 1st year of the Basic Education Degree program attending an Ecology course), which is assumed to be particularly singular, and where one tries to discover what characterizes it, as well as to understand the participants points of view. As Ponte (2006) concludes, it

ELISABETE FERNANDES LINHARES | PEDRO REIS

is hoped that the case study will contribute to a better understanding of the problems of practice, helping to understand certain aspects of everyday reality related to the training of future teachers for sociopolitical action. The purpose of this study is to identify the potentialities and limitations associated with the use of interactive science exhibits, in the training of future teachers for sociopolitical action. In order to reach this objective and to study the implications of the implementation of the "Geoengineering: Climate Control" module of the IRRESISTIBLE project, we collected data from participant interviews, a final evaluation questionnaire and participant observation. The choice for semi-structured interviews as the main technique for data collection is related to the possibility of expanding viewpoints and opinions regarding the phenomenon under study (Gray, 2012). According to Quivy and Campenhoudt (1992), its main advantages are due to the depth of the collected contributions, and the respect for the interviewees reference frameworks. The administration of a final evaluation questionnaire aimed at accessing the visitors' opinions, allowing for a considerable number of individuals to be questioned in a short time (Quivy & Campenhoudt, 1992). Participant observation sought additional information about the study for its better understanding. As Gray (2012) points out, observation allows us to go beyond people's opinions and interpretations about their own attitudes and behaviours, allowing us to evaluate their actions. This method allows the capturing of behaviours as they occur (Quivy & Campenhoudt, 1992). Observation involves a systematic look at people's actions and the recording, analysis, and interpretation of their behaviour (Gray, 2012). Observation data was recorded using field notes.

The study included 19 participants, students of initial teacher training, from a 1st year course on Ecology from the Degree in Basic Education program. The exhibition had as target audience students of the 3rd Cycle of Basic Education (a group of the 8th grade) and Secondary (a group of the 12th grade). However, the interactive exhibition was open and divulged to all citizens who had an interest in visiting it.

Data sources were submitted to content analysis complemented with a statistical analysis (Bardin, 2009). The quantitative treatment can suggest trends and descriptive information about the participants and their perceptions. The entire process of analysis sought to systematically organize the collected data in order to increase its understanding through reduction (Bogdan & Biklen, 1994).

INTERACTIVE SCIENCE EXHIBIT DEVELOPMENT PROCESS

Planning, designing and implementing an interactive science exhibit on the topic of Climate Geoengineering (CG) came about following the proposal introduced in the "Geoengineering: Climate control?" module as part of the IRRESISTIBLE project. The exploration of the module followed an *Inquiry* Based Science Education strategy (5E model) to which the *Exchange* and *Empower* phases were added. All phases were thoroughly explained to the class and, over the course of eight weeks, all work was developed around this issue, in order to arouse the interest and deepen the future teachers' knowledge. In order to achieve the proposed tasks, the class was organized into four to five-member working groups.

The didactic approach involved several stages that are schematically presented in Table 1.

Table 1

Schematic summary of the main activities developed during the module

Phases	Activities and tasks
Engage	- Identification students' prior knowledge - Analysis of cartoons, videos and newspaper articles
Explore	- Research on CG techniques through guiding questions; - Experimental activity: "Albedo and the effect of surface colour"
Explain	- Construction of a collaborative document about the studied techniques (*Popplet* and *Glogster*); - Presentation of the document and group discussion
Elaborate	- Introduction of the RRI concept; - Analysis of CG news in the world and class discussion
Exchange and *Empower*	- Planning and developing the final interactive exhibit
Evaluate	- Concept net, poster; discussion activity; evaluation of the exhibition artefacts and of the exhibition itself.

In order to recall the theme of Climate Change, a task was proposed to the students where they had to define this concept based on their previous knowledge, and then compare it with the definition used by the Intergovernmental Panel on Climate Change (IPCC). The group was also reminded to include the layers that make up the atmosphere, and to provide captions to a figure illustrating a model of the natural greenhouse effect impact, as well as other factors in the energy balance of the climate system, including the main greenhouse gases.

In the *Engage* phase, each group had the task of analysing a *cartoon*, related to the issue being studied, and interpret its message. Their ideas were later shared within the class. After this first contact with the module topic, in pairs, the students explored some resources about CG with the purpose of elaborating a concept net in *Popplet*, in order to display their initial understanding. The concept net elaborated by each pair was presented and discussed in the class. The *Explore* phase sought to deepen students' knowledge of CG, understanding that there are a number of CG strategies that are being researched. Each group, based on their research about the technologies used in one of the CG categories - removal of CO_2 from the atmosphere and management of solar radiation, prepared a collaborative document in the form of a poster (built with *Glogster software*). A second stage of this phase consisted in an experimental activity for the future teachers to research the effect of surface colour in the Albedo, with the goal of restructuring the knowledge built about one of the strategies of Solar radiation management - painting the roofs white. In the *Explain* phase, the groups presented and discussed the ideas included in the *Glogster* posters and answered an online questionnaire (elaborated by each group) about the techniques that each group explored in their posters, in order to assess their learning and to evaluate the effectiveness of the presentations. Each student also had to elaborate a new concepts net about their learning until that moment. The introduction of RRI happened during the *Elaborate* phase through the reading of texts, and the discussion of the dimensions that integrate RRI

using a matching activity. In order to enrich this phase, participants were also requested to research and analyse news about CG strategies that have been implemented worldwide, in order to reflect about the consequences of its use in social, environmental and ethical terms, and to understand who participates in this process. Finally, a discussion activity was carried out in the form of role-playing for a deeper understanding of the problem. Exposure to planning, designing and facilitating the exhibit still integrates the *Elaborate* phase, and corresponds to the *Exchange* and *Empower* phases. With this exhibit, the future teachers are expected to share with the community their research results, and communicate the knowledge they have built. The preparation of the exhibition took place over two weeks. During the period of planning and design, the teacher clarified doubts and guided the work of all the groups both inside and outside the class, meeting with the work groups and sending written feedback by e-mail. Through this collective action, we intend to promote the visitors' awareness regarding this issue, and simultaneously contribute to solving problems affecting our society. The last phase, *Evaluate*, was carried out during the whole module, through the evaluation of the various products and tasks completed by the future teachers. The future teachers' progress was assessed against established learning objectives, creating opportunities for to reflect about their performance (Reis & Marques, 2016a).

RESULTS AND DISCUSSION

LEARNING OUTCOMES AND ENGAGMENT IN SOLVING SOCIAL PROBLEMS OF SCIENTIFIC AND TECHNOLOGICAL NATURE

The content analysis of the interview transcripts allow to detect the following main lessons learned by the future teachers during the development of interactive science exhibits: a) deepening/consolidating knowledge (N=9); b) organizing an exhibit (N=7); c) communicating (N=3); d) explaining the problem (N=2); e) importance of collaborative work (N=2); f) adapting to the age group (N=1); and g) citizens' duty to participate (N=1) (Table 2).

Table 2
Future teacher's opinion about main lessons learned from the exhibit

Category	N	%
Deepening/consolidating knowledge	9	47,4
Organizing an exhibit	7	36,8
Communicating	3	15,8
Explaining the problem	2	10,5
Importance of collaborative work	2	10,5
Adapting to the age group	1	5,3
Citizens' duty to participate	1	5,3

Legend: N - number of future teachers who mentioned a particular category.

Many of the above-mentioned learning instances are related to active citizenship competences that the students recognize they developed. According to the respondents, the exhibit allowed them to deepen and consolidate their knowledge during the "Climate Geoengineering" module. As the future teachers are not only the exhibit facilitators, but also the ones who produce and create the visitors experience, they are encouraged to research, organize and systematize information, explaining the various CG techniques, and communicate this information in an understandable and adequate way, leading them to learn more about the issue. The knowledge developed during this process is expressed in the following excerpts:

"When a person is explaining something, being able to articulate some discourse, explain things and learn with them. At the same time, we end up interiorizing, this happened to me". (T17)

"I got to understand more about the Geoengineering topic". (T14)

The field notes allow to support the data obtained by the interview, evidencing the knowledge built by the future teachers, namely in terms of the advantages and disadvantages associated with CG techniques. However, they add information about the process developed, since, at an early stage, some students have shown difficulties in understanding the subject. As the tasks were being carried out, accompanied by discussion in the classroom and feedback from the teacher, the difficulties were overcome.

"In general, the class is able to understand the various techniques involved in the CG, identifying advantages and disadvantages. When I presented the problem that we were going to study, I found that no one had heard of this area of research. Little by little, and after doing some tasks, the groups that showed some difficulties in understanding the theme (through the work and interventions) ended up overcoming their main shortcomings". (Field notes, April 24, 2017)

The competence to organize an exhibition was the second most mentioned category (N=7). In fact, the students were confronted with a reality unknown to the majority – organizing an exhibit, becoming aware of all the work required by such an initiative, in particular, the importance of adequate planning and time management.

"It's a little bit hard to organize exhibits, isn't it, once we have the objectives, we have to follow certain phases and so I think that this was the main thing I became aware of, how important it is to have everything organized, that is, to have time well distributed". (T4)

"All the work in the background! I had no idea that for such a small exhibit there was so much background work, from the teacher and ours!". (T6)

Communicating was also a competence emphasized by the future teachers (N=3). Thus, if the expression of ideas was initially seen as difficult, this experience allowed to overcome it. The exhibit provided an interaction with the visitors, which ended up developing the students' communication competence, allowing them to gain confidence to express their ideas.

"The first step is really hard, because after that it is really easy to talk with other people, and if people show interest it's very good, because we feel we are spreading a very important message!" (T5)

"Concerning the issue of being able to talk to… other people… unknown (…) It helped me a little bit to work on the part of… not being at ease, of feeling more restrained". (T18)

In the process of interacting with the target audience, another lesson expressed by the future teachers was related to their ability to explain the problem (N=2) and to answer questions posed by the visitors. Notwithstanding this insecurity, the participants considered that they have overcome this limitation by explaining the problem adequately and becoming more comfortable doing so as they further interacted with the public.

"(…) initially I was very concerned, how would it be explaining to the students and making them understand, or some doubts that they might have, not being able to answer (…) the best part of the experience was this one. It was being more at ease and becoming more confident". (T16)

"With them [visitors], we learned how to explain, and present the work". (T19)

The science exhibit also allowed future teachers to work collaboratively (N=2), to adapt their intervention to different age groups (N=1), as well as to become aware of the duty of all citizens to participate in solving problems affecting society (N=1).

"It's very important to work in a team". (T2)

"(…) we had the chance to engage with other age groups, I for example had never had the opportunity to interact with a group of much older kids". (T13)

"I learned that people should show more interest and should get more engaged in the issues, in society, because it is also something that affects them, that affects all of us". (T1)

Regarding the potentialities emphasized by the future teachers, the answers were organized in the following categories: a) knowledge (N=9); b) raising interest (N=4); c) raising awareness (N=2); and d) satisfaction (N=2) (Table 3). The references related to the knowledge provided by interactive science exhibits were organized in scientific (N=8) and didactical knowledge (N=1).

Table 3
Potentialities attributed to interactive science exhibits

Category	Subcategory	N	%
Knowledge	Scientific	8	42,1
	Didactic	1	5,3
Raising interest		4	21,1
Raising awareness		2	10,5
Satisfaction		2	10,5

Legend: N - number of future teachers who mentioned a particular category.

With the exception of one respondent, for whom these experiences may encourage future teachers to adopt lecturing as a teaching strategy in their classes, the others valued the exhibits as a dynamic strategy to facilitate learning.

"If they have a good experience with the exhibits, later and in the science domain, in this case, they will also like to be the ones making certain exhibits. If they think they will benefit from it (…) it's a good teaching tool that they can later reproduce". (T16)

"In an interactive exhibition (...), as I have a participative role, I end up getting better knowledge and I can put the doubts (...), and I think this is important because it is possible to consolidate the knowledge better". (T4)

According to the future teachers, this type of initiative has another advantage, which is the fact of raising the visitors interest. Because it is able to stimulate the interaction among visitors, and between these and the artefacts, it becomes more appealing and grabs the visitors' attention.

"If it's a more monotonous thing, there's a tendency to divert attention to other things that are happening; if it's a more interactive thing, the person is more focused on what is happening at that moment in that station". (T6)

ELISABETE FERNANDES LINHARES | PEDRO REIS

"An exhibit arouses interest. That is, addressing a subject that is not known, and if it is in an interactive format, if it uses multimedia or other kind of support, it ends up almost requiring the person to react to it." (T17)

Another benefit of the exhibit is related to the awareness it raises in visitors through the shared knowledge, discussion, and reflection promoted about the addressed issue. This way, future teachers hope that their action alerted others about the issue, so that they can play an active role in addressing it, and thus introduce improvements in society.

"Alert someone to the problem and try to show, in this case, how harmful it is" (T2)

"(…) were able to became aware and stay alert to this problem, and may in the future use some of the things they have learned" (T4)

The future teachers also highlight the visitors' satisfaction, evidenced through their engagement in the various activities designed by the students. This students' perception is confirmed by the evaluation carried out by the visitors at the end of the exhibit, as illustrated by the data that will be presented in the section on evaluation (exhibit impact on visitors).

DESIGNING AN INTERACTIVE EXHIBIT AS A STRATEGY OF ACTIVE PARTICIPATION AND SOCIAL ACTION FOR FUTURE TEACHERS

Future teachers considered that features related to design – time management (N=7), artefact (N=7), and the exhibit itself (N=2); group work – between group members (N=6) and between groups (N=2); facilitating the exhibit – communication (N=3), group organization (N=2) and time management (N=1), are unfavourable factors to the achievement of an interactive exhibit (Table 4).

Table 4

Unfavourable factors to the achievement of an interactive exhibit

Category	Subcategory	N	%
	Time management	7	36,8
Design	Artefact	7	36,8
	Exhibit	2	10,5
Group Work	Between group members	6	31,6
	Between different groups	2	10,5
Facilitating	Communication	3	15,8
	Group Organization	2	10,5
	Time management	1	5,3

Legend: N - number of future teachers who mentioned a particular category.

Time management was mentioned by the students as one of their biggest challenges. They struggled to have everything ready for the exhibit set up, making them unable to include some of the things they would have liked. For some groups, this problem was also related to their lack of organization.

> "*Even in the set up. It was a lot to do! We had to assemble the exhibit, and then we wanted to do things that we didn't do because there was no time*". (T5)

> "*We left a lot of things for the last minute! Everything was a rush, some of us were organized, others weren't and we weren't together, it seems that things get more difficult*". (T11)

The artefact design was also, for some students, a difficult process requiring adjustments and input from the teacher to overcome some difficulties. Two students mentioned their lack of knowledge about the procedures to design an exhibit, as well as the complexity associated with organizing the exhibit space, and the interconnection between different sections.

> "*In the beginning, I felt I hasn't understanding anything about Kahoot! (…) But after, with the teachers help, I did it. After all it wasn't that hard to move!*". (T8)

> "*(…) it was hard to organize the space as well as to interconnect all the groups*" (T16)

Reconciling all group members availability was difficult, making group work sometimes problematic to organize. It was also difficult for different working groups to articulate and share their work with each other (as planned in the classroom) in order to achieve a more coherent and relevant final result.

> "*We would meet now and again during our free afternoons, we tried to reconcile our time with other tasks, each other's time-schedules – sometimes it was not easy!*". (T1)

> "*[Between different class groups] we have to articulate different ways of being, and effectively, when there isn't an agreement, either each person gets involved in a certain way, and there were people that got more involved and participated, while others didn't*". (T 17)

Communication was considered by three students, during the facilitating phase, as a factor that could hinder the exhibit, given some facilitators struggles to express themselves and explain the issues. Another problem identified by the students was

related to the lack of organization in some groups. In a specific case, this even prevented parts of the artefact to be ready in a timely manner. For one of the participants, the lack of time to properly explore all exhibit areas was the reason for a less profound and enriching experience.

"(…) *when presenting, which is where I struggle the most to explain the techniques and how things are organized*". (T15)

"(…) *organization was not up to our expectations, given that at the time it was all supposed to be ready, it effectively was not.*" (T4)

"*If we had more time …maybe things could have been better explored* (…)." (T18)

The difficulties related to time management and communication were also dimensions registered in the field notes. The problems mentioned focus on the lack of groups' organization in order to finish on time the tasks and oral communication:

"*The process developed until the final stage of exhibition's development was not easy. The class only became aware of the work to be done for the exhibition previous day of its development, despite constantly alerting and advising the working groups about the need to send me the objects built. Despite the difficulties, some groups struggled in the final phase of the work: the exhibition was completed on time and the space was pleasantly well organized. Many groups did not share with me the fears they had and their anxiety, because they had to accompany students of different levels of education, explaining the problem and interacting with them ... I only understood this at the end, when some students admitted that this dimension - communication oral - was their great fear, but they quickly overcame it*". (Field Notes, June 30, 2017)

EXHIBT IMPACT ON VISITORS

In the interview, for 16 of the 19 future teachers, the exhibit had the intended impact, two of the participants did not answer this question, and one admitted not being sure about the exhibit impact saying *"I do not know exactly what impact it had on the public that came here (...)"* (T18). However, he also acknowledges that *"it must have had some impact ..."* (T18) on the visitors, mainly because he considered the issue to be new to them.

Most future teachers (N=14) considered visitors learning as the main exhibit impact, followed by the interest it may have aroused in the target audience (N=11). Exploring the

exhibit allowed visitors to understand an issue that was new to them. Their interest could be perceived through their attention and questions raised.

> "*By chance, I knew two people that came to visit and asked them if they had liked it, and if they understood the topic, and they said that they did, and that they liked it a lot* (…)". (T14)

> "*In general, I found that students were motivated, that they listened and participated. Teachers said the same (…) they wanted to see the procedure of the experience so that they could reproduce it, in their classes, and of course all these comments show that it had a positive impact in the students that were there* ". (T16)

The exhibit acted as a way to raise awareness in the community to the issues being presented, and through the reflection it promoted. This way, it might have helped participants (visitors and facilitators) to elaborate an opinion about the issue.

> "(...) *they become more aware, and I think that they started thinking differently*". (T2)

> "*It might have changed the visitor's opinions, and even the opinion of those involved!*". (T14)

The written evaluation of the exhibit allowed the collection of 33 visitors answers. In this questionnaire, the evaluated criteria focused on the Exhibit characteristics. For this purpose, a Likert scale was used with the levels "insufficient, reasonable, good and excellent". The questions sought information on the aspects that they liked the most, and least. They were also asked to include any suggestion that they might consider relevant for the improvement of this experience.

All criteria were positively assessed by the visitors, who did not select the "insufficient" level for any of the characteristics indicated in the evaluation table (Table 5).

Table 5

Visitors evaluation of the interactive science exhibit

Criteria	Insufficient	Reasonable	Good	Excellent
Educational			17 (51,5%)	16 (48,5%)
Interactive		2 (10,5%)	16 (48,5%)	15 (45,5%)
Informative		1 (3%)	8 (24,2%)	24 (72,7%)
Innovative		3 (9,1%)	14 (42,4%)	16 (48,5%)
Fun		3 (9,1%)	12 (36,4%)	18 (54,5%)
Attractive		5 (15,2%)	15 (45,5%)	13 (39,4%)
Interesting		3 (9,1%)	11 (33,3%)	19 (57,6%)
Clarifying		1 (3%)	18 (54,5%)	14 (42,4%)

FINAL REMARKS

Planning, designing and facilitating interactive science exhibits supported the future teachers development of a diverse set of skills, fundamental for changing attitudes towards issues affecting society. Lessons learned on Climate Geoengineering and Responsible Research and Innovation were essential to get to know and understand the scientific issue, in order to design a relevant and interesting exhibit. In this way, the knowledge built on the socio-scientific issue studied was fundamental to their understanding (Hodson, 2014). The purpose of the IRRESISTIBLE project was thus achieved, by verifying that whole process around the exhibit raised awareness to the issues being studied, and helped to realise that all research and innovation should be guided by responsibility principles (Reis & Marques, 2016a). Through the exhibit, the study participants had the opportunity to participate in collective community action on a controversial issue, functioning as a platform for raising awareness and providing information for the community and themselves (Reis & Marques, 2016b). Therefore, particular attention should be given to planning, designing and creating the exhibit. Artefact characteristics are emphasized by future teachers, as fundamental factors to the implementation of an exhibit, similarly to Reis and Marques (2016b). Artefacts should actively engage the visitor, stimulating reflection about the experience. Digital resources also play a key role in the design of the artefact, given that they can help to attract the visitors'attention, and provide a better visually representation of what is intended (Reis & Marques, 2016b).

Among the limitations pointed out by future teachers, the main problems when organizing an exhibit are related to inadequate time management of group work, that often procrastinated their tasks. Therefore, the future teachers should better organize their time, in order not to compromise the quality of their work. Consequently, the way groups are organized is crucial, since it is often difficult to articulate tasks between all group members, and between groups. One way to better support and ensure the sharing and exchange of ideas within groups could be through the inclusion of more classroom work classes during the two weeks dedicated to the design of the exhibition. This could also help groups to find solutions to the problems faced during the design of their artefacts, namely using technological tools (although most of them have been explored in classroom with the whole class). For the exhibit facilitation, it is important to provide future teachers with situations that allow the development of oral communication and interaction between different groups of visitors, in order to overcome their shyness and interaction challenges. For exhibits to be more successful, visitors must be available in order to interactively engage with the proposed artefacts, as well as include time for reflection and discussion. This experience was very restricted in the exhibit held by the future teachers, because the visiting groups had very limited time to explore the artefacts, recognizing that its purpose may have been compromised, given the more superficial and less reflected approach used. The evaluation carried out at the end of the exhibit confirms the positive impact of the future teachers on the visitors. All visitors who responded to the questionnaire (on paper) positively evaluated the initiative presented by the class, namely in the criteria related to its educational, informative, interesting and clarifying characteristics. This data illustrates how implementing interactive science exhibits, especially contributes to raise awareness and promote critical reflection.

However, this training experience turns out to be insufficient to have a more reflected and effective influence in these future teachers' practices.

Thus, teacher education has an important role to play in this area, and should provide students with more teaching-learning scenarios that provide the opportunity to develop knowledge on how to approach Responsible Research and Innovation (related to cutting-edge science and technology issues) through the construction of exhibits centred on these issues with *Inquiry* based activities (Reis & Marques, 2016b).

As discussed by Carter et al. (2014), in their study with initial teacher training students, when they are exposed to relevant issues and include critical reflection, their existing frameworks are questioned regarding their knowledge, understanding and opinions. This way, the produced confrontation encourages students to act. The development in students, future teachers, of a new awareness towards social and educational realities, based on current social issues, works as an incentive for transformation. In fact, transformative learning theory provides a powerful framework to promote students' awareness about current social and socio-environmental issues, contributing to informed decisions that lead to sociopolitical action.

Framed by the problematizing education of Freire (1987), it is concluded that the interactive exhibition had an important contribution in the formation of another view of the future teachers on the problem studied, providing them with skills to participate in changing society.

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