EXPLORING HIGH SCHOOL TEACHERS' AND STUDENTS' EXPERIENCES IN THE DEVELOPMENT OF INTERACTIVE EXHIBITS ON NANOTECHNOLOGY APPLICATIONS INTEGRATING RESPONSIBLE RESEARCH AND INNOVATION: PRACTICAL APPROACHES, CHALLENGES AND BENEFITS

by

Büşra Açıkel

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ABSTRACT

EXPLORING HIGH SCHOOL TEACHERS' AND STUDENTS' EXPERIENCES IN THE DEVELOPMENT OF INTERACTIVE EXHIBITS ON NANOTECHNOLOGY APPLICATIONS INTEGRATING RESPONSIBLE RESEARCH AND INNOVATION: PRACTICAL APPROACHES, CHALLENGES AND BENEFITS

The present study was designed to explore the knowledge and experiences of a group of high school teachers and students about exhibitions, interactive and science exhibitions before and after *the development and exhibiting of interactive science exhibit on nanotechnology applications integrating Responsible Research and Innovation (RRI)*, their practical approaches in the process, challenges they faced in the process, and benefits they obtained from the process. The data from 3 high school chemistry teachers and 13 high school students were collected through the pre and post interviews, video recordings of the school club periods and meetings held by the teachers, weekly logs filled by the participants, field notes and the exhibits developed by the students. First, the results of the content analysis indicated that there was a remarkable improvement in the participants' understandings of exhibition, interactive exhibitions and science exhibitions especially in terms of roles of exhibition, the types and benefits of interaction and methods used. Secondly, the researcher identified many common and different practical approaches taken by the participants during the process and classified them under themes depending on different phases of the process like *Practical Approaches in Planning of Exhibit,* and into sub-themes basing on a certain aspect or task such as *Practical Approaches in Making Exhibits Interactive*. Thirdly, the analysis revealed some challenges the participants confronted with in the process, which were categorized under 6 themes building on challenges in different stages of the process like *Challenges in the Stage of Production of Exhibits*, and into 11 sub-themes referring challenges in specific task or facet of the process such as *Challenges in Integration of RRI.* Finally, the benefits identified were sorted into 5 themes such as *Increase in Awareness and Motivation,* and into 19 sub-themes like *Doing Self-reflection and Self-evaluation*. Different as well as common challenges and benefits identified for the participants are explained, discussed and exemplified under different sections regarding the teachers and students.

ÖZET

LİSE ÖĞRETMEN VE ÖĞRENCİLERİNİN NANOTEKNOLOJİ UYGULAMALARINA SORUMLU ARAŞTIRMA VE İNOVASYONU ENTEGRE EDEN ETKİLEŞİMLİ SERGİ ÜRÜNÜ GELİŞTİRME SÜREÇLERİNDEKİ DENEYİMLERİNİN İNCELENMESİ: UYGULAMA YAKLAŞIMLARI, ZORLUKLAR VE KAZANIMLAR

Bu araştırma bir grup lise kimya öğretmeni ve öğrencisinin *nanoteknoloji uygulamalarına Sorumlu Araştırma ve İnovasyon temasını entegre ederek etkileşimli sergi ürünü geliştirme ve sergileme* süreci öncesi ve sonrasında sergi, etkileşimli sergi ve bilim sergisi hakkında bilgilerini, süreç içerisindeki uygulama yaklaşımlarını, karşılaştıkları zorlukları ve bu süreçteki deneyimlerinden elde ettikleri faydaları araştırmak üzere tasarlanmıştır. Bu amaçla, 3 lise kimya öğretmeni ve 13 lise öğrencisinden ilk ve son görüşmeler, okul kulüp saatlerinin ve öğretmenlerle yapılan süreç içi toplantıların video kayıtları, katılımcılar tarafından doldurulan günlükler, alan notları ve öğrencilerin geliştirmiş oldukları sergi ürünleri ile veri toplanmıştır. Veri analizi sonuçları, katılımcıların sergi, etkileşimli sergi ve bilim sergisi konusundaki bilgilerinde özellikle serginin rolü, etkileşim türleri, avantajları ve kullanılan yöntemler açısından önemli ölçüde gelişme olduğunu göstermektedir. İkinci olarak, araştırmacı katılımcıların süreç içerisinde göstermiş oldukları birçok uygulama yaklaşımını belirlemiş ve bunları *Sergi Ürünü Planlamasındaki Uygulama Yaklaşımları* gibi sürecin farklı aşamalarına bağlı olan temalar altında ve *Sergi Ürününün Etkileşimli Yapılmasındaki Uygulama Yaklaşımları* gibi süreçteki belirli bir göreve dayanan alt-temalar altında sınıflandırmıştır. Üçüncü olarak, katılımcıların süreç içerisinde karşılaştıkları bir takım zorluklar tespit edilerek *Sergi Ürünlerinin Yapım Aşamasındaki Zorluklar* gibi sürecin farklı aşamalarındaki zorluklar üzerine yapılandırılan 6 tema altında ve *SAİ Entegrasyonundaki Zorluklar* şeklinde sürecin belirli bir yönünde ya da süreçteki belirli bir görevdeki zorluklara dayanan 11 alt-tema altında sınıflandırmıştır. Son olarak, katılımcıların elde ettikleri faydalar *Farkındalık ve Motivasyonda Artış* gibi beş temada ve *Öz-yansıtma ve Öz-değerlendirme Yapmak* gibi 19 alt-tema altında toplanmıştır. Süreç içerisindeki ortak zorluklar ve faydaların yanı sıra tespit edilen farklılıklar öğretmen ve öğrencilere ilişkin çalışmanın ayrı bölümlerinde açıklanmış, tartışılmış ve örneklenmiştir.

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LIST OF ACRONYMS / ABBREVIATIONS

AAAS	American Association for the Advancement of Science
AFM	Atomic Force Microscope
CoL	Community of Learners
EU	European Union
FP7	7^{th} Framework Programme for Research and Technology Development
IE	Interactive Exhibition
ITU	İstanbul Technical University
NASTS	National Association for Science, Technology and Society
NCISE	The National Center for Improving Science Education
NGOs	Nongovernmental Organizations
NSF	National Science Foundation
NST	Nanoscience and Nanotechnology
NSTA	National Science Teacher Association
RQ1/2/3/4/5/6	Research Question 1/2/3/4/5/6
RRI	Responsible Research and Innovation
SEM	Scanning Electron Microscope
SH1/2/3	School 1/2/3
SH1/2/3E1/2/3/4	School 1/2/3 Exhibit 1/2/3
SH1/2/3G1/2/3/4/5	School 1/2/3 Group 1/2/3/4/5
SH1/2/3S1/2/3/4/5/6	School 1/2/3 Student 1/2/3/4/5/6
SH1/2/3T1	School 1/2/3 Teacher
SSI	Socio-Scientific Issues
STS	Science-Technology-Society
STSE	Science, Technology, Society and Environment Approach
TUBITAK	The Scientific and Technological Research Council of Turkey
US	United States

1. INTRODUCTION

The exhibitions created by students are more common on art or history whereas the ones focusing on science are less frequent (Kampschulte & Parchman, 2015).Yet, science fairs have begun to gain more attention all around the world and are getting popular day by day (McComas, 2011). On the other side, although Nanoscience and Nanotechnology (NST) are among rapidly developing areas, and gain public and media attention recently, projects or educational programs encouraging students to develop exhibits on NST are limited (Kampschulte, 2015; Laherto, 2011; Tirre *et al.,* 2015; Yeh *et al.*, 2011). Furthermore, when it comes to science, it brings socio-scientific issues (SSI) together. In this manner, since 2010, Science in Society Action Plan, managed by European Union, has focused on developing the framework of "*Responsible Research and Innovation*" (RRI), which brings a broader perspective to SSI by referring a research and innovation process at which all societal actors work together and are mutually responsive to each other from the beginning to the end in order to align better both the process and its outcomes regarding values, needs and expectations of the society as well as great challenges and problems of our time (European Union, 2012; Sutcliffe, 2011; von Schomberg, 2013). Recent emphasis on RRI promoted its integration in education through numerous projects funded by the European Union. The Project IRRESISTIBLE, which is one of these projects, aims to raise awareness on RRI by increasing students' content knowledge on cutting-edge science topics and by encouraging discussion among students on introduced topics within a RRI perspective (European Union, 2017a).

The present study, which is conducted under the Project IRRESISTIBLE, is structured around qualitative method with the approach of phenomenological research. This study was designed to explore the knowledge and experiences of a group of high school chemistry teachers and students about exhibitions, interactive exhibitions and science exhibitions before and after *the development and exhibiting of interactive science exhibits on nanotechnology applications integrating RRI*, their practical approaches in the process, challenges they faced along the process, and benefits they obtained from their experiences in the process.

This study has a potential to contribute to the literature through exploration of high school students' and teachers' knowledge on exhibitions and their experiences in interactive science exhibit development and in a science fair because as Şahin (2012) pointed out most of the research studies on science fairs involve elementary school students. Besides, this study contributes the literature also through inclusion of Nanoscience and Nanotechnology (NST) in its scope because as it was remarked in the beginning studies involving teachers and students, who develop exhibits on NST are very limited (Kampschulte, 2015; Tirre *et al.,* 2015; Yeh *et al.*, 2011). Finally, this study contributes in the literature through examination of students' experiences in integration of Responsible Research and Innovation (RRI) in their exhibits. Consequently, this research introduces some innovative elements, such as RRI integration, interactive exhibit and cutting-edge science theme, to the literature on science fairs.

2. LITERATURE REVIEW

This section of the study is intended to provide a summary about the related literature, which consists of an overview on exhibitions, student-created exhibitions, science fairs, views and experiences of teachers on science fairs, views and experiences of students on science fairs, student-created exhibitions on NST, integration of socio-scientific issues (SSI) in science education, RRI, views and experience of teachers on teaching about RRI, and challenges students face when learning about RRI respectively.

2.1. Exhibitions

Exhibitions have been defined as comprehensive grouping of exhibits and displays of industrial or commercial products or artifacts with the purpose of presentation of collections and information for public use (Dean, 1999; Dean, 2002; Khoon and Ramaiah, 2008). Dudley (1990) regards exhibitions, in general, as platforms of promotional events providing curators and target audience to establish a dialog. However, the motivation behind curating exhibition may vary based on content and context. While a commercial exhibition has a goal of financial gain, a public-service exhibition has mission of changing attitudes and behaviors by informing the public (Dean, 2002). On the other hand, visitors attend exhibitions for catching up with recent developments, seeing new products and technologies, gathering ideas and information or just for social reasons (Khoon and Ramaiah, 2008).

2.1.1. Types of Exhibitions

Exhibitions have been mainly classified in terms of the field they are in the scope of. Exhibitions can be developed on any topic or area of interest, but art, history, natural history and science are the most common fields that exhibitions are created on (Falk and Dierking, 2000). Although exhibitions on these disciplines have many common aspects, each has idiosyncratic characteristics as well. For instance, visual discovery of surprising and unexpected works of art is an aspect of visiting an art exhibition (Schwartz, 2006). Art exhibitions are usually in attempt to reveal an emotional reaction (Burton, 2006). In contrast to other types of exhibitions, engagement with ambiguity of meaning-making is another central feature of an art exhibition (Siegel, 2006). Exhibitions on history, more than exhibitions on science and art, engage with content that is "familiar, personal and fundamentally human" (Filene, 2006, p.21). Besides exploring class, genome and species, exhibitions on history has the power of "changing the public understanding of not only of historical events but of how history is written" (Siegel, 2006, p.19). Science exhibitions, however, are organizations where the visitors have the role of explorers of scientific instruments, experiments, equipment, laboratory reagents, industrial devices or recent scientific developments (Science Exhibition, 1946). They gain insight about the nature of science through their experience. Each element and certain practices in a science exhibition belong to 'the proper realm of science' and as opposite to art exhibitions, lack of clarity in a science exhibition is considered as a failure (Macdonald, 1998, p.2; Siegel, 2006). Although "science fairs" and "science research competitions" are used interchangeably with "science exhibition" (McComas, 2014), they have different specifications and therefore should be regarded as some other forms of science exhibition instead. In science fairs, exhibits are mostly models and demonstrations of actual experiments and participants are usually evaluated on the work they had done and communicating findings both verbally and visually, however in science research competitions participants are asked to bring a solution to a problem on specific subject or theme (Blenis, 2000; McComas, 2014; Yasar and Baker, 2013). Science museums, science centers, botanical gardens, aquariums and zoos are a kind of permanent science exhibitions, besides they sometimes host temporary science exhibitions as well (Falk and Dierking, 2000).

2.1.2. Interactive Exhibitions

<u>2.1.2.1. Engagement of Visitors in Exhibits.</u> Classification of exhibitions also bases on the level of engagement they provide for visitors besides scope of the subject area. In a traditional exhibition environment, displays can mostly be "described as hands-off" (Rhee and Kim, 2013), however there is a need for transformation of exhibitions from "curator-driven processes" to more interactive one because of struggle they face in meeting highly "participatory culture's" anticipations (McLean, 2011, p.1). In the past, designers were mostly focusing on creating three-dimensional design to present them to visitors' taste, however visitors now are expecting to explore things on their own as they walk around in an

exhibition (Simpson *et al., 2006*). Fortunately, there are new forms of exhibits offering visitors active engagement and participation (Rhee and Kim, 2013).

Bitgood (1991) classifies exhibits in three according to type of response engagement*: simple hands-on, participatory* and *interactive*. *Simple hands-on exhibit* includes physical involvement and produces sensory learning by prompting the visitor to touch, climb etc. *Participatory exhibit,* however, includes visitor's response and aims to teach similarities and differences between objects or phenomena by allowing visitors to make comparisons between their response and some standards. It goes further than simple hands-on exhibits in ensuring active response engagement. Tasting several types of wine and grouping them based on characteristics such as sweetness, acidity and fruit might be an example. On the other hand, participatory exhibition has been used in different meanings as well. McLean (2011) and Simon (2010), for instance, describe experience of participatory museum exhibition as the ones connecting different stakeholders (i.e. creators, distributors and consumers) and visitors by engaging them in conversations to ensure information flow between institutions and users. In addition, Blankenberg (2014) defines participatory exhibitions as where the public participates in creating or delivering and acts as curator in the process through collaboration with museum staff.

The last type of exhibits that Bitgood (1991) defines is interactive exhibit. *Interactive exhibit* includes a cause-effect relation between visitor's response and adjust in exhibit coming after. In other words, visitor's control over exhibit causes a relevant change in it. Interactive computer applications allowing self-testing might be an example for Bitgood's definition. McLean (1993), on the other hand, defines interactive exhibition as "those in which visitors can conduct activities, gather evidence, select opinions, form conclusion, test skills, provide input, and actually alter a situation based on input" (p.93). Visitor's input is a central aspect of interactive exhibits, however, "reciprocity of action", which implies the reaction of exhibit in some way regarding visitor's input, establishes extensive interaction (Allen and Gutwill, 2004, p.199; Bitgood, 1991; McLean, 1993). McLean's (1993) definition involves "mental interaction" besides the "physical interaction" (Bitgood, 1991, p.4) and therefore is adopted in this study.

2.1.2.2. Examples of Interactive Exhibitions. Interactive exhibits are mostly seen in science centers, but their integration in art and history exhibitions as well as in cultural activities is a rising trend (Allen and Gutwill, 2004, Heath and Lhen, 2009). The following examples of interactive exhibitions indicate varying ways of making exhibits interactive. Some examples showed that creating interactive exhibits was also possible with the integration of technology (i.e. Web 2.0 tools and tablet or cell phone applications) in the exhibits in such a way that engaging visitors. For instance, "SNSE (Science Now, Science Everywhere) Overview Panels" established in Liberty Science Center in 2005 permit visitors to retrieve extra content and improve the learning experience by using their mobile phones such that visitors were able to interact with the exhibit through their mobile phones both in and outside of the museum (Labar *et al.,* 2006). In addition, Jeff Kennedy Associates designed an Astronomy gallery, which allows visitors create their own planetarium mini-shows that they can play immediately, in Science Center of Iowa in 2005 (Simpson *et al.,* 2006). Another example of technology integrated interactive exhibit is the "Gallery One", which was developed in 2013, in the Cleveland Museum of Art. "Gallery One" is an art-space letting visitors to examine the permanent collection of the museum through hands-on activities and ArtLense free ipad application (Dawkins, 2014). Finally, in 2015, Modiki Brand and Advertising Agency developed "Sons of Gallipoli", which offers visitors with a multi-layered interactive exhibition through a digital experience with the purpose of sharing memories from the tragedy of Gallipoli during World War I (Kale Group, 2016).

Developing interactive exhibits is also possible with using concrete tools and materials. For instance, in 2013, Miller and Neyer developed "Color Me _ _ _ _ _", which they called as a collaborative exhibit and it is a touring exhibition, at which visitors paint illustrations on walls with giant crayons (Miller, 2013). In addition, "Waste Container" encouraging visitors to design new products from waste material, and "Design Atelier" allowing visitors to develop prototypes of their design projects by regarding mathematical and physical facts are two examples of interactive exhibits, which promote use of concrete materials, in Konya Science Center (KBM, 2017). Finally, in Kid's Research Laboratory of Ars Electronica Center, "Analog 3-D Printer" exhibit, which is a model built from wood panels, hose, metal wires and silicone, allow youngsters to simulate the working principle of 3-D printers (AEC, 2017).

Various examples of exhibitions show that making an exhibit interactive is possible through many ways including from integration of Web 2.0 tools to use of basic materials such as crayons and an empty wall. The materials and tools to be used are restricted with the imagination and creativity of the exhibit developer.

2.1.2.3. Benefits of Interactive Exhibits. Studies on interactive exhibitions revealed some advantages of interactive experiences for visitors, developers and curators. Firstly, providing visitors with an interactive experience they increase the chance of capturing visitors' interest and engagement (Heath and Lhen, 2009; Hein, 2002; McLean, 2011). Bequette and colleagues (2011), who examine the impacts of exhibits about nanoscale science on museum visitors, suggested that the engagement of visitors, especially kids, with an exhibit on a new topic like nanoscience was highly related with the interactive elements of the exhibit. Secondly, involvement in an interactive exhibit helps visitors associate new experience and information with their existing knowledge and conceptual structures (Allen and Gutwill, 2004), and therefore, they find it more relevant (Bequette *et al*., 2011; Hein, 2002). Thirdly, interactive exhibits promote and improve learning by keeping attention of visitors, facilitating meaning making and allowing them to take ownership of their learning process (Allen and Gutwill, 2004; Bitgood 1991; Heath and Lhen, 2009; Labar *et al.,* 2006; McLean, 2011). On the other side, developing an exhibit encouraging visitors to spend time on meaning making is a fruitful experience for designers because it "must present a powerful meaning making" process for them as well (D'Acquisto and Scatena, 2006, p.39; Gilbert and Stocklymayer, 2001). Furthermore, curating an interactive exhibition gives curators an opportunity for presenting a unique experience for each visitor because exhibits are adjusted according to visitor's response and control (Simpson *et al,* 2006). Finally, with an integration of an interactive digital tool, curators can collect data about number of visitors engaged in and time that visitors spent for each exhibit (Labar *et al, 2006*). Evaluation of this data collected through interactive means can enhance the improvement of the exhibitions' quality regarding public interests and needs.

2.1.3. Exhibitions as Informal Learning Environments

Mission of museums has broadened since they established in the 17th century for the first time and their educational aspects has arisen. Early on, museums were the place of preserved knowledge and collection of objects, with the aim of classification and conservation of them (Kampschulte and Parchmann, 2015). However, with the realization of their substantial impact on individuals' learning and engagement, exhibitions in museums and in general have taken their place in education since middle of the 20^{th} century. Educational role of institutions such as museums and galleries was introduced in the sixties through the share of knowledge in collections with visitors and through field trips (Khoon and Ramaiah, 2008). Thereafter, the interest of formal education institutions towards museums as learning environments has decreased. Intense attempt to meet academic standards and do well on national exams resulted in schools sacrificing meaningful learning for test preparation (D'Acquisto and Scatena, 2006). However, students need learning opportunities that let them have active and experiential role both in and out of the school environment firstly because the primary sources of satisfaction and realization are the extracurricular activities and secondly significant amount of an individual's knowledge come from nonacademic sources (D'Acquisto and Scatena, 2006; Falk and Dierking, 2000; Sherburne and Patton, 1971). This is a concomitant outcome of the fact that people spend substantial portion of their time in informal environments from infancy to adulthood (Banks *et al*., 2007).

What is intended with an informal environment and informal learning? There is no clear-cut definition of informal learning that is built on consensus (Hofstein and Rosenfeld, 1996; Türkmen, 2010). Some descriptions of informal learning based on its comparison with formal learning (Stocklymayer and Rennie, 2017). According to such definitions, formal learning takes place in school settings and is compulsory, structured, curriculum-based and assessed; while informal learning occurs at out of school environments such as museums, science centers and zoos, and is voluntary, unstructured, not curriculum-based and unassessed (Şahin and Çelikkanlı, 2014). Hofstein and Rosenfeld (1996) point out such approach as "overly simplistic" (p.89) and give a museum visit as an example as it could be either structured and compulsory or unstructured and voluntary. On the other side, there are definitions showing a "hybrid approach" (Hofstein and Rosenfeld, 1996, p. 90), which signifies "the intersections of formal and informal" learning environment (Avraamidou and Roth, 2016, p.xxii; Türkmen, 2010). In such definitions, informal learning regarded as learning from activities that are not developed primarily for school use and are not part of school curriculum, but can support formal learning, may be structured or unstructured, involves voluntary participation, are student-centered and come up with many unplanned learning outcomes (Crane *et al*., 1994; Hofstein and Rosenfeld, 1996; Yıldırım and Şensoy, 2016).

Hofstein and Rosenfeld (1996) introduces five “learning modes” in the context of informal learning: (i) *school-based field trips,* (ii) *student projects,* (iii) *community-based science youth programs;* (iv) *casual visits to museums and zoos;* and (v) *the press and electronic media* (p.93). Exhibitions as informal learning environments are given place under the mode of “Casual visits to museums and zoos” (Hofstein and Rosenfeld, 1996). Informal environments such as museums, galleries, zoos, science exhibitions and art exhibitions have a great potential for contributing in informal learnings of pupils and adult citizens (Dean; 1999; Heath and Lhen, 2009; Hofstein and Rosenfeld, 1996; Lord, 2014; Molineux, 2014; Padovani *et al.*, 2013; Şahin and Çelikkanlı, 2014). Providing visitors with an informal and comfortable atmosphere help them easily to adapt their surroundings (Dean, 2002). When students enter in such environments, feeling of curiosity and desire for a discovery arise in them (Bevan *et al*., 2010; Czor, 1990). Then, they involve in informal conservations with personnel, peers, family members or teachers to learn about exhibits and inquire them (Wolf and Tymitz, 1979; Yeh, 2017). Besides, answering visitors’ need of “preferred mode of instruction” fitting their own learning styles, and situated, context-based characters of such environments form a base for a meaning-making in informal fashion (Heath and Lhen, 2009; Hofstein and Rosenfeld, 1996, p.88). In addition, examining exhibits in informal environments provide students with the opportunity of relating theoretical information with daily life. Bevan and colleagues (2013) state that collaboration between “science-rich institutions” (p.11) and schools enhance students’ awareness on scientific issues and their relevance with their own life. These characteristics of exhibitions all together provide visitors with an informal learning environment.

The efficiency of exhibitions as informal learning environments might be improvable with the inclusion of interactive elements. Studies on interactive and participatory exhibits show that such exhibits improve the effectiveness of informal settings compared to non-interactive ones because their motivational, engaging, stimulating and entertaining characteristics broaden perceptual opportunities and lead students to spend more time with exhibits (Hofstein and Rosenfeld, 1996; Koran *et al.*, 1986; Macdonald, 1998; Molineux, 2014). These aspects of interactive exhibitions show how integration of engaging components in an exhibit make difference in the quality of transfer of exhibits' messages.

2.2. Student-Created Exhibitions

Besides to students' investigation of exhibits and displays created by others, student-created exhibits and projects are getting more popular day by day. In the following two sub-sections, firstly in detail-descriptions about stages of developing an exhibit are given and then, the benefits of student-created exhibitions are explained.

2.2.1. How to Develop an Exhibit?

In the literature, there are some studies explaining the phases of exhibit development in detail (Burton, 2006; Dean; 1999; Hatcher, 2009). For instance, Burton (2006) summarizes the development process of art exhibitions, "whether presented in schools by students or in galleries and museums by professional curators" (p.2), in 5 steps: *theme development, design, installation, publicity* and *event/assessment.* First, students specify a theme that forms a conceptual base for the exhibition such that rest of the steps of exhibit development are built on; then, students make their design plans regarding their intentions to reach audience and at the installation phase, students create their artworks and the exhibition space (Burton, 2006). After that, exhibition is announced to public through press and digital media such as newspapers, newsletters or brochures, and at the final stage exhibition takes place. Hatcher (2009) consider this process as an opportunity for teachers to assess students' knowledge. Dean (1999) describes a similar outline for developing museum exhibitions. Exhibition project model, as he calls it, is composed of four main phases: *conceptual phase, developmental phase, functional phase* and *assessment phase.* The most remarkable difference of these two approaches is the suggestion of an evaluation report based on developers' self-assessment and suggestions on "improvements of the product and the process" (Dean, 1999, p. 194).

D'Acquisto (2006) examined the whole process of exhibition development in three parts: *pre-production, production, post-production* (D'Acquisto, 2006). Pre-production is the beginning research step, which involves clarifying research questions and gathering, summarizing, analyzing and synthesizing information; Production is the phase where students share tasks and build their exhibit; and Post-production is the stage that students get feedback from visitors to assess their weaknesses as well as strengths (Reis and Marques, 2016). In the research step, students focus on their areas of interest to specify the topic they work on; use diverse resources such as books, magazines, the internet and people having first-hand experience and knowledge on topic to gather ideas and information; then they come together to share their findings and brainstorm on the topic. (D'Acquisto and Scatena, 2006). This process enhances students' information literacy (Marsee and Wilson, 2014). After their research ends, students start to design their exhibits. Before starting to design, D'Acquisto and Scatena (2006) advice a museum trip, if it is possible, in order for students' examination on exhibits in terms of their display techniques, effectiveness, engagement capacity and characteristics increasing their quality. In the design stage, D'Acquisto (2006) suggests students to ask themselves what they will use to give their message, how they will make their exhibit relevant and engaging, how their end-product will look like and whether the completed exhibit serve their goals (Reis and Marques, 2016). In the production phase, students make construction plan including task sharing and due dates, then they should check their progress in accordance with their plan and make adjustments if necessary (D'Acquisto, 2006). In planning stage as well as during the production of exhibit, students need to stimulate their creativity, be persistent and patient (Sherburne and Patton, 1971) and to work in collaboration as a whole body. All students are expected to contribute in some way for the development of the whole project (Lefler, 1956). Although the exhibit should be the original works of students, constant mentorship and feedback of any staff, who can improve the exhibit, is suggested at the production stage (Rogers, 1956). Students may consult with personnel in school like art teacher or with an expert out of school like scientists, engineers and technicians (Rogers, 1956). During the exhibition event, students interact with visitors by asking and answering questions, involving them in a discussion or activity, and guiding them in interpretation of the exhibit (D'Acquisto and Scatena, 2006). Meanwhile, students can assess the effectiveness of their exhibit and their performance through observation, exit survey or questionnaire (D'Acquisto, 2006).

2.2.2. Benefits of Exhibit Development for Students

“Student projects” are one of the “learning modes” as Hofstein and Rosenfeld (1996) reported. Development and preparation of an exhibit or a project is regarded as a powerful vehicle for learning because it is a complex and comprehensive process that demands progress in multiple phases from finding an idea to communicating the theme of end product (D’Acquisto and Scatena, 2006; Dean, 2002; Kampschulte and Parchmann, 2015). Besides, students get a chance of expressing their ideas to the public (Livingood, 1955) and teaching others is one of the efficient way in learning about a subject (Padovani *et al.*, 2013). When the exhibition organization is at international level, students also get chance of meeting students from other nations and learn about their exhibits (Galen, 1993).

Students, who develop exhibits, involve in a real problem-solving, research, designing, writing, interpreting activities as well as teamwork, management and communicating within the procedure (D’Acquisto and Scatena, 2006; Dean, 2002; Hofstein and Rosenfeld, 1996; Livingood 1955; Reis and Marques, 2016). In this sense, developing an exhibit is an opportunity for students to use their knowledge in a meaningful real-life context, which creates a space for independence, imagination and initiative (D’Acquisto and Scatena, 2006; Sherburne and Patton, 1971). In addition, from the beginning to the end, activities students involved in the process of exhibition development allow students to engage in different learning styles (Marsee and Wilson, 2014; Reis and Marques, 2016). These characteristics of developing an exhibit are absent or very limited in traditional formal education students meet at schools (D’Acquisto and Scatena, 2006; Sherburne and Patton, 1971; Ulusoy, 2016).

The overall process of student-created exhibition is a fruitful experience for students from the point of its contribution in their cognitive and affective development. First of all, providing students with a platform, at which they can share their knowledge and creations, and lead others, gives them the feeling that their voices and ideas are valued and matter, and so improves their confidence (Livingood, 1955; Marsee and Wilson, 2014; Şahin and Çelikkanlı, 2014). In addition, students’ involvement in exhibition development improve their skills in finding resources such as budget, time, material and staff; their intrapersonal skills like self-management, taking responsibility and problem-solving; their interpersonal skills such as team working, leading, communicating and negotiating; and their information processing skills like gathering, organizing, analyzing, interpreting and evaluating data (Marsee and Wilson, 2014). In this sense, involving in such activities prepare students for professional life because these are “the competencies coveted by employers” (Marsee and Wilson, 2014, p. 83).

2.3. Science Fairs

This section of the literature review presents an overview on history of science fairs, benefits of science fairs and some criticism on science fairs in the following sections.

2.3.1. History of Science Fairs

Student-created exhibitions on art and history are more common whereas ones with science theme are less frequent (Kampschulte & Parchman, 2015). However, science fairs, which started in the early 20^{th} century, have begun to gain more attention all around the world and are getting popular day by day (McComas, 2011). The roots of science fairs date back to 1920s and was in the form of “science club movement”, which arose in the United States (US) (Bowen and Bencze, 2015, p.896). Students having interest in science were encouraged to prepare and display their projects in schools for their classmates and other students (Livingood, 1955). The first science fair in the US was organized at the American Museum of Natural History in 1928 with the purpose of giving students the opportunity to encounter with nature and to learn some scientific facts to gain their appreciation of science (McComas, 2011; Schank, 2015; Yasar and Baker, 2003). The first National Science Fair, which based on students’ works, was held in 1950 in US (Blenis, 2000; Bowen and Bencze, 2015; Wartinger, 1999).

With the growing competition between America and Russia in advancing technology and space research, the need of professionals working in the field of science and technology increased (Levaren, 2009; Wartinger, 1999). This was the rationale behind the attempt in making science attractive and popular for youngsters. In 1965, National Science Fair transformed into International Science and Engineering Fair in US with the participation of nine foreign countries (Blenis, 2000). In the early 1960s, national science fair in Canada started and European Union Contest for Young Scientists begun in the late 1960s, when Belgium, France, Germany, Italy, Luxembourg and Netherlands were the members of

European Union (EU) by then (Bowen and Bencze, 2015; European Union, 2017b). On the other hand, in 1964, the first science fair at high school level was organized by Spanish Ministry of Education in Spain, which was not a member of EU by the time (Science Fair in Spain, 1964).

Educational reforms had taken place in science education of the Western world countries in 1950s impacted national education of Turkey as well and gave rise to establishment of collaborations with leading institutions and organizations like UNESCO, OECD, European Council and Ford Foundation (Yılmaz and Morgil, 1992). Most of the improvements arising with these collaborations focused around formal education such as foundation of Science High Schools and developing science curriculum or educational materials. In 1963, The Scientific and Technological Research Council of Turkey (TUBITAK) was found with the aim of supporting junior scientists (TUBITAK, 2013b). It started to fund and support educational projects in 1967 with attempt to improve science curriculum (Yılmaz and Morgil, 1992). Science fairs in the form of science project contests were another top-list projects of TUBITAK and the first science contest it organized was the *National Secondary School Research Projects Contest* in the fields of physics and biology in 1968 (TUBITAK, 2013b). Today, the scope of the contest expanded and the number of fields reached to ten including mathematics and social sciences, at high school level (TUBITAK, 2015a). Another project contest organized by TUBITAK at high school level is *Secondary School Students Entrepreneurship and Innovativeness Competition*, which was held in 2013 for the first time (Erinç, 2014; Ulusoy, 2016). TUBITAK organizes project contests for elementary school students as well in cooperation with Ministry of National Education in Turkey (Tortop, 2014). In 2006, TUBITAK held the first *National Middle School Research Projects Contest* in the field of science and mathematics for grade 5-8 students (TUBITAK, 2016) and in 2015, it coordinated the *Robotics Science Fair* for the 5-7 graders for the first time (TUBITAK, 2105b). In addition, in 2013 TUBITAK began to organize project competitions for undergraduate students under three categories: *University Entrepreneurship and Innovativeness Competition*, *Undergraduate Students' Software Projects Competition* and *Industry-Oriented Graduation Projects Competition* (TUBITAK, 2014a). TUBITAK also supports students in participating international organizations. In 1978, Turkey, for the first time, participated in International Science Olympiads in the fields of mathematics, physics and chemistry. In recent years, students from Turkey have begun to involve in Intel International Science and Engineering Fair (TUBITAK, 2014b). Besides science project contests, since 2013, TUBITAK has begun to fund schools to organize science fairs through the call 4006 Science Fairs under "TUBITAK Science Fairs Support Program" with the purpose of disseminating science culture in Turkey through establishing environments, where 5^{th}-12^{th} grade students can learn from their researches about the topics they have determined in the frame of curriculum and their interests (Çolakoğlu, 2018; TUBITAK, 2013c). The participation in TUBITAK 4006 Science Fairs is increasing such that 4006 Science Fairs were held in 880 schools in 2014, in 3201 schools in 2015, in 5980 schools in 2016 and in more than 10000 schools in 2017 (Çolakoğlu, 2018). These science fairs, where the participant teachers and students were awarded with certificate of participation, got over two million visitors and contributed in dissemination of science culture (Çolakoğlu, 2018). Another example of organization held by TUBITAK is *Annual National Sky Observation Festival,* which has been arranged since 1998 (TUBITAK, 2015c). Such festivals play an important role in bringing professionals in the field of science and technology, and public together.

Project contests, olympiads, science expositions, sky observation festivals and many others are organized at national and international level in many countries all around the world. Then, what is in the scope of science fair or is there any clear agreement on what science fair is? In the literature, there are different definitions of science fair, which can be fit under three main categories. The first approach regards science fairs as an environment for competitions of projects based on students' independent research studies including a hypothesis testing in pure or applied sciences (Galen, 1993; Tortop, 2013a; Yıldırım and Şensoy, 2016). The exhibits of science fairs under this category are students' poster presentations reporting their research studies (Bowen and Bencze, 2015). Such organizations usually take place out-of-school institutions with the participation of students from different schools and can be local, national or international. The second point of view, consider science fair as an exhibition where students display their works such as scientific experiments, models, computer programs, engineering designs, games and tests or their demonstration of a scientific apparatus and collections of scientific items on the area of science and interrelated areas like engineering, computer science and mathematics (Bowen and Bencze, 2015; Fredericks and Asimov, 2001; Levaren, 2009). Science project exhibition taking place simply in schools may fall into this category (Davis, 1955). The third perspective define science fair as any programs and projects that provide individuals with an "authentic and personal experiences in doing science" (McBurney, 1978; McComas, 2011, p.35). Olympiads, science exhibitions, science festivals and expositions are in the scope of science fair under this category.

The main purpose of science fairs is developing students' interest in science and fulfilling the shortage of science staff (Jones, 1953; Moore, 1958; Rogers, 1956; Wartinger, 1999). Such an approach may have a point because many scientists state that their primary motive for a scientific career arose after they carried out their own project (Moore, 1958; White *et al.,* 1963). In this sense, science fairs are medium to identify scientific talents by giving them the opportunity of showing their works (Jones, 1953; Rogers, 1956). There are also other varying views on aims of science fairs in the literature. For instance, Abenarty and Vineyard (2001) think that main goal of science fairs is complementing curriculum by promoting learning of scientific method through designing and doing experiments. On the other hand, McBurney (1978) considers primary goal of science fairs to be simply a learning experience for students, who get professional assessment, and opposes any other objectives that are not centered around students' learning. Similarly, Fredericks and Asimov (2001) and Levaren (2009) put students' gain on focus, and thinks that the purpose of science fairs is stimulating students' curiosity about the world by helping students to discover more about science topics that interest them. Literature shows that although ideas about the purposes of science fairs vary, many statements is centered around students' learning about science.

2.3.2. Benefits of Science Fairs

Studies on science fairs report many advantages of them. Firstly, involving in a science fair can promote obtaining "science-specific" skills and knowledge in addition to interpersonal and intrapersonal competencies acquired in exhibition development (Bowen and Bencze, 2015). Firstly, students developing a project for a science fair involve in a research process in the pre-production and production phase and meanwhile benefit from many resources like books and magazines in press or online (Çolakoğlu, 2018; D'Acquisto, 2006). Therefore, science fairs may enhance students' scientific literacy (Bowen and Bencze, 2015; Tortop, 2013b). Secondly, students, who are in the phase of finding an idea for a science fair, are recommended to visit other science events like fairs, exhibitions, museums and expositions to examine the exhibits in there and get inspired (D'Acquisto and Scatena, 2006; DeClue *et al.*, 2000). Visiting such events and examining the exhibits from an analytical perspective may contribute students evaluative and observational skills (Şahin and Çelikkanlı, 2014).

Thirdly, students perform a multistage research and series of problem-solving tasks, which do not have "prescribed responses or preset solutions" (Kuhlthau *et al.,* 1997, p.711; Watson, 2003). Such process asks more than a plane paper and pencil work, and from a pedagogical perspective, involving in a such inquiry help students to understand what real researchers and scientists do and scientific method better (Çolakoğlu, 2018; Fredericks and Asimov, 2001; Jaworski, 2013; Wartinger, 1999; Watson, 2003; Yıldırım and Şensoy, 2016). Fourthly, science fairs provide students to get recognition and professional evaluation for their scientific endeavors (Fredericks and Asimov, 2001; Jones, 1953; Livingood, 1955; McBurney, 1978; Moore, 1958) and regarded as a forum to discuss their findings (Wartinger 1999).

In addition, extra-curricular science activities, which provide students with hands-on experiences increase the possibility of female students' engagement in science by improving their confidence and interest in science (TUBITAK, 2013a; Wartinger, 1999). Prof. Yücel Altunbaşak, who was the president of TUBITAK in 2013, reported that the amount of applications had increased by about 10% each year, but it increased by 35% in 2013 (TUBITAK, 2013a). He also pointed out a remarkable change in the amount of female applicants in recent years. Prof. Altunbaşak reported that the amount of female participants increased by 36% between 2010-2013 and reached to number of males (TUBITAK, 2013a). Abernathy and Vineyard (2001) also point out a similar trend in participation of female students in the science fair and Science Olympiad in their study. They regard this situation as "a positive sign that efforts directed at encouraging girls in science may be paying off" (Abernathy and Vineyard, 2001. p.275). Besides, the findings of Çolakoğlu's (2018) study, which involves 77% of middle school students and 23% of high school students involving in TUBITAK 4006 Science Fairs, show that their science fair experiences have a positive impact on their interest towards Science, Technology, Engineering and Mathematics (STEM) areas. Furthermore, studies show that overall process of involving in a science fair encourages students to be more active in science lessons and develops students' academic success in science (Padovani *et al.*, 2013; Şahin, 2012; Yıldırım and Şensoy, 2016). Finally, science fairs bridge formal and informal education and encourage to build collaboration between institutions such as schools, universities, science centers, organizations and corporations (Çolakoğlu, 2018; Yasar and Baker, 2003).

Besides many opportunities that science fairs provide students with; they also have potential to impact public opinion on scientific issues. Citizens, who attend science fairs, engage with science topics, become more aware about current developments in science and gain some insight of the way scientists works (Lefler, 1956). Scientists in a society having understanding and appreciation of science may work more efficiently (Lefler, 1956). This situation also might create more job opportunities for ones who want to follow a scientific career, which is parallel to goals of science fairs.

2.3.3. Criticism on Science Fairs

Although their numerous contributions in education and positive impacts on students, there are studies examining science fairs with a critical approach and pointing out some possible adverse aspects of them. Firstly, the most common characteristic of a science fair that is criticized is competition (White *et al.,* 1963). Competitive nature of science fairs may discourage students, who are not competitive, to participate in such activities from the beginning (Yasar and Baker, 2003). In addition, talented students with high skills, interest and with previous experience are more likely to survive and win in a competitive atmosphere, while other students may disappoint when their works do not win award and as a result "they can develop negative attitudes about science" (Blenis, 2000; Bowen and Bencze, 2015, p.897; White *et al.,* 1963). Besides, science fairs centered around the atmosphere of competition may underestimate the value of personal motivation for challenge of going through an investigation and problem solving (Bencze and Bowen, 2009), and stressing about competition may result in performance anxiety among some students (Reis *et al.*, 2014). Opponents of these approaches consider that competition strengthens students and prepares them for future life and teaches them winning and losing (Blenis, 2000; Moore, 1958). In addition, participants of a science fair, who compete for a predetermined standard set of criteria, benefit more from the process compared to students compete against each other (Blenis, 2000).

Secondly, another aspect of science fairs criticized by researchers is the issue of unequal conditions of students. For instance, students involving in a science fair do not have same opportunity to reach resources and to get family support in funding and guiding (Craven and Hogan, 2008; Reis *et al.*, 2014; Yasar and Baker, 2003). These are among the primary factors that affect the quality of students' projects.

Thirdly, judgement process is another contradictive aspect of science fairs. Judging should be valid and reliable, but this is not always the case (McComas, 2011). Any bias in judgement diminishes the effectiveness of evaluation, and lead students to think that they did not get a fair, adequate assessment and to feel frustrated (Bencze and Bowen, 2009; Grote, 1995; McBurney, 1978; Strauss, 2001;). McBurney (1978) suggests that judges should not only have comprehensive knowledge on content area, but also should have pedagogical background about education of students. Some kind of training for science fair judges about how to evaluate a science project properly might help to increase the quality of judging process (McComas, 2011).

Another crucial element of science fairs is voluntary involvement (White *et al.,* 1963). Students should never feel an academic pressure because of their unwillingness to participate in a science fair (McBurney, 1978; Yasar and Baker, 2003). In addition, making students' participation in a science fair mandatory may lead some students to feel that they are not capable of doing science, especially when they don't have background and prior experience on developing a science project (McComas, 2011). On the other side, White and colleagues (1963) point out that some students are so involved to develop their project such that they neglect their ongoing school works and pass their exams with the extra credits given by their teachers, even they don't comprehend the exam topics at all.

Individuals claiming that a science fair project should base on students' independent scientific research studies believe the necessity of distinction between a creative science project and a display (White *et al.,* 1963). While the first is harder and involve the steps, which students state a problem, formulate a hypothesis, test it, draw a conclusion and report it; the latter is easier and is mostly a collection of scientific items or simulation and illustration of a scientific phenomenon or law (White *et al.,* 1963). Formulating categories or subcategories for awards such as *Best Research Study*, *Most Interactive* or *Most Creative* may help to develop a fair judging process.

Finally, there is a criticism on the fact that the amount of parent or mentor involvement in the development of students' science fair project sometimes might be excessive such that the creator of the final product is more parents' or instructors' than students' (Craven and Hogan, 2008; Schank, 2015; Strauss, 2001; Tortop, 2013a; White *et al.,* 1963). Pushkin (1987) recommends students to avoid choosing a project that is too complex in design and principle, and to keep it simple and relevant without limiting creativity so that not only the owner of the work, but also other students "learn from what is presented" (p.962). However, McBurney (1978) thinks that "we cannot justify conducting a science fair unless it is first and foremost a learning experience for the student - not for the community, nor for other students, nor for parent" (p.420). Miller (1964) suggests that if a project requires more than teachers' guidance along the process, then students should not undertake it. On the other hand, such approach might be regarded as restrictive by the proponents of collaboration between different stakeholders such as school, university, science center, related organizations and institutions.

2.4. Views and Experiences of Teachers on Science Fairs

Science teachers have an important role in guiding students along the development of a science fair project or science exhibit. It is a demanding process transforming teachers into "research directors" who advise students through their investigations and coordinate the process from the beginning to the end (Lefler, 1956, p.308). They do not need to know all the answers, but should be able to counsel students in the journey and therefore should have access to related resources that they can benefit from when they need (Lefler, 1956). Their approach in the whole process is a very deterministic factor for both their and students' experience to be fruitful or not (Blenis, 2000; Tortop, 2013a).

On the other hand, teachers mostly have a very tightly scheduled programs for covering curriculum, which are barely or not flexible, meaning that setting time for extra-curricular activities might be quite challenging (Padovani *et al.*, 2013). Besides, organizing a science fair brings extra responsibilities together such as planning the science fair, supervising developers of each project and in some cases creating a judge, especially if the fair is not held by an organization or an institution (Demirel *et al.,* 2013; Livingood, 1955; Menicucci, 1994). Each responsibility requires some specific skills and knowledge like how to organize an effective science fair, what the properties of a good project are, who the judges should be and what the judging criteria for a science fair should be (Menicucci, 1994). Lack of time and overloaded responsibilities may cause teachers to feel insufficient to conduct a science fair and so, may discourage teachers in involving science fairs (Menicucci, 1994). With all the advantages and disadvantages, experiencing a science fair may impact teachers' views on science fairs and enthusiasm for participating in science fairs differently. Learning about their views and experiences in this process may help to improve the quality of future science fairs (Tortop, 2013a).

2.4.1. Teachers' Motivations and Gains in a Science Fair

Some studies in the literature reveal teachers' motivations for involving in a science fair and their gains from this experience. In her study with middle school teachers, Watson (2003) reported that teachers' primary goal in involving in a science fair is helping students to learn about the step by step procedure and process of doing a science fair project rather than learning a new content in detail. On the other hand, sometimes teachers feel external pressure for involving such activities rather than their intrinsic motivations. For instance, Tortop (2013a) in his study with two middle school teachers, found that primary motives of teachers in attending a science fair are pressure of school administration, students' desire to participate and advertising school. Besides, teachers perceive their role in the science project development as mentor who guides, motivates, helps students and solves problems if necessary rather than an authority making decisions and giving directions (Demirel *et al.,* 2013; Tortop, 2013a). Galen (1993), as a teacher author, considers the whole process as an opportunity to know about students more and set a closer relationship with them. Teachers also get chance to come together with their colleagues (Çolakoğlu, 2018), see other students' works in the science fair and to evaluate their own students' projects (Rogers, 1956). They also got opportunity to meet with college scientists and involve in an interaction, which might be a reference for future collaborations (Rogers, 1956).

2.4.2. Teachers' Views About Students' Experiences and Gains in a Science Fair

Exploring teachers' opinions about students' experiences and gains in participating in a science fair may give science educators and science education researchers a fruitful insight about science fairs. First of all, most teachers believe science fairs promote interest and desire to pursue science as a career (Galen, 1993; Grote, 1995; Jaworski, 2013; Livingood, 1955). Secondly, some teachers think that science fairs are one of the best efficient way that helps students to get the habit of working independently on projects they decided and students developing an independent science project gain skills and knowledge, which cannot be duplicated in school instruction and be useful in the rest of their lives even if they don't get a career in science (Galen, 1993; Grote, 1995; Moore, 1958). Some teachers resemble the whole process of developing a science project with doing a scientific research (Watson, 2003) and therefore believe that science fair experience develop students' comprehension of scientific inquiry, science process skills and problem solving skills (Galen, 1993; Jaworski, 2013; Tortop, 2013b). Besides, teachers regard science fairs as an environment providing students with the opportunity to communicate with others having interest in science, learn from others' projects (Grote, 1995; Tortop 2013a) and to understand "not only what other people have discovered, but also whatever still hidden in the limitless reaches of what nobody knows" (Moore, 1958, p.283).

Although views of many teachers are about positive experiences and gains of students in science fairs, expressions of some teachers also reveal their negative thoughts about these two aspects. For instance, some teachers think that science fair they involved do not contribute science education at all although they demonstrated their positive impacts on students (Tortop, 2013a). In addition, teachers' opinions are divided on controversial aspects such as judging process in science fairs and their impacts on students (Grote, 1995). Teachers, having negative thoughts about judging process, concern about a poor quality judgement and the fact that it may get ahead of the actual value of students' scientific endeavors (Grote, 1995; Tortop, 2013a).

Research studies on science fairs show that majority of teachers have positive impressions about the experiences and gains of students, while minority state negative opinions and their concerns in the process.

2.4.3. Challenges Teachers Face in a Science Fair and Some Suggestions for Improvement

Some studies reveal the difficulties teachers encounter at guiding students along doing a science fair project. Most common problem faced in this process is the lack of time and space (Demirel *et al.,* 2013; Tortop, 2013a). These two factors lead some teachers to think that activities like science fairs "disrupt ongoing lessons" (Demirel *et al.,* 2013, p.1309). Lack of funding and administrative support are other challenging aspects dissuade teachers from involving in a science fair (Demirel *et al.,* 2013). Another concern for teachers is motivating and convincing students, who will enter the national exams, to pay attention to their science fair projects (Demirel *et al.,* 2013). Because these exams play a crucial role in students' academic life, they do not make enough effort in the phase of production even they have interest in the beginning (Tortop, 2013a).

Finding an idea is the most difficult phase of the all process according to teachers in the study of Tortop (2013b). In attempt to help students to get an idea, teachers showed them daily-life problems and let them examine the previous projects to get inspiration (DeClue *et al.* 2000; Tortop, 2013b). Teachers having inadequate access to resources like materials, tools or internet have difficulty in the production phase (Demirel *et al.,* 2013). DeClue *et al.* (2000) suggests that contacting with a university or an industrial company is a best way to get financial support or project idea. Writing the project report is another stage that teachers had difficulty in guiding students because of lack of experience and knowledge about how to report conclusions they draw and results in a proper way. (Demirel *et al.,* 2013, Tortop, 2013b).

Furthermore, Teachers' opinions differ in their self-efficacy in guiding and coordinating the process (Grote, 1995; Tortop, 2013b). Majority of teachers feel inefficient in their mentorship and need professional help (Grote, 1995; Tortop, 2013b). Some teachers emphasize the necessity of a scientist advisor because some thinks that teachers do not have adequate expertise in specific science topics (Grote, 1995). Most high school teachers, in the study of Demirel and colleauges (2013), emphasized "the lack of cooperation with universities" (p.1309). Studies show that teachers collaborating with universities, industrial institutions, organizations or science center are more likely to be successful at guiding through science fairs and be pleasant about the efficiency of the process (DeClue *et al.* 2000; Tortop; 2013b).

Many teachers do not get any instruction for developing exhibits (Jones, 1953). Because participating in a science fair demands certain knowledge and skills, some middle and high school teachers suggest "preservice training" on how to conduct an independent research projects with students at all levels (Demirel *et al.,* 2013; Grote, 1995; Tortop, 2013a). In his study, Tortop (2013a) asked teachers for their suggestions upon promoting the students' involvement in science fairs. Teachers recommended giving students extra credits or points in national exams, doing financial support, and objective and professional judging in science fairs to encourage participation (Tortop, 2013a). Some teachers believe that if Ministry of National Education supports teachers and students more, the problems faced in science fairs can be solved (Demirel *et al.,* 2013). Teachers also suggest organizers, teachers and students to understand better the purpose of science project contests for improving the quality of science fairs (Tortop, 2013a).

2.5. Views and Experiences of Students on Science Fairs

Likewise, varying experiences of science teachers, students as chief actors in the science fairs get diverging experiences and perceptions in the whole process. In this section, students' experiences in science fairs are covered regarding their motivations and gains in participating in science fairs, and difficulties they faced in such experience by referring examples from the literature.

2.5.1. Students' Motivations and Gains in Participating in a Science Fair

Students' rationales for participation base on both intrinsic and external motives. Grote's study (1995) shows that winning a prize is the major motivating factor in doing a science project for students. Most common rewards stated by high school students are preparing for future, meeting students from other schools, sharing ideas with others, pleasing teachers or parents, and learning the scientific process (Abernathy and Vineyard, 2001). On the other hand, the Keçeci's (2017) study, including middle school and high school students, points out some additional aims of students for involving in science fairs such as acquiring new information and applying the knowledge they acquire in everyday life.

Some studies in the literature give idea about how students feel and how their attitudes toward science change after they participate in a science fair. Majority of students reported that they had fun in the whole process from doing a project to share it in a fair (Abernathy and Vineyard, 2001; Keçeci, 2017; Şahin and Çelikkanlı, 2014). Many students also stated that they were curious and excited along the process (Şahin and Çelikkanlı, 2014). Some students liked the teamwork most, while others' favorite part was developing the exhibit (Padovani *et al.*, 2013). Students also stated they felt important when they were presenting their projects to visitors (Şahin and Çelikkanlı, 2014). In addition, some students stated they felt motivated to visit exhibitions more because they experienced and now know about how to create an exhibit (Padovani *et al.*, 2013). Yıldırım and Şensoy (2016), in their study with middle school students, found that students, who involved in a science fair, got higher mean score of attitude toward science. Besides, some students thought that winning a prize in a science fair urged their desire to follow a scientific career (Moore, 1958).

On the other hand, some students felt worried because of the competitive nature of the science fair (Reis *et al.*, 2014), and some students got negative feelings because of compulsory participation in science fairs (Şahin and Çelikkanlı, 2014). In the study of Blenis (2000), students in the "mandatory/competitive" group got lower scores for attitudes after participating in a science fair; however, students in the "mandatory/noncompetitive" group developed more positive attitudes and interests toward science. However, between two mandatory groups, the mean of project scores of the competitive group was higher compared to noncompetitive groups' (Blenis, 2000).

Gaining knowledge in their experience of science fairs has been also important for students. For instance, high school students reported that they learned about a new science topic, as well as remembering old ones and learned how to apply knowledge (Padovani *et al.*, 2013; Keçeci, 2017; Şahin and Çelikkanlı, 2014). Majority of students, in the study of Padovani *et al.* (2013), stated knowledge obtained in the overall process was useful in the following years of the school. Students also remarked that they acquired communicative skills. Many students in the study of Moore (1958) pointed out that involving in a science fair contributed their skills in communicating scientific facts. Students also stated that the whole process had positive impact on their communication with friends, visitors, parents and their teachers (Şahin and Çelikkanlı, 2014). Besides, students got some idea about how to make an exhibit more "user-friendly" for visitors at different ages (Padovani *et al.*, 2013, p.5). Furthermore, many students reported that their organizational skills were improved (Padovani *et al.*, 2013). In addition, students pointed out that engaging in a science fair raised their awareness on their responsibilities, skills and deficiencies (Şahin and Çelikkanlı, 2014). On the other hand, some students remarked that they learned to control their excitement (Şahin and Çelikkanlı, 2014).

2.5.2. Challenges Students Face in a Science Fair and Suggestions for Improvement

Some studies, conducted with middle school and high school students, revealed difficulties students came across with in engaging in a science fair. Abernathy and Vineyard (2001) found that participation from junior high school was higher compared to high school and think that requirement of more content knowledge and effort is a possible explanation for decreasing amount of involvement. Some high school students report that the subject they worked on was over their level of understanding and so they memorized some facts and recited them in the science fair (Şahin and Çelikkanlı, 2014).

In the production of their projects, students often face with the problem of finding required tools and apparatus to develop or experiment their projects (Tortop, 2013a; Reis *et al.*, 2014; White *et al.,* 1963). This situation might be overwhelming and sometimes cause loss of interest (White *et al.,* 1963). Another factor that creates difficulty for students in the production phase is lack of their knowledge in doing a project (Tortop, 2013a). Another challenging factor of developing phase pointed out by students is collaboration among students. Some students reported that group members, who had not discharged their responsibilities, caused increasing burden for the rest of the team (Şahin and Çelikkanlı, 2014).

Some students faced with difficulties during the science fair organization. Students reported that lack of coordination and disruptions in physical conditions caused their enthusiasm to go down (Şahin and Çelikkanlı, 2014). "Uncertainty around the public's perception of the project" is another factor of anxiety for students (Reis *et al.*, 2014, p.45). Some students revealed that sometimes they came across visitors making negative comments or looking uninterested (Şahin and Çelikkanlı, 2014). In addition, the approach of judges was another concern of students in science fairs (Tortop, 2013a).

These difficulties faced in the process sometimes lead performance anxieties to show up among students (Reis *et al.*, 2014). For students who lack in knowledge about developing a project, offering courses like "Science Project Seminars" and "Independent Study" helps them in learning research methods (Galen, 1993, p.464). Students who struggle in any phase of involving in a science fair, most of the time, consult their teachers to overcome the challenges they face and consider their teachers as a main source of help (Abernathy and Vineyard, 2001; Tortop, 2013a). Students describe their teachers' roles as guider, motivator, supporter, skill developer and helper (Tortop, 2013a). Students, especially in lower grades, also sometimes get help from their parents to cope with the difficulties or to get an idea (Abernathy and Vineyard, 2001).

2.6. Student-Created Exhibitions on Nanoscience and Nanotechnology (NST)

Although Nanoscience and Nanotechnology (NST) are among rapidly developing areas, and gain public and media attention day by day awareness and knowledge of the public on NST are low (Laherto, 2011). Developing instructional modules about nanotechnology has been given importance and worked on in recent years (Yeh *et al.,* 2011), however projects encouraging students to develop exhibits on NST are limited (Kampschulte, 2015; Tirre *et al.,* 2015; Yeh *et al.*, 2011). Today many industries from electronics to cosmetics and textile, to the medicine benefit from NST to improve the quality of their products or to feature them. This situation arises two concerns: need for raising experts in the field of NST (Yeh *et al.*, 2011) and raising awareness of future citizens that will have to make decisions on NST-related issues (Laherto, 2011). As it aforementioned, developing exhibit can be used as a learning tool as well as communicating science (Kampschulte and Parchmann, 2015).

It is possible to come across with few examples of student-created exhibits on NST at the local news or school websites (Bilim Şenliği, 2009; Bodrum Haber, 2016; Cunha, 2013; OCR, 2009; PCS, 2015). Most of these projects address environmental issues or health problems and are on similar topics such as “Cancer Treatment” and “Cleaning Up Oil Spills with Nanotechnology” (OCR, 2009; PCS, 2015; The Catholic Voice, 2015). Students’ projects on NST have also started to appear in national and international science fairs in recent years. For instance, in 2016, a group of students won scholarship for their project about nanoscience applications in a medical field in The Siemens Competition in Mathematics, Science and Technology (Iselin, 2016). Their projects were a high-level academic research and therefore they were mentored by two experts from a university in the Department of Materials Science and Chemical Engineering throughout their project development (Iselin, 2016).

In Turkey, projects on NST have started to show up in *National Secondary School Research Projects Contest* organized by TUBITAK since 2005. Figure 2.1. visualize the increasing trend in number of students participating the contest with a NST-related project in the field of physics, chemistry or biology (TUBITAK, 2017). The project “Treatment of Wastewater in Textile Industry by Using Catalyzers in Nano Structure through Catalytic Wet Air Oxidation Method” in chemistry, the project “Responses of Bacteria to Nanowave Signals and DNA Resonance” in biology and the project “Pressure of Photon Gas at Nano Size” in physics are some examples of high school students’ NST projects in the contest hold by TUBITAK (TUBITAK, 2017). These are also higher level projects that require mentorship of an expert from the field and additional facilities like well-equipped research laboratory to conduct their research studies.

Another example of high-level projects about NST developed by high school students also base on university-high school collaboration. The Renewable Energy Laboratory in Temple University conducted Nano Outreach Program in collaboration with the coordinator of the Science Department of Central Bucks High School – West with the purpose of facilitating science fair projects in nanotechnology for gifted high school students between 2011-2014 (Temple University, 2014). Within the four years, members of the laboratory hosted seven high school students, who want to pursue careers in science and engineering, and mentored them in doing their research projects, which each won a prize in regional or state science fair (Temple University, 2014).

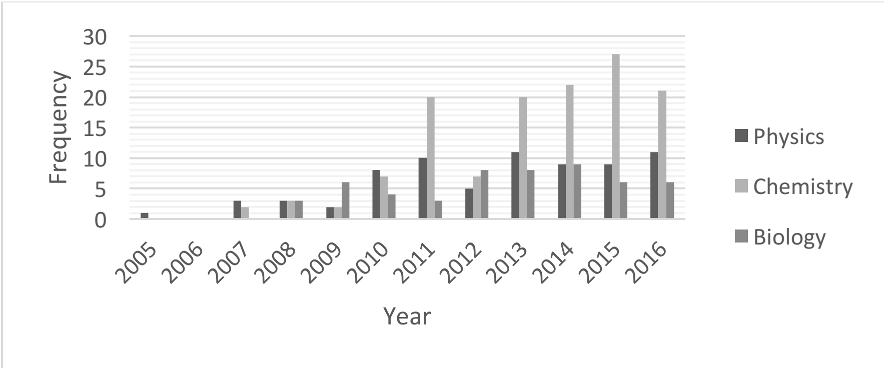

Figure 2.1. Number of students' NST projects[1] in National Secondary School Research Projects Contest organized by TUBITAK.

Students' NST projects like the ones developed for The Siemens Competition in Mathematics, Science and Technology or TUBITAK's National Secondary School Research Projects Contest are quite sophisticated and students' cooperation with academic people is applaudable. On the other hand, most of these students have high interest in science and science process skills, which arouse their curiosity to learn more about science and therefore, they have prerequisite background to make higher level research studies. However, this is not the case for all students and besides most students do not have opportunity to work in out-of-school facilities in collaboration with experts in the field. Therefore, there is a need for an inclusive approach that encourages engagement of all students in developing projects and exhibits on NST topics.

In the study of Yeh and colleagues (2011), secondary school science teachers designed and developed teaching activities on nanotechnology to arise students' interest in NST hands-on works. Students learned about fundamental NST concepts and how to develop "creative hands-on works" with the guidance of their teachers (Yeh *et al.,* 2011, p.481). Then, teachers and students were asked for developing an exhibit on NST by benefiting from resources in the library for searching the related information for their study, and their works were exhibited in the library of National Tsing Hua University for a month (Yeh *et al.,* 2011). Students developed models, posters and some multimedia exhibits on NST. Researchers found that the whole process improved both students' and teachers' interest and knowledge

[1] Graph in Figure 2.1. is created by the researcher based on TUBITAK (2017) reports.

in NST, and the discussion among students and teachers in the process contributed on students' problem solving and communicative skills (Yeh *et al.,* 2011).

Collaborative Research Center SFB 677, having interdisciplinary approach on their research area "Function by Switching" in Kiel University, and the Leibniz Institute for Science and Mathematics Education collaborated in EXPOneer project with the purpose of developing a technical frame that encourages student-curated exhibitions, which can be built on budget and reach different target groups from pupils to public, and then they developed the prototype *"Nano Research in Kiel"* using IKEA shelves (EXPOneer, 2011; Kampschulte and Parchman, 2015). 11th grade students in a high school in Germany used this frame to develop an exhibit on NST, after learning about NST in "science-profile course" in their school and visiting *Nanotechnology Student Lab "Klick"*, which was developed by Collaborative Research Center SFB 677 (Kampschulte, 2015; Tirre, 2015). Students divided each shelf of the unit thematically into four: *What nanotechnology is*, *Nanotechnology in everyday life*, *Where to find nano in nature*, and *The opportunities and risks of nanotechnology* (Kampschulte, 2015). Students used printed posters, concrete materials, nano products as well as natural objects (i.e. leaf, stone, sand) to display in shelves (Kampschulte, 2015). Then, these nano shelf units were presented in students' school by including few demonstrations of students (Kampschulte, 2015).

Another example of students developing an exhibit on NST base on students' end-product in a science camp about NST. Tirre and colleagues (2015), in their study, designed a week-long science camp called "*Science and Science communication*" offering high school students to learn about NST through improving relevance with the topic by bringing about socio-scientific issues and discussing opportunities and risks, and also to present their own "communication concept" (i.e. poster, model, website) reflecting their "self-directed research projects" (Tirre *et al.,* 2015, p.179). Students also attended literature and art courses simultaneously in one-week duration. In the beginning, Nature of Science (NOS) is addressed in the context of NST and scientific content is presented based on findings of NST research, then students are introduced with scientific method through "5 stations" and are asked to propose their own NST-related research questions that can independently investigate in groups of 2-3, and at the end students attended a workshop on science communication and prepared their presentation to convey their research findings (Tirre *et* *al.,* 2015). “Which cosmetic products have hydrophobic properties and keep what the advertising promises?” and “Which metal surfaces can be measured under the scanning force microscope?” are two examples of student-generated research problems (Tirre *et al.,* 2015, p.185). Students from the departments of natural science and pure science coached high school students while they formulating their research questions. While exhibiting their findings students used materials that they easily accessed and prepared different formats of communication: blogs, webpages, newspaper articles and a sculpture (Tirre *et al.,* 2015). During the “feedback sessions”, students reported positive attitude toward the camp. Researchers also pointed out few gains for students: understanding the nature of scientific research method, self-assessment on their own research studies, collaboration with students from varying grades as well as undergraduate students, and understanding the importance of science communication (Tirre *et al.,* 2015).

2.7. Integration of Socio-Scientific Issues (SSI) in Science Education

This section of the study addresses integration of socio-scientific issues (SSI) in science education through introduction of brief history of SSI in education, importance of SSI in science education, challenges faced in SSI education, Responsible Research and Innovation (RRI), how RRI relates with SSI, and integration of RRI in science education.

2.7.1. History of Socio-Scientific Issues in Education

Rapid developments in science and technology, coming after industrial revolution, have brought environmental concerns, growing attention to equity issues, and complex ethical, political problems together, and therefore have led to arise of some controversial issues (Jenkins, 2015). Levinson (2006) describes three characteristics of controversial issues based on definitions in the literature: (i) people have different beliefs, values, understandings and conflicting explanations or solutions on it, (ii) it involves varying number of people or groups, and (iii) “when the issue is not capable of being settled by appeal to evidence” (p.1204). Childhood vaccinations, genetically modified foods, protection of species diversity and energy conversation, global warming, cloning, disposal of waste water are few examples of issues creating debate and dilemma (Levinson, 2006; Sadler, 2002). Because social and scientific elements play a key role in such issues, they have been called as Socio-Scientific Issues (SSI) (Sadler, 2002). SSI comprise the characteristics of controversial issues and also have two main properties: (i) science-related content and (ii) social importance (Eastwood *et al.,* 2012). SSI require individuals to do a risk assessment, a data interpretation and an overall process evaluation regarding multiple scientific and nonscientific perspectives that include ethical, political, economic, sociocultural and epistemological aspects, which are also built upon controversial structure (Lee, 2015; Levinson, 2006). This situation arose the need of integrating SSI in education in order to raise generations that are capable of thinking critically on such issues (Lee, 2015).

Introduction of controversial issues in education in United Kingdom have firstly begun in 1970s with inclusion of topics in the scope of humanity and citizenship such as relations between races, relations between genders and law and order (Levinson, 2006). Beginning in 1970s, infuse of controversial issues in education gained importance with the rise of debates in anti-racism and multicultural education (Levinson, 2006). Controversial issues in science context began to draw substantial attention in the 1970s together with *the Science Technology and Society (STS) Movement* (Jenkins, 2015; Levinson, 2006; Ratcliffe, 2001). Integration of SSI in education has initiated in Europe (Bybee and McInerney, 1995). “The first large-scale STS education project started in Holland in the mid-70s as a result of a government decision to hold a referendum on nuclear power and an eight-year programme of public education to support it” (Ratcliffe, 2001, p.84). *Science in Society* and *Science in a Social Context* projects in United Kingdom, and *Projekt Leerpakket Ontwikkeling Natuurkunde (Physics Curriculum Development Project)* in the Netherlands are initial national programs integrating STS (Levinson, 2006; Ratcliffe, 2001; Yager, 1996).

In the United States, from the late 1970s to the early 1990s, many projects and reports involving STS formed a basis for the 1990 Science Curriculum Reform (Bybee and McInerney, 1995; Yager, 1996). Norris Harm’s *Project Synthesis* in 1977 is considered as one of the kick-off projects raising concern about STS in education (Yager, 1996). In 1980, the National Science Teachers Association (NSTA) reported that it took a stand in favor of a science education centered around STS (Yager, 1996). National Science Foundation (NSF) funded project *Science through STS* in 1985 led to foundation of National Association for Science, Technology and Society (NASTS) (Yager, 1996). “American Association for the Advancement of Science (AAAS) 1989 report *Science for All Americans*, NSTA 1989 project *Scope, Sequence and Coordination*, The National Center for Improving Science Education (NCISE) reports on middle school and secondary school education" are some other examples of actions taken in attempt to integrate STS in science education (Bybee and McInerney, 1995, p.13). In 1997, the Councils of Ministers of Education of Canada developed the first national program, establishing a Science, Technology, Society and Environment (STSE) approach, called as the *Common Framework of Science Learning Outcomes* (Aikenhead, 2000).

In Turkey, SSI were included in science education for the first time with the science curriculum introduced by Ministry of National Education in 2013 (Koştur, 2017; Topçu *et al.,* 2014). Before the 2013 science curriculum, there is no use of the terminology "socio-scientific issue", but the emphasis is rather put on the relations among science, technology, society and environment both in elementary school and high school science curricula (MEB, 2005; MEB, 2006; MEB, 2011a; MEB, 2011b; MEB, 2011c). In the 2013 Elementary School Science Curriculum of Turkey, four learning areas are determined as Knowledge, Skills, Affective Learning and Science-Technology-Society-Environment; and SSI are given place under "Science-Technology-Society-Environment", however it does not include any subject-specific suggestion or description on integration of SSI in-class practice (MEB, 2013a). On the other hand, integration of SSI in the 2013 high school science education programs of Turkey differs based on disciplines. In the 2013 Secondary School Physics Curriculum, the importance of SSI is described in "Science-Technology-Society-Environment" section under the title "Fundamental Skills", but it is addressed directly only in one of the 9th grade chapter "Energy" with the suggestion of discussion upon alternative energy sources by regarding SSI (MEB, 2013b). In the 2013 Secondary School Biology Curriculum, the importance of developments of students' understandings about the relation between science, technology and society is given place under the section "Science-Technology-Society Relations" without referring "SSI", and it is addressed directly in just one of the 11th grade chapter "Human Physiology" with the recommendation of discussion upon importance of vaccination by considering SSI (MEB, 2013c). In the 2013 Secondary School Chemistry Curriculum, the importance of improving students' understandings on technological, economic, environmental and social impacts of chemistry is pointed out under the section "Science-Technology-Society-Environment and Economy" without direct inclusion of the term "socio-scientific issues", and there is no any topic-specific suggestion on how to integrate such issues in chemistry topics as well (MEB, 2013d). General overview on 2013 science curricula in Turkey at elementary and high school school levels shows that although there is emphasis on SSI directly or indirectly, there is a lack of description or topic-specific suggestion on practical integration of these kind of issues in science lessons. On the other side, the topic-specific integration of SSI is given place in the 2017 Secondary School Chemistry Curriculum through covering the impacts of current developments in nanotechnology on science, society, technology, environment and economy among the grade 12 topics (MEB, 2018).

2.7.2. Importance of Socio-Scientific Issues in Science Education

Inclusion of controversial issues in education has begun with the aim of coping with such issues in high school schools (Levinson, 2006). With the integration of SSI in science education through STS, goals have expanded. These goals are:

- Raising individuals that are scientifically literate, able to apply scientific knowledge and have habits of mind (Kolstø, 2001; Kumar and Chubin, 2000; MEB, 2013a; Sadler, 2002; Topçu, 2015; Yager, 1996;)
- Showing the applicability of science in daily life and improving the understanding of its relevance to students' lives (Harms and Yager, 1980; Ratcliffe, 2001; Sadler *et al.*, 2006; Yager, 1996)
- Developing students' understanding about interrelations of science-technology-society-environment and their impacts on each other (Harms and Yager, 1980; MEB, 2013a; Lee, 2015)
- Giving students the opportunity of addressing socio-scientific issues at local level as well as global level (Yager, 1996)
- Improving students' skills of solving problems on socio-scientific issues by regarding risk-benefit evaluation and impacts on varying stakeholders (Harms and Yager, 1980; Lee, 2015; Sadler *et al.*, 2006)
- Empowering and preparing students as responsible citizens that make knowledge-based decisions on issues meeting science, technology and society at a common ground (Harms and Yager, 1980; Hassard and Dias, 2013; Kolstø, 2001; Kumar and Chubin, 2000; Levinson, 2006; Sadler, 2002; Sadler *et al.*, 2006).

STS education has further potentials besides to acquisition of competencies and knowledge specified in these goals. Students, who experience STS education, are empowered to develop strategies in studying and learning on their own (Yager, 1996). Topçu and colleagues (2014), referring numerous studies, point out that learning science in STS context "improve students' conceptual understanding, attract their interest, provide additional motivation for learning, and improve their epistemological development and attitudes towards science" (p.2341).

2.7.3. Challenges Faced in SSI Education

Studies on SSI in education show that science teachers and students face with some difficulties when SSI are put in practice (Kolstø, 2001; Mansour, 2007). Based on his study, Mansour (2007) categorizes sources of these difficulties that teachers encounter into two: (i) *external constraints* and (ii) *internal constraints.* External constraints are outside of teachers' control. For instance, teachers report that they feel pressure of giving priority to cover subject matter because of national examination systems (Mansour, 2007; Sadler *et al.*, 2006). Absence of SSI in curriculum standards is also regarded as a constraint by teachers (Sadler *et al.*, 2006). Besides, they regard lack of time (Sadler *et al.*, 2006) and crowded classrooms as obstacles to involve students in discussions on STS issues (Mansour, 2007). Some teachers also feel insecure in discussing value-based ethical and political issues in school environment because of their job security concern (Sadler *et al.*, 2006). Being controversial, science-related and socially significant, some value-laden and political issues such as abortion, organ donation, euthanasia or deforestation for construction, are examples of SSI that teachers might have difficulty to manage discussion and therefore hesitate to bring about in classroom environment.

Internal constraints, on the other hand, are related to teachers themselves (Mansour, 2007, p.10). For example, teachers have problems in finding appropriate topics that improve students' skills in "interpreting science-related statements" (Kolstø, 2001, p. 293). Another aspect that challenges teachers in guiding discussions on SSI is narrowing down values, limits, risks and benefits that should be addressed (Kolstø, 2001). Assessment of learning objectives based on SSI is also challenging for teachers (Kolstø, 2001; Topçu, 2015). Some studies point out that teachers need to be trained well both at pre-service and in-service education to teach these kind of controversial issues, and they need to a guideline including specific descriptions and instructions (Kolstø, 2001; Mansour, 2007; Sadler *et al.*, 2006). On the other side, several teachers, in the study of Sadler and colleagues (2006), do not consider teaching SSI as a priority in their science class and suggest social studies teachers to discuss such controversial issues with students.

Teachers also report some difficulties stemming from "students' backgrounds about STS issues, lack of co-operation, varying learning habits, interests, attitudes, and motivations" (Mansour, 2007, p.20). Most students have difficulty in understanding relevance of some science-related topics for their daily lives (Kolstø, 2001; Levinson, 2006; Mansour, 2007). Students also have difficulty in discussing on STS issues because they are not aware of current STS problems at local and international level because they do not follow these kind of news (Mansour, 2007). In addition, although decision-making on SSI mostly based on values, students sometimes hesitate to express their opinions because they think their scientific knowledge are insufficient for developing strong arguments (Kolstø, 2001).

2.7.4. Responsible Research and Innovation (RRI)

Since 2010, Science in Society Action Plan has focused on developing the framework of "*Responsible Research and Innovation*" (RRI) (European Union, 2012). RRI defined as a research and innovation process at which all societal actors work together and are mutually responsive to each other from the beginning to the end in order to align better both the process and its outcomes regarding values, needs and expectations of society as well as great challenges and problems of our time (European Union, 2012; Sutcliffe, 2011; von Schomberg, 2013). Science and technology based research and innovations are at the center of RRI, however, it does also cover ICT, system or service innovations, sustainable development, financial resources, consumers and human rights (Sutcliffe, 2011, p.3). RRI also puts emphasis on limitations of current political strategies in "managing ethically-problematic areas of science and technology" (Owen *et al.,* 2012, p.751).

RRI framework consists of six key aspects: *engagement, gender equality, science education, open access, ethics* and *governance* (European Union, 2012). *Engagement* implies the involvement of all societal actors including industry, corporations, nongovernmental organizations (NGOs), policy makers, researchers and society for joint practices and solutions within the process of research and innovation (European Union, 2012). *Gender equality* points out the integration of gender dimension in the research and innovation process for giving both women and men the equal opportunity of contribution (European Union, 2012). *Science education* aspect puts emphasis on equipping students with necessary knowledge, skills and tools to encourage their full participation in the research and innovation process as future researchers, societal actors and responsible citizens (European Union, 2012). Science education, in the scope of RRI, also have the goal of transmitting similar approach for public education to promote “informed-decisions” (Sutcliffe, 2011) and appreciation of scientific knowledge in a wider range (Ratinen, 2015). RRI framework aims to achieve this through governmental encouragement in interdisciplinary cooperation of different stakeholders to contribute science education (Sutcliffe, 2011). *Open access* aspect of RRI signifies the importance of free access to the results of a research and innovation both for the transparency of the process and for increasing the use of scientific information by all stakeholders (European Union, 2012). *Ethics* aspect implies that research and innovation should regard fundamental rights and ethical standards to ensure their relevance and acceptability for societal actors (European Union, 2012). *Governance* is the comprising aspect that points out the responsibility of policymakers in preventing any harmful or unethical developments in research and innovation by developing harmonious models for Responsible Research and Innovation that integrate public engagement, gender equality, science education, open access and ethics (European Union, 2012).

The six key aspects of RRI, altogether, reflect three remarkable features of the frame: (i) *science for society,* (ii) *science with society* and (iii) *reframed mutual responsibility* (Owen *et al.,* 2012). *Science for society* feature shows the existence of “a deliberative democracy” aligning target of research and innovation with societal challenges through an ethical and inclusive approach (Owen *et al.,* 2012, p.757). *Science with society* feature indicates integration of a responsive mechanism engaging public and other stakeholders in a dialogue and debate as decision-makers (Owen *et al.,* 2012). *Reframed mutual responsibility* feature shows the existence of extended responsibility of research funding agencies, policy-makers, universities and industry in creating capacity for RRI through educational programs (Owen *et al.,* 2012).

2.7.5. How does RRI Relate with SSI?

Responsible Research and Innovation (RRI) is clearly built upon the fundamentals of Socio-scienific Issues (SSI), which gained importance substantially with the Science-Technology-Society (STS) Movement, and therefore they have a lot in common in their approaches, however, with its specific aspects, RRI takes more in-depth positions while generating missions in some facets (Blonder *et al.,* 2016). Blonder and colleagues (2016) made an analysis on how RRI and SSI relate and differ, whereas Laherto and colleagues (2018) made connections between RRI and socio-institutional aspects of Nature of Science.

Engagement, ethics and *open access* dimensions of RRI highly overlap with SSI approach such that both give importance to involvement of different stakeholders in decision-making, address ethical aspects, and point out the necessity of an information transfer between scientists and public so that they can access necessary information, which their reasoning base on (Blonder *et al.,* 2016). Besides, Blonder *et al.* (2016) think that the RRI dimension of *Gender equality* is not directly related with SSI approach although SSI is known to be motivating for female students and affect their self-efficacy perceptions positively. On the other hand, Levinson (2006) points out that the introduction of SSI in education begun with early discussions on social issues, such as relations between races, relations between genders and right of equality, showing a common understanding with RRI. Laherto and colleagues (2018), on the other side, make connections between these four dimensions of RRI and Nature of Science through soico-institutional aspects of Nature of Science, namely scientific ethos, social certification and dissemination, professional attitudes, social values, social organizations and interactions, financial systems and political power structures.

Science education and *governance* are two dimensions bringing new perspectives and widen the scope of SSI (Blonder *et al.,* 2016). For instance, *science education* factor of RRI goes further than SSI's understanding of the construction of scientific knowledge by giving experts (i.e. scientists) from different organization and institutions the responsibility of enhancing science education (Blonder *et al.,* 2016). *Governance* dimension of RRI addresses questions like "Who will supervise the work?", "What stages of research and development do need to involve supervision?", "What should be the source of authority for this supervision?", "Do scientists and technologists have an obligation to report their work?", and "What specifically should be involved in the process of supervision?" (Blonder *et al.,* 2016, p.1148). According to Blonder and colleagues (2016), these are addressed very limited in SSI. Overall comparison between RRI and SSI showed that RRI forms a systematic framework to guide the implementation of SSI in science education (Blonder *et al.,* 2016). On the other hand, Laherto and colleagues (2018) found the *governance* dimension of RRI highly related with the aforementioned socio-institutional aspects of Nature of Sciene except *the social values*, however, they reached the conclusion that the *science education* dimension of RRI does not overlap with any elements of Nature of Science mentioned before.

2.7.6. Integration of Responsible Research and Innovation in Science Education

Recent emphasis on Responsible Research and Innovation (RRI) bring its integration in education together. European Union made call for projects being in the scope of the Framework Programme for Research and Innovation, and funded over 25000 projects under 7th Framework Programme for Research and Technological Development (FP7) between the years 2007-2013 (CORDIS, 2015). 184 of these projects were funded under the FP7 Science in Society (SiS) Action Plan (CORDIS, 2015), and 4 of these projects are supported by FP7-SiS.2013.2.2.1-1 - Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education Program: *Irresistible, Engage, Parrise* and *Ark of Inquiry* (CORDIS, 2014). These projects base on the idea of involving youngsters in RRI related topics through inquiry based activities (CORDIS, 2014).

The Project IRRESISTIBLE was supported by EU between the years 2013-2016 (European Union, 2016). IRRESISTIBLE was a project on teacher training with the goal of fostering the involvement of students and the public in the process of Responsible Research and Innovation (RRI) by bridging formal and informal learning (European Union, 2016). The project was aiming to raise awareness on RRI in two ways: by increasing students' content knowledge on cutting-edge science topics and by encouraging discussion among students on introduced topics within a RRI perspective (European Union, 2017a). For these purposes, in the first phase of the project each partner formed a Community of Learners (CoL) involving in-service science teachers, informal education experts from science centers or museums, science education experts and research scientist from universities (European Union, 2017a). Each CoL developed and tested a teaching module on a specific cutting-edge science topic: (i) Healthy aging, (ii) Genomics and oceanography, (iii) Oceanography and climate change, (iv) Climate change, (v) Renewable energy sustainability, (vi) Nanomaterials, (vii) Nanoscience, (viii) Nanoscience application, (ix) Nanoscience and Nanotechnology and (x) Nanotechnology (Nanocrystals and nanoporous materials) (European Union, 2017a). After implementation of the modules with group of students, students designed and developed an exhibit centered around the module topic and addressing RRI (European Union, 2017a). Student-created exhibitions were held in schools as well as universities, institutions, science centers and museums, and served to introduce the theme of RRI and to bridge science and public (European Union, 2017a). In the second phase of the project, CoL was expanded with the participation of additional science teachers and teachers from the first phase coached new starters (European Union, 2017a). Similar to first phase, teachers implemented modules with group of students and then, students displayed the exhibits they had develop.

In IRRESISTIBLE Report Summary, characteristics of teaching modules are described (European Union, 2017a). According to the Report, each IRRESISTIBLE teaching module

"1. Introduces an everyday situation/ subject (in order to make the topic contextualized and relevant to students),
2. uses an Inquiry-based Science Education (IBSE) approach, advances to the observing, classifying, experimenting and explaining the phenomena and the properties that are relevant to the chosen application,
3. addresses the broader issues related to the application in question: societal and environmental implications, ethical issues, and other RRI aspects,
4. includes instructions for teachers on how to use the module and utilize the platform (e.g. exemplary schedule for the course, suggestions for lesson plans...),
5. provides additional reading material on the topic in question, to be included in the textbook-like information source for teachers and students,
6. let students design exhibit that
    a. presents the chosen subject (the same one as in the teaching module),
    b. highlights the phenomena and properties relevant to that application,
    c. addresses the societal and environmental implications and related ethical issues"
    (p. 2).

Many researchers from the Project IRRESISTIBLE did studies examining the effectiveness of teaching modules, and the experiences of both teachers and students in the process (Adadan and Akaygun, 2016; Akaygun *et al.,* 2015; Akaygun and Adadan, 2016;

Alexopoulos *et al.,* 2015; Apotheker *et al.,* 2016; Blonder *et al.,* 2016; de Vocht *et al.,* 2015; de Vocht *et al.,* 2016; Kampschulte *et al.,* 2016; Kampschulte and Parchmann, 2015; Maciejowska and Apotheker, 2015; Marques *et al.,* 2016; Ratinen *et al*., 2015; Venturi *et al.,* 2015). Some of these studies are addressed in the next section of the literature review to examine the gains of teachers in teaching about RRI, gains of students in learning about RRI and difficulties they face in the process; based on first-hand experience of some teachers and students in the Project IRRESISTIBLE.

2.8. Views and Experience of Teachers on Teaching About RRI

This section of the literature review comprises of collection of studies addressing teachers' opinions and experiences on benefits and challenges of RRI education. The benefits and challenges of RRI education for teachers and students are reported in different sections following.

2.8.1. Teachers' Gains in Teaching About RRI

First of all, teachers, implementing RRI aspects in their science lessons, at which they teach about 4.5-hour "The Story of Lead", report that they personally have started to analyze the world around them through RRI approach such that when they confront with any SSI issue they examine it by using the six dimensions of RRI (Blonder *et al.,* 2016). They also report that they shared their RRI insight with their close environments and begun to discuss it with them (i.e. family and colleagues) (Blonder *et al.,* 2016). Besides, they state that once they thought about RRI within Project IRRESISTIBLE modules, they transferred this approach in their regular school lessons (Blonder *et al.,* 2016). In addition, Venturi and colleagues (2015) found that teaching science with RRI perspective facilitates teachers to relate content knowledge with everyday life for their students. Finally, RRI seems to give teachers a new perspective about their students because RRI gives teachers the opportunity to learn more about varying personal ideas of students (Venturi *et al.,* 2015). These examples show that teaching about RRI improves teachers' personal and professional development.

2.8.2. Teachers' Views on Students' Gains in Learning About RRI

Besides reporting their experience in teaching about RRI, teachers also shared their thoughts about the impacts of learning about RRI on students and their experience in the process. Firstly, teachers believe that RRI brought a new perspective, which establishes a link between scientific content and students' daily life, and stimulates students' interest toward science (Venturi *et al.,* 2015). This situation creates an engaging and motivating in-class atmosphere, which encourages also low-performing students to ask questions, share their ideas and discuss on social effects of scientific research and innovations (Blonder *et al.* 2016; Venturi *et al.,* 2015).

Teachers think students realized that social implications are inherent in any research and innovation, and they internalized the importance of discussing about these issues after learning about RRI within a cutting-edge science topic in the Project IRRESISTIBLE (Venturi *et al.,* 2015). Teachers also reported that students were able to transfer their RRI knowledge to different socio-scientific contexts and evaluate the new situation by using six key factors of RRI (Blonder *et al.* 2016; Venturi *et al.,* 2015).

2.8.3. Challenges Teachers Face when Teaching About RRI

Studies of show that teaching about RRI was a fruitful process for both teachers and students, however, it was not easy for them and teachers faced with some challenges (Blonder *et al.,* 2016; Ratinen *et al.,* 2015; Venturi *et al.*, 2015). In the beginning teacher concerned about whether students will like talking on SSI in a science lesson because they have never experienced something similar (Blonder *et al.,* 2016). In addition, some teachers report that they worried about being inadequate in teaching about RRI and needed training that helps them to develop strategies in order to introduce RRI to students (Venturi *et al.*, 2015).

An effective teaching about RRI is possible with activities and lesson plans, which are planned well for this purpose (Venturi *et al.*, 2015). This requires teachers to have an interdisciplinary approach so that they can cover a scientific content by addressing different cases and actors (i.e. institutions, scientists, NGOs). However, the study of Ratinen and colleagues (2015) showed that this is challenging for teachers. After examining RRI integrated plans of student-teachers, Ratinen *et al.* (2015) found that governance, gender equality and engagement dimensions of RRI are not included in the lesson plans, while open access and ethics are addressed. Researchers think that this is the case because these two dimensions of RRI are the ones they can associate most with their daily lives (Ratinen *et al.,* 2015). Teachers also had difficulty in identifying "suitable spots" for bringing up RRI, proposing an appropriate path to introduce RRI in a science lesson, relating the RRI aspects with the science curriculum objectives and developing an assessment method for RRI topics (Ratinen *et al.,* 2015, p.130; Venturi *et al.*, 2015).

Some teachers experienced difficulty in discussing RRI with students, especially with the middle school students because terms like ethics, gender equality, open access and governance sounded unfamiliar to them and were hard to comprehend (Venturi *et al.*, 2015). At this stage integration of informal elements in formal education helped teachers to establish relevance of RRI for their students (Venturi *et al.*, 2015).

Venturi and colleagues (2015) summarized the factors affecting teachers' attitude toward RRI introduction as,

(i) "effects on students' motivation,
(ii) effects on the quality of teaching contents,
(iii) updating of teaching contents,
(iv) level of integration in the ordinary curriculum,
(v) relation to other disciplines and
(vi) opportunity of collaboration with institutions outside the school" (p.1184).

Findings of Ratinen *et al.* (2015) and Blonder *et al.* (2016) support the items in the list. These findings also show the difficulty of integrating RRI in science lesson (Ratinen *et al.,* 2015). Researchers recommend a workshop that allows teachers to experience RRI-integrated scientific inquiry as learners in the first place, before they implement it with their students (Blonder *et al.,* 2016; Ratinen *et al.*, 2015). Ratinen and colleagues (2015) also recommend pre-service and in-service education, at which RRI aspects, integration of them in lesson plans and strategies on how to engage students in RRI discussion are explicitly addressed.

2.9. Challenges Students Face when Learning About RRI

Responsible Research and Innovation (RRI) approach is a new for students and most of them have never related scientific content with a society in their school lessons before, which makes discussing on RRI is challenging for most students, even for the high-performing students (Blonder *et al.,* 2016). For instance, Akaygun *et al.*'s study (2015) with group of 21 including middle school and high school students showed that although the overall RRI understanding of students improved after involving in the *Nanotechnology Applications in Health Sciences* module (new name of the module is Nano and Health), only the understanding of two aspects of RRI, namely "*gender equality"* and "*open access",* reached to significantly higher level (Akaygun *et al.,* 2015). Another RRI aspect that students have difficulty to understand is *"ethics"* (Adadan and Akaygun, 2016). These studies point out important role of familiarity of a RRI concept in comprehension of it.

Besides to its unfamiliarity for students, value-based nature of RRI approach makes it difficult to discuss on such that there are many aspects to think on and there is no one right answer (Blonder *et al.,* 2016). Younger students (i.e. 13-14 year olds) have more difficulty in producing an idea and talking about RRI because some dimensions of RRI, specifically ethics, gender equality, open access and governance, are incomprehensible to them (Venturi *et al.*, 2015).

Limited studies in the literature shows that difficulties students face when learning about RRI are needed to be studied more in order to improve the quality of RRI teaching in science education.

3. SIGNIFICANCE OF THE STUDY

Science fairs, starting at 1920s in US and at 1960s in Turkey, has begun to get more attention gradually and the number of participants are increasing each passing year (McComas, 2011; TUBITAK, 2013a; TUBITAK, 2013b). Despite the world-wide trend in rising interest and the number of participants in science fairs, studies on science fairs are limited (Dionne *et al.,* 2012; Paul *et al.,* 2016; Yasar and Baker, 2003). There are very few studies about science fairs in Turkey as well (Tortop, 2013a; Şahin and Çelikkanlı, 2014; Yıldırım and Şensoy, 2016). Most of the research studies, examining the impacts of science fairs on students' attitudes, involve elementary school students (Şahin, 2012). Therefore, there is a need to examine high school students' and teachers' experiences in science fairs more. Besides, studies involving teachers and students, who develop exhibits on Nanoscience and Nanotechnology (NST) are very limited (Kampschulte, 2015; Tirre *et al.,* 2015; Yeh *et al.*, 2011). In addition, the literature review shows that there is no study about students' integration of socio-scientific issues (SSI) in their exhibits.

Learning about views and experiences of Turkish teachers and students, who participate in science fairs, may contribute to science education in Turkey in many ways:

- It helps understanding the nature of a science fair (Watson, 2003) as a multistage process starting with brainstorming to find an idea and ends with evaluation and reflection on the process,
- It facilitates finding out problems faced in science fairs (Tortop, 2013a) and helps developing strategies to clear off the sources of problems,
- It gives an insight about the place of science fairs in Turkey compared to science fairs in developed countries (Tortop, 2013a),
- It promotes adjustments in educational philosophy and principles, educational programs, and educational objectives to improve the overall quality of science fairs (Sherburne and Patton, 1971).

In this study, high school science teachers guided their students along the development of Responsible Research and Innovation (RRI) integrated interactive science exhibits on

NST, and then they participated a science fair exhibition in a science center (see Section 5.3. for full description of the settings of the study). Therefore, learning about specifically these teachers' and students' opinions and experiences in the process, may make contribution to science education in many aspects additional to ones listed above:

- It reveals teachers' and students' strategies to make a science exhibit interactive for engaging visitors
- It gives some ideas about how to develop an exhibit on NST
- It reveals difficulties teachers and students faced in developing a science exhibit on NST
- It gives an insight about teachers and students' strategies to integrate RRI in a science exhibit
- It reveals challenges teachers and students faced in integration of RRI in a science exhibit
- It may constitute a framework for infusion of socio-scientific issues in science lessons.
- It may inspire other science teachers to develop an exhibit on a cutting-edge science topic

In addition, involving in this study provides the participants with doing a self-reflection about

- what they gain from the process,
- how their knowledge improved,
- what kind of process they went through,
- quality of their exhibit.

Consequently, this study focuses around the views and experiences of teachers as mentors and of students as chief actors in the process of RRI integrated interactive science exhibition development. Therefore, this research introduces some innovative elements, such as RRI integration, interactivity and cutting-edge science theme, to the literature on science fairs.

4. THE PURPOSE OF THE STUDY

The present study was designed to explore knowledge of teachers and students about exhibitions, interactive exhibitions and science exhibitions before and after *the development and exhibiting of interactive science exhibit on nanotechnology applications integrating Responsible Research and Innovation (RRI)*, their practical approaches in the process, benefits they obtain from their experiences in the process and challenges they face along the process.

The following research questions guided this study:

1. How do teachers describe exhibition, interactive exhibition and science exhibition before and after guiding students along developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
2. What are the teachers' practical approaches in guiding students along developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
3. What are the challenges and benefits of guiding students along developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
   a. What are the challenges of guiding students along developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
   b. What are the benefits of guiding students along developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
4. How do students describe exhibition, interactive exhibition and science exhibition before and after developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
5. What are the students' practical approaches in developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
6. What are the challenges and benefits of developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?
   a. What are the challenges of developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?

b. What are the benefits of developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications?

Some terminology used in the research questions require operational definitions. Firstly, *exhibition* refers to comprehensive grouping of exhibits and displays of industrial or commercial products or artifacts with the purpose of presentation of collections and information for public use (Dean, 1999; Dean, 2002; Khoon and Ramaiah, 2008). Secondly, *interactive exhibition* refers to “those in which visitors can conduct activities, gather evidence, select opinions, form conclusion, test skills, provide input, and actually alter a situation based on input” (McLean, 1993, p.93). Thirdly, *science exhibitions* are organizations giving the visitors an opportunity to have the role of explorers of scientific concepts, phenomena or tools, as well as giving them insight about the nature of science through their experience in an environment that includes elements and practices belong to ‘the proper realm of science’ (Science Exhibition, 1946; Macdonald, 1998, p.2). Finally, the concept of *practical approach* refers to individuals’ practical applications, which are based on their existing experiences, ideas and theoretical knowledge, in managing, handling or guiding a situation.

Each specific research question, in this study, is addressed with the abbreviation “RQ” and the number of question coming after it for simplification. For example, the third research question is referred as RQ3.

5. METHODOLOGY

The methodology section of the study comprises of research design, participants of the study, setting of the study, data collection, data analysis, and credibility and reliability, which are described in the following sub-sections.

5.1. Research Design

Research studies are classified into four categories in terms of intention of the researcher: *exploratory, descriptive, explanatory* or *policy- oriented* (ISites Harvard, 2017). This study is centered around exploratory and descriptive purposes with the research questions starting with "what" and "how" instead of "why" (Kowalczyk, 2014). Having an *exploratory purpose,* this study aims to develop an understanding of a new phenomenon by identifying key issues, key concepts and key variables, and most often provides "new angles and new ways of looking at" a phenomenon (ISites Harvard, 2017; Kowalczyk, 2014). On the other side, having a *descriptive purpose,* this research offers to describe the course of events occurring within a specific context in detail (ISites Harvard, 2017; Kothari, 2004).

Research studies are categorized under three fundamental designs in terms of their methods: *quantitative design, qualitative design* and *mixed method design* (Creswell, 2014). This study is structured around qualitative design such that the objective is generating meanings and concepts hidden in the data, concepts are presented in the form of themes, settings are specific to study and hard to replicate, and the data is coming from interviews transcripts, observations and field notes (ISites Harvard, 2017). Creswell (2013) categorizes qualitative design into five approaches: *narrative research, phenomenological research, grounded theory research, ethnographic research* and *case study research.* Among five approaches Creswell (2013) described, the present study is *a phenomenological research* seeking for meanings from participants' lived experiences on a common phenomenon, which is *developing and exhibiting RRI integrated interactive science exhibit about NST* in this case. It is important that the participants experience the phenomenon consciously or on purpose (Creswell, 2013). After determining the phenomenon, researchers conducting a phenomenological research, explore the phenomenon with a heterogeneous group of 5 to 25 through various sources of data such as interviews (mostly multiple interviews with the same participants), observations and documents (Creswell, 2013). Then, the researcher describes "the essence of 'what' the individuals have experienced and 'how' they experienced it" (Creswell, 2013, p.79). Creswell (2013) also defines two types of the phenomenological research: *hermeneutical phenomenology* and *transcendental phenomenology.* While the researcher's interpretation is dominant in hermeneutical phenomenology, in transcendental phenomenology the focus is more on participants' descriptions of their experiences (Creswell, 2013). In this sense, current study corresponds to the transcendental phenomenology because the researcher tries to explore what the participants lived, how did it happen and what they feel about it by putting their' statements about their experiences and feelings in a center.

Creswell (2013) defines four philosophical assumptions made when researchers conduct a qualitative study: *ontological, epistemological, axiological* and *methodological. Ontological assumption* is about "the nature of reality and its characteristics" and implies "the idea of multiple realities" (Creswell, 2013, p.20). This study is built on the ontological assumption because it presents multiple forms of data collection, and reports ideas and experiences of different individuals. *Epistemological assumption* is about "how knowledge is known" and implies that knowledge base on participants' individual experiences, and therefore the distance between researcher and participants or what is explored should be minimized (Creswell, 2013, p.20). This study was also based on the epistemological assumption because the researcher was present in the field, which were school laboratories and science fair exhibition area in this case, when participants were working or presenting their works. *Axiological assumption*, on the other hand, is about the role of researchers' and participants' values in the study and "researchers acknowledges that research is value-laden and that biases are present" (Creswell, 2013, p.20). This study also involved axiological assumption first because data coming from interviews were based on subjects' own perceptions and experiences in the process, second because field notes taken by the researcher, and the conclusions drawn from data partially depends on researchers' interpretations as well as participants' expressions. Finally, *methodological assumption* is about how procedures of a qualitative study is formed and it signifies that it is an "inductive and emerging" process, which is "shaped by researchers' experience in collecting and analyzing the data" (Creswell, 2013, p.22). Although the fundamental outline of this study was determined at the beginning, it evolved and was elaborated in the process.

Creswell (2013) categorizes several "interpretive frameworks" that guide a qualitative research together with the four philosophical assumptions: *postpositivism, social constructivism, transformative frameworks, postmodern perspective, pragmatism, feminist theories, critical theory and critical race theory, queer theory,* and *disability theories* (p.23). *Social constructivism,* also known as interpretivism, aims to make meaning from nature of individuals' experiences, which are "usually formed through interaction with others" or through a context in which individuals have specific tasks, missions or goals (Creswell, 2013, p.25). Researcher generates some kind of "patterns of meaning" from the data instead of "starting with a theory" (Creswell, 2013, p.25). Ideas are emerged through researchers' induction on the data gathered with "methods like interviewing, observing and analysis of texts" (Creswell, 2013, p.36). With all of these characteristics, this study adapted the social constructivist framework.

5.2. Participants of the Study

When the nature of qualitative research is considered, *purposeful sampling* is recommended (Creswell, 2013). More specifically, in a phenomenological research, participants are "individuals, who have all experienced the phenomenon being explored and articulate their lived experiences" (Creswell, 2013, p.150). In this sense, the target group is determined through *criterion sampling* at the beginning in phenomenological research (Creswell, 2013). In this study, the set of criteria for participants are listed below:

For teachers

- Being a high school chemistry teacher in Turkey
- In the 2015-2016 academic year, implementing the module Nano and Health as extra-curricular activity, teaching about Responsible Research and Innovation (RRI), and interactive exhibition through the module "Nano and Health", which was developed by the Turkish team under the Project IRRESISTIBLE (See Table 5.3 for short description of module chapters)

- Guiding students along developing and exhibiting RRI integrated interactive science exhibit about NST after completing first eight chapter of the module

For students

- Being a high school student in Turkey
- In the 2015-2016 academic year, learning about the module Nano and Health as an extra-curricular activity, RRI and interactive exhibition through the module “Nano and Health”, which was developed by the Turkish team under the Project IRRESISTIBLE
- Who are expected to develop a science exhibit about NST integrating interactive elements and RRI after completing the first eight chapter of the module
- Exhibiting the science exhibit in the science fair exhibition organized in ITU Science Center by Turkish team under the Project IRRESISTIBLE.

In the Project IRRESISTIBLE, there were 16 chemistry teachers, some of whom worked in pairs, and 102 students, from 11 schools, meeting these sets of criteria. Among 11 schools, 3 schools were chosen through *stratified purposeful sampling.* This type of sampling illustrates the commonalities as well as variations among particular units or subgroups, which are referred as *strata* (Creswell, 2013; Patton, 1990). In the present research, the key dimension forming strata is “the school culture” of participants. The school culture refers to complex components of a school including values, beliefs, traditions, rituals, ceremonies, language, vision and mission that shapes behaviour and relationships within the school atmosphere (Peterson and Deal, 2011). Among other schools ensuring different school cultures in the project, these 3 schools were chosen regarding the accessibility of teachers and students.

The first school (SH1), in the scope of this study, is one of the well-established educational institutions founded as private school for high school students in 1950s in Turkey (Kalmun, 2017). Today, it is a public Anatolian high school, whose students are in 0.42% among the students entering the national exam (Pembe and Sekmenli, 2014). The student population of school is around 1200 involving 300 boarding students (Kalmun, 2017). The school has 92 teachers (KAL, 2017a). The school is rich in facilities such that it has about 50 classrooms, 6 laboratories, 2 music classrooms, 2 art classrooms, 1 computer classroom, a library, a conference room, a sport hall, a dormitory, a dining hall, a medical room, and a psychological counselling and guidance unit (KAL, 2017a). The school gives 5-year education involving a 1 prep year in English and use national curriculum developed by the Ministry of National Education in Turkey (Kalmun, 2017). The School has various traditions such as hosting music festivals, chest tournament, alumni day, conferences, guest speakers and award ceremonies, and having school clubs, sport teams and a student council (Kalmun, 2017). The school also makes collaborations, and conducts joint projects and exchange programs with schools in abroad (KAL, 2017a). Finally, this school also holds and participates in science-related activities such as national and international science fairs. For example, the school hosts the TUBITAK 4006 Science Fair in 2017 (KAL, 2017b)

The second school (SH2) is a private school, whose roots dates back to 1880s, and was established by a foundation founded by a group of businessman (TVO, 2017a). The school functions in its current campus since 1994-1995 academic year and offers education from preschool level to high school level including a regular high school and a science high school (TVO, 2017a). The student population of the regular high school is around 700 and of the science high school is around 100 (TVO, 2017a). The regular high school has 110 teachers and the science high school has 45 teachers, and both high school includes Turkish teachers as well as teachers from other nations (TVO, 2017b). This school is also rich in facilities such that it has about 40 classrooms, a gene laboratory as well as typical science laboratories, few computer classrooms, studios for music, art and photography, a cultural center, an indoor swimming pool, 2 gyms, a dining hall, a study hall, 2 medical rooms, and a psychological counselling and guidance service (TVO, 2017c). The school gives 5-year education involving a 1 prep year in English. The school adapts national curriculum developed by the Ministry of National Education in Turkey with integrating additional educational programs such as German, Spanish and French language, robotics, various art classes, various sports branches, and various design programs according to students' interests and skills (TVO, 2017c). It also offers International Baccalaureate Diploma Programme for students. Students having knowledge gap have the opportunity to get support from teachers after school hours (TVO, 2017c). Similar to the first school, this school has many traditions such as hosting several festivals in the field of art and science, history days, chest tournament, conferences, guest speakers, graduation ceremonies, and having school clubs, sport teams and a student council (TVO, 2017c). The school also organizes conferences for parents and teachers. Like the first school, this school makes collaborations, and conducts joint projects with schools in abroad (TVO, 2017c). Finally, this school also holds and participates in science-related activities. For instance, two high school students participating in 11th International Robotic Science Fair Contest organized with the collaboration of Turkish Ministry of Education (MEB) and TUBITAK in 2017 (TVO, 2017d).

The third school (SH3), in the scope of this study, is a public high school, which was established in 2004 as a teachers' high school, and was transformed into an Anatolian high school in 2014 (MKAOL, 2017a). The student population of the school is about 600, whereas the number of teachers is 43 (MKAOL, 2017a). This school is a typical public high school in terms of the range of facilities including about 20 classrooms, 3 laboratories, a music classroom, an art classroom, a computer classroom, a small library, a sports hall, a dining hall, a conference room, a medical room, and a psychological counselling and guidance unit (MKAOL, 2017a). The school gives 4-year education without a prep year and use national curriculum developed by the Ministry of National Education in Turkey (MKAOL, 2017a). The school hosts seminars and graduation ceremony; participates in contests in the field of music and sports, and recently has formed a student council (MKAOL, 2017b). For example, the school hosted a seminar about jobs of the future and vocational preference in collaboration with a private university (MKAOL, 2014). This school also participates and conducts projects at national and international level, but not as often as the first two schools. For instance, the school conducted a Comenius Project in collaboration with Germany, Poland and Finland about intercultural communication in 2015 (MKAOL, 2015).

In the current study 3 science teachers and 13 students, in total, are interviewed. One science teacher out of 2, and 5 students out of 21 from the first school; the science teacher and 2 students out of 8 from the second school; and the science teacher and 6 students out of 7 from the third school are chosen to interview with through *convenience sampling* such that available and volunteer individuals participated in the current study (Creswell, 2013). The demographic information of the teacher-participants is presented in Table 5.1 and of the student-participants is presented in Table 5.2.

Table 5.1. The demographics of the teacher-participants.

Code	Gender	School Level	Field	Years of Experience	School Type
SH1T1	F	High School	Chemistry	25	Public School
SH2T1	M	High School	Chemistry	20	Private School
SH3T1	F	High School	Chemistry	25	Public School

Table 5.2. The demographics of the student-participants.

Code	Gender	School Level	Grade Level	School Type
SH1S1	M	High School	10	Public School
SH1S2	F	High School	10	Public School
SH1S3	F	High School	10	Public School
SH1S4	M	High School	10	Public School
SH1S5	F	High School	11	Public School
SH2S1	M	High School	11	Private School
SH2S2	M	High School	11	Private School
SH3S1	M	High School	10	Public School
SH3S2	M	High School	10	Public School
SH3S3	F	High School	10	Public School
SH3S4	F	High School	10	Public School
SH3S5	M	High School	10	Public School
SH3S6	M	High School	10	Public School

5.3. Setting of the Study

The setting of the study is presented under different sections referring the process participants went through in the project before and during developing and exhibiting interactive science exhibits on nanotechnology applications integrating RRI.

5.3.1. The Process Participants Went Through in Project IRRESISTIBLE Before Developing and Exhibiting Their Science Exhibits

The participants of this study involved in the second phase of the Project IRRESISTIBLE in Istanbul, Turkey. Teachers participated in a two-day “Nanotechnology

Applications in Health Sciences Workshop", which was held at Boğaziçi University Faculty of Education in June, 2015. In the workshop, the Project IRRESISTIBLE was introduced and then the project coordinator and two researchers from Boğaziçi University implemented the first eight chapter of the module "Nano and Health", which was developed in the first phase of the project by the first Community of Learners (CoL) involving in-service science teachers from various public and private schools in Istanbul, a science center expert, and two science education experts, a research scientist, and the project assistant from Boğaziçi University. Teachers in the workshop had the role of learners and were coached by science teachers, which had involved in the first phase of the project. The participation of new teachers expanded the CoL, which will be referred as the second CoL in the current study.

Teachers set up a Nanoscience Club in their schools and volunteer students joined in the club. Teachers and students were supplied with the module booklet, worksheets and any other materials needed for the module by the Project IRRESISTIBLE such as videos, chemicals, documents and additional sources they can benefit from. Then, teachers implemented the module "Nano and Health" with the club students as an extra-curricular activity in the 2015-2016 academic year. Three science teachers, in the scope of this study, implemented the module in the chemistry laboratory of their school.

The module "Nano and Health" consists of 9 chapters. The first eight chapter of the module includes some big ideas of nanoscale science and engineering (i.e. size and scale, size dependent properties) (Stevens et al., 2009), and Responsible Research and Innovation (RRI) in the context of nanotechnology applications in health science. In the last chapter, students develop an RRI integrated interactive science exhibit about NST. The detailed description of the module "Nano and Health" are given in the Table 5.3. The second CoL came together once every 3 weeks at meetings held at the university to share their experiences in their implementation of the module, give feedback to each other, get support from academics and science center staff, and to get materials they need.

Teachers and students made 2 field trips at different stages within the Project IRRESISTIBLE. Firstly, they visited the Nanochemistry Laboratory and the Medicinal Chemistry Laboratory at Boğaziçi University after completing the first four chapters of the module, "Nano and Health". They were guided by graduate students working in these laboratories during their visit. Graduate students introduced instruments and tools they use in the laboratories such as Scanning Electron Microscope (SEM) and glove box, and told about the research studies they were conducting such as synthesizing medicine via nanotechnology for curing cancer. Secondly, teachers and students visited the Istanbul Technical University (ITU) Science Center after completing the first eight chapters of the module, just before starting to develop a science exhibit. Their visit was guided by science center staff. During teachers' and students' visit, science center staff introduced the exhibits, and they experienced many interactive exhibits about optical illusion, mechanics, electricity, astronomy, mathematics, fluid dynamics, sound and vibration.

Table 5.3. "Nano and Health" module. (Akaygun *et al.,* 2016)

Ch. No	Chapter Name and Short Description
1	Hospital-Acquired Infections (2 x 40 min.): Students watch a news video about cross infections in hospitals and discuss on sources of it. Based on a scenario, brochure taken from a hospital's public relations department, includes a group of researchers' suggestions on using nanosilver products for prevention of cross infections. A committee is established to decide whether the suggestions should be put in practice or not. Students discuss who should take part in the committee and discuss on risks and benefits of these suggestions.
2	Size and Scale (3 x 40 min.): Students examine the concepts of size and scale through various activities. They make some predictions about change in interactions with the environment, when their size becomes thousand times bigger and thousand times smaller. They watch scenes from movies illustrating these two cases and play card sorting games on size and scale.
3	Modelling Drug Release or Absorption (2 x 40 min.): Students examine size-dependent properties. They design and conduct an experiment to explore whether the size of the medical tablets affect its absorption and release time.
4	Imaging Bacteria (2 x 40 min.): Students learn about instruments used in NST. They investigate the images of the bacteria on agar cubes with different tools such as optic microscope, magnifying glass, and Scanning Electron Microscope (SEM). Then, they involve in two different activities modelling Atomic Force Microscoby (AFM).
5	Synthesizing AgNP and Testing Its Antibacterial Effect (2 x 40 min.): Students synthesize silver nanoparticles, and design and perform an experiment to explore whether silver nanoparticles have antibacterial effect or not.
6	Antibacterial Nanoproduct (2 x 40 min.): Students test the durability of the antibacterial effect of a nano-product textile against washing.

Table 5.3. "Nano and Health" module. (Akaygun *et al.,* 2016) (cont.)

Ch. No	Chapter Name and Short Description
7	Other Nanoparticles (2 x 40 min.): Students search for the uses, advantages and risks of other nanoparticles such as gold, silica, and iron nanoparticles. They read scientific articles about these nanoparticles, and they view some videos about such particles. Then, they prepare a presentation about the use, advantages and risks of the nanoparticle they choose and share their ideas as a group.
8	Responsible Research and Innovation (2 x 40 min.): Based on the scenario in the first lesson, students evaluate a report on risks and benefits of silver nanoparticles submitted to hospital's administration, and they decide if the hospital should accept or decline using silver nanoparticles through discussion by developing valid arguments. Then, they discuss on six key aspects of RRI.
9	Developing an Interactive Exhibit (8 x 40 min.): Students develop and exhibit an RRI integrated interactive science exhibit on NST. They display their exhibits first in their schools, then in a science center/museum.

5.3.2. The Process of Developing and Exhibiting RRI Integrated Interactive Science Exhibit on NST

Before starting to guide their students along exhibit development, teachers attended in a workshop on exhibition, which was specifically developed for teachers in Project IRRESISTIBLE. It was held at Boğaziçi University by the project team including the project coordinator, two researchers and project assistant from Boğaziçi University as well as the director of ITU Science Center. In the workshop, types of exhibits (i.e. models, posters, experiments and digital apps), interactive exhibitions and integration of Responsible Research and Innovation (RRI) were addressed, and then few examples of students' exhibits from the first phase of the project were presented. The examples shared with teachers were kept limited on purpose of not to affect teachers' ideas and encourage originality. Teachers asked their questions and got support from the project team. Five weeks and eight weeks after the workshop (including a two-week semester break), two CoL meetings were held, where teachers discussed on their progress in the exhibit development process.

Students knew they would develop a science exhibit and present it at a science center from the beginning. Teachers mentioned about this aspect of the Project IRRESISTIBLE, while they were introducing the Nanoscience Club to students. After completing the first eight chapters of the module "Nano and Health", and attending to the workshop on exhibitions, science teachers made an introductory speech to their students about what kind of procedure they would follow roughly, what were the criteria they needed to meet in their exhibit and how much time they spent to develop exhibits. Students were encouraged to work in groups, however, they were also free to develop their own individual exhibits. Teachers informed students about the costs of the materials they wanted to use in exhibits would be funded by the Project IRRESISTIBLE. The exhibit development process was guided through "the Chapter 9. Developing an Interactive Exhibit" in the Nano and Health module booklet. Students were given worksheets including questions that provide students with 4-week planning (See Appendix A, Akaygun *et al.,* 2016). After students developed their exhibits, the project team visited the schools to give feedback to students to improve their exhibits before displaying them in the science fair exhibition that would be held at ITU Science Center. At this stage, the researcher as a project assistant also gave verbal feedback to students about how they can improve the quality of their exhibits and integrate RRI more effectively.

Finally, students and teachers participated in the exhibition, named "Responsible Research and Innovation in the Context of Nanotechnology Applications Exhibition", which was organized under the Project IRRESISTIBLE at ITU Science Center and consists of exhibits of the Nanoscience Club students participated in the project. The science fair exhibition lasted for 2 days on April 1-2, 2016. Twenty-four science teachers together with 153 high school and middle school students from 17 private and public schools in total participated in Responsible Research and Innovation in Nanotechnology Applications Exhibition. Sixty-four science exhibits about NST applications in many fields from medicine to textile were displayed at the exhibition. In two days, about 200 visitors involving middle school and high school students from other schools, undergraduate students, parents, science center experts, and academics visited the exhibition. Visitors are introduced to the concept of NST and their applications as well as interactive exhibit and RRI. Students and teachers participating in the Responsible Research and Innovation in Nanotechnology Applications Exhibition, science center experts and visitors evaluated the exhibits via an evaluation form asking the exhibits reflecting the nanotechnology applications best, reflecting the RRI best, integrating the RRI into nanotechnology applications best, reflecting the interactivity best, that is the most interesting, that they liked most, and also asking their suggestions. After the exhibition, the final ranking of the exhibits was made by the project team regarding the evaluation of students, teachers, and visitors. These were the common stages that the participants went through, however there were also few differences in the process.

5.3.3. The School-Specific Process of Developing and Exhibiting RRI Integrated Interactive Science Exhibit on Nanotechnology Applications

The process of developing and exhibiting exhibits varied depending on the school culture including many components such as the school settings, facilities, student and teacher profile and level of support coming from school administration (See Section 5.2. for detailed description of each school culture).

In the first school (SH1), the chemistry teacher collaborating with a biology teacher guided 21 students (15 females, 6 males) in the Nanoscience Club. These teachers could not attend the workshop on exhibition, but they watched the video recording of the workshop, and asked their questions to the researcher later. Biology teacher did not involve in the club hours regularly. In the exhibit development process, technician in the school and the Engineering Club students gave support in some technical issues such as suggesting alternative materials and methods if students confront with a problem (See Section 5.2. for more information about the school). The Nanoscience Club students, in this school, were from various grade levels (Grade 10-12). During the exhibit development, the club activities were held once a week for 2 x 50 minutes in the chemistry laboratory after formal school hours. At the beginning of the exhibit development process, there were 6 groups including 3-5 students and students themselves established the groups; but while trying to decide the exhibit theme, two groups, who wanted to work on the same idea, merged into a group of 6. Then, a group of 3 left this combined group to develop their own exhibit idea at a very late stage of exhibit development process. Students developed their exhibits in the Nanoscience Club hours as well as during their free time (i.e., lunch break) within 6 weeks. They came together at out of school environment for getting their materials. In addition, in this school, groups collaborated with each other such that they gave feedback to each other’s ideas, they bought materials for each other if somebody have an easy access to the shop and they helped each other in construction of the exhibit. After finishing their projects, the project team came to visit in the school and gave feedback on exhibits a week before the science fair exhibition. In the overall process, the groups spent about 15 hours to develop their exhibits. During the exhibition, 20 students out of 21 participated the Responsible Research and Innovation in Nanotechnology Applications Exhibition for two days, but a 12th grade student in a group of 4 could attend the exhibit for one day because of being prepared for the university entrance examination.

In the second school (SH2), the chemistry teacher guided 8 students (4 females, 4 males) in the Nanoscience Club. Students were from various grade levels (Grade 9-11), and there were students from both regular high school and science high school of this private school (See Section 5.2. for more information about the school). The Science Project Coordinator, and Technology and Design Teacher of the school involved in the exhibit development process as consultants to give technical and technological support. During the exhibit development, the club activities were held once a week for 50 minutes in the chemistry laboratory after formal school hours with two-weeks exceptions at which they met twice (2nd-3rd meetings and 5th-6th meetings). Students worked together to develop few exhibits instead of working in groups upon their desire to contribute each exhibit. Students developed their exhibits in the Nanoscience Club hours as well as at their free time (i.e. after school) within 6 weeks. The teacher bought the materials needed and students did not come together at out of school to work on their exhibits. After finishing their projects, the project coordinator came to visit in the school and gave feedback on exhibits 2 days before the science fair exhibition. In the overall process, the groups spent about 15 hours to develop their exhibits. During the exhibition, 8 students participated in the Responsible Research and Innovation in Nanotechnology Applications Exhibition alternately such that 2 students represented the whole group in the first day of the science fair exhibition, while 6 students attended in the second day of the exhibition.

In the third school (SH3), the chemistry teacher guided 7 students (3 females, 4 males). Students were from the 10th grade (See Section 5.2. for more information about the school). The teacher did not get support from any other teacher or technical personnel in the school. During the exhibit development, the club activities were held once a week for 40 minutes in the chemistry laboratory during a lunch break time within the formal school hours. At the beginning of the exhibit development process, there were 6 students working in groups of 2 and a student working alone, but later 2 more students decided to work individually and 4 students worked in groups of two and 3 students worked individually. Students worked in groups or alone and developed their exhibits mostly at their free times (i.e. weekend) as well as in the Nanoscience Club hours during 7 weeks. Students bought or ordered their materials that they used in their exhibits. In addition, in this school, the groups gave feedback to each other's ideas before the construction of exhibits. After finishing their projects, the project team form the university, including two science educators and a science researcher, visited their school and gave feedback on exhibits 4 days before the science fair exhibition. In the overall process, the groups spent about 15 hours to develop their exhibits. During the exhibition, all 7 students attended the Responsible Research and Innovation in Nanotechnology Applications Exhibition for both two days of the exhibition.

The Table 5.4 shows the number of students, the number of groups, the number of the club hours in a week, where the students worked, whether they got any support other than their club teachers, and how much time they spent in total during the exhibit development process.

Table 5.4. Basic information about the exhibit development process in the schools.

School	**Number of Students and Groups**	**Club Hours in a Week**	**Where Students Worked**	**Support Students Took**	**When Students Worked**	**Total Time Spent**
SH1	- 21 students - 5 groups	2 x 50 minutes	Chemistry Laboratory	- Their science teachers - Engineering Club - Technical staff in the school	- During the club hours - Free times	15 hours

Table 5.4. Basic information about the exhibit development process in the schools. (cont.)

School	Number of Students and Groups	Club Hours in a Week	Where Students Worked	Support Students Took	When Students Worked	Total Time Spent
SH2	- 8 students - All worked together	1 x 50 minutes	Chemistry Laboratory	- Their science teacher - The Science Project Coordinator - Technology and Design Teacher	- During the club hours - Free times	15 hours
SH3	- 7 students - 2 groups - 3 individual workers	1 x 40 minutes	- Home - Chemistry Laboratory	- Their science teacher	- During the club hours - Free times	15 hours

5.3.4. Role of the Researcher

In qualitative studies, researchers can never be totally neutral even though they try to avoid bias and keep their values away (Ormston *et al*., 2013). Therefore, researchers need to reflect on their role in the study, how they interact with the participants, and how their backgrounds and past experiences may impact the study (Creswell, 2013). The researcher studied in “Integrated MS and BS Program in Chemistry Teaching” at Boğaziçi University and after graduation she started to “Secondary School Science and Math Education” master program in the same university. With her interest in in-service science teacher education, the researcher took place as an instructor in a foundation’s few workshops for chemistry in-service teachers and began to attend the Community of Learners (CoL) meetings of Project IRRESISTIBLE. Then, the researcher started to work as project assistant in the project IRRESISTIBLE and actively involved in the first and the second phase of the project.

In the first phase of the project, the researcher attended to the project meetings of CoL and contributed to the development of the “Nano and Health” module. As a project assistant, the researcher involved in preparation of materials and development of documents for the module activities, developed digital designs (i.e. certificates, posters, banners, roll-ups, video, brochures, newsletter) for events and dissemination of the project, collaborated with

CoL members, and took place in data collection, data analysis, reporting and presenting processes. The researcher participated in the exhibition involving exhibits of students in the project and made interviews with some students. The researcher also attended to one Project IRRESISTIBLE meeting hosted by a different partner of the project (See Section 2.7.6. for learning more about the Project IRRESISTIBLE).

In the second phase of the Project IRRESISTIBLE, the CoL expanded with the participation of 20 new science teachers. In this phase of the project, the researcher actively involved in the organization of workshops, and attended to the workshops and CoL meetings as well. Similar to the first phase of the project, the researcher, as a project assistant, involved in preparation of materials and development of documents for the module activities, developed digital designs (i.e. certificates, posters, banners, roll-ups, video, brochures, newsletter) for events and dissemination of the project, collaborated with CoL members, and took place in data collection, data analysis, reporting and presenting processes. The researcher participated in the exhibitions involving exhibits of students in the project and made interviews with some students and teachers. The researcher also attended to one Project IRRESISTIBLE meeting hosted by one of the partners of the project.

The experience that the researcher went through in the first phase of the project gave her an insight about what kind of exhibits students can develop, how they make exhibits interactive, how they integrate RRI, what kind of difficulties students and teachers face in the process, and what are their attitudes about developing and exhibiting an RRI integrated interactive science exhibit on NST. Then, the researcher decided to investigate the impact of developing and exhibiting RRI integrated interactive science exhibits about NST on teachers' and students' knowledge about exhibitions and their experiences in the process (See Section 4. for the purpose of the study).

The researcher had a constant communication with the teachers in the project in order to ensure the implementation of the modules and gave necessary technical support such as answering their questions about preparation of some chemicals, growing bacteria in a petri dish, use of Web 2.0 tools in the module or dealing with official proceedings, and she also gave pedagogical support such as answering their questions on how to implement a specific activity in the module or guiding them in their Nanoscience Club settings in implementation of a module chapter. Before the workshop on exhibitions, the researcher asked permission of 3 science teachers, who implemented the "Nano and Health" module, to observe their Nanoscience Club periods during the development of science exhibits, and made a pre-interview with these teachers. Then, the researcher conducted pre-interviews with some students, who were volunteer and available before starting to develop an exhibit. The researcher met with student-participants for the first time at an hour-lasting field trip made to the Nanochemistry Laboratory and the Medicinal Chemistry Laboratory at Boğaziçi University.

The researcher had also developed some exhibits while she was 5^{th} grader in elementary school and 6^{th}, 7^{th} and 8^{th} grader in middle school. These exhibits were mostly artistic such as paintings and sculptures, and the ones in science were models of a natural phenomenon or an object such as model of the Moon's craters. These exhibits were displayed in her schools while she was attending In addition, when the researcher was doing internship in undergraduate program, she took place in a juree and judged students' projects at a science fair, which was organized by a private school and was involving science projects of students from different schools.

Finally, while analyzing the data, the researcher tried to avoid any biases by focusing mostly on participants' statements on their lived experiences. On the other hand, her experiences about exhibit development of students and teachers in the first phase of the Project IRRESISTIBLE might have been affected her interpretation and conclusion-drawing in the data analysis. In addition, the researcher regarded some ethical considerations coming from the nature of the studies with qualitative designs and more specifically with the phenomenological approach (See Section 5.7. for full description of ethical considerations).

5.4. Data Collection

In a qualitative study with a phenomenological approach, the main source of data is interviews with individuals who experiences a common phenomenon (Creswell, 2013). Creswell (2013) suggests multiple interviews with the same participants. In this study the researcher made pre-interviews and post-interviews with 3 teachers and 13 students developing and exhibiting Responsible Research and Innovation (RRI) integrated interactive science exhibit about Nanoscience and Nanotechnology (NST). Semi-structured, one-on-one interviews including open-ended questions were done with the participants (Creswell, 2013). The pre-interviews with the teachers were conducted at the Boğaziçi University Faculty of Education before the workshop on exhibition. Interviews with students and post-interviews with the teachers were conducted in their schools' chemistry laboratories within formal school hours. Different interview protocols were established for teachers and students as well as for pre-interviews and post-interviews, which also have some common questions. The pre-interview protocol for teachers is presented in Appendix B, the post-interview protocol for teachers is presented in Appendix C, the pre-interview protocol for students is presented in Appendix D, the post-interview protocol for students is presented in Appendix E. The average time of interviews with teachers and students varied. While the pre-interviews with each student took about 13 minutes on average, the pre-interviews with each teacher took about 21 minutes on average. Also, the post-interviews with each student took about 30 minutes on average, whereas the post-interviews with each teacher took about 85 minutes on average. The total and average time periods spent for interviews are given in Table 5.5 below.

Table 5.5. The total and average time periods spent for interviews.

Interview	**Total Time**	**Average Time per Individual**
Pre-interviews with 13 students	2h 41′	13′
Pre-interviews with 3 teachers	1h 2′	30′
Post-interviews with 13 students	6h 36′	21′
Post-interviews with 3 teachers	4h 11′	1h 25′

Another form of collecting data in a qualitative study is observations (Creswell, 2013). Creswell (2013) defines four types of observations in terms of researchers' roles: *complete participant, participant as observer, nonparticipant/observer as participant* and *complete observer*. In this study, most of the time, the researcher was "observer as participant", who was "outsider of the group under study, watching and taking field notes from a distance" during observing the Nanoscience Club periods (Creswell, 2013, p.167). At a few times, the researcher had conversations with teachers and students when she wanted to understand what they were doing in more detail. However, these conversations never interrupted the natural flow or the atmosphere of the Nanoscience Club periods. In addition to school club hours, the researcher was present and had chance to make observation in the project team's visits to school for giving feedback to students' exhibits before the exhibition. The number and time period of observations for each school are presented in the Table 5.6. The amount of observations done during the project team's school visits are presented as plus one and corresponding amount of time. The time periods presented in decimal points stem from the extra time used for exhibit development other than the school club periods.

Table 5.6. Basic information about the observations of Nanoscience Club periods and the project team's school visits.

School	Number of Weeks	Number of Visits for Observations	Number of Observation Hours
SH1	4	4 + 1	7.5 x 50 minutes + 115 minutes (8h 10′)
SH2	6	7 + 1	7.5 x 50 minutes + 25 minutes (6h 35′)
SH3	6	5 + 1	4.5 x 40 minutes + 53 minutes (3h 53′)

Field notes are a typical form of data coming from the observations (Creswell, 2013). In this study, the researcher took field notes through the guide of the research questions while observing teachers and students developing science exhibits. The field notes include descriptions of what happened such as interactions among teachers and students, and some specific conversations or instants of activity. The field notes also comprise of reflections of the researcher on some situations. The timeline of the field notes taken in each school is presented in Appendix F.

Another source of data, coming from the observations, is the video-recordings of the Nanoscience School Club periods and the project teams' visits to schools. Most of the videos recorded by putting the camera at an angle, which can view all the students or a certain group. At few circumstances, the researcher zoomed in and recorded specific instants to view students' works in more detail. These video recordings never destroyed the ongoing flow or the atmosphere of the school club periods.

Besides, students and teachers filled weekly log for three weeks after the week the teachers made introductory speech about the exhibit development. The weekly log comprised of 3 questions aiming to follow students' or groups' progress in the process and teachers' planning. Students and teachers filled printed logs presented in the Table 5.7. First two logs were filled by each student, while the last log were filled as a group if students worked in groups and filled by a student if s/he worked individually.

Table 5.7. Weekly log.

Name:	**Date:**
Question	Answer
What were you planning to do about exhibit development until the club activity today? Could you make it?	
What did you do in the club activity today? Was it efficient?	
What are you planning to do until the next club activity?	

Final source of data collected for this study is the video recordings of the workshop on exhibition organized for teachers, and two CoL meetings were held within the process of exhibit development. These sources of data were included to gain more insight about teachers' concerns if any and their reflections on their guiding experiences in the ongoing process such as their practical approaches or difficulties they faced. The timeline of the workshop and meetings are presented in Appendix G.

5.5. Data Analysis

Among the qualitative data collection methods, whether it is interviews, field notes or video recordings, in all cases, *content analysis* is carried out by focusing on "words" or images transferred into verbal descriptions (Miles *et al.,* 2014; Saldaña, 2011). Content analysis is "systematic examination of texts, visuals or media" to produce "manifest and latent meanings" (Saldaña, 2011, p.10). The *manifest meanings* are obvious ones, which refers to direct semantics in the data, while the *latent meanings* are obscure ones, which lie in the data and depend on indirect inferences of the researchers (Saldaña, 2011). In the current study, the data analysis mostly bases on the manifest meanings.

Creswell (2013) summarizes three core steps of data analysis in a qualitative research. The first step is generating *codes* from the data through the reduction to "meaningful segments". Saldaña (2013) call this stage as *First Cycle Coding* and defines codes as

> "… research-generated constructs that symbolizes and thus attributes interpreted meaning to each individual datum for later purposes of pattern detection, categorization, theory building, and other analytic processes (p.4)."

The second step of qualitative data analysis is grouping identified codes under a broader category called as *theme* (Creswell, 2013). Saldaña (2013) call this stage as *Second Cycle Coding* at which the researchers make pattern coding. Coding and forming themes are cyclic processes, at which the researchers go back and forth while analyzing the data (Creswell, 2013; Saldaña, 2013). Finally, the third step of qualitative data analysis that Creswell (2013) points out is visualizing and comparing the data through "graphs, tables and charts" (p.180). Miles and Huberman (1994) state that in some cases transforming a qualitative data into quantities provided with the qualitative descriptions. In this study, the frequencies of identified codes are presented in graphs.

The first source of the data in the current research is interviews with the participants. The researcher acquired some initial analytical insights and thoughts through the interviews (Braun and Clarke, 2006). For the analysis, the interviews, which took about 14h 30′ in total, were transcribed verbatim in 224 pages. This was the phase, where the researcher began to familiarized herself with the data and took some notes for further analysis (Braun and Clarke, 2006). Then, from each transcript, important statements corresponding to the research questions were obtained and organized in a table. Subsequently, codes were identified and combined into the themes, which defined shortly, and number of frequencies of codes were presented in column graphs. Quotations referring particular themes were organized in tables. In the First Cycle coding, *elemental methods* and *affective methods* are used. Saldaña (2013) defines *elemental methods* as "foundation approaches to code qualitative texts" (p.67).

Based on Saldaña's (2013) descriptions, Miles *et al.* (2014) defines three approaches of the elemental method: (i) *Descriptive coding,* (ii) *In Vivo coding* and (iii) *Process coding* (p.74). Descriptive codes are used to summarize passages with one or two words, In Vivo codes originates from the participants' own expressions and are in the form of phrases, and Process codes are used to imply actions through "–ing words". On the other hand, *affective methods* aim to investigate participants' subjective qualities such as emotions and values (Saldaña, 2013). Miles *et al.* (2014) also defines three approaches of the affective method: *Emotion coding, Values coding* and *Evaluation coding.* Emotion codes are used to describe participants' emotions based on their expressions or inference of the researcher. Values codes imply the participants' values, attitudes and beliefs, and Evaluation codes are based on participants' evaluations on phenomena and includes *subcodes* specifying the various judgements on the same phenomenon (i.e., science fair: informative, science fair: interactive).

The second source of the data is the field notes taken in the observations of the Nanoscience Club periods. The field notes were transformed into "*write-ups*", which include additional content that are missing in the field notes as Miles, Huberman and Saldaña (2014) suggested (p.71). Then, some *memos* were noted. Memos are the researcher's short reflections and thoughts on the data regarding the research questions (Creswell, 2013; Miles *et al.,* 2014; Saldaña, 2013). The field notes, which were converted into write-ups including memos, were analyzed through First Cycle and Second Cycle coding with approaches similar to the analysis of the data coming from interviews. The themes identified with the analysis of field notes are organized in tables.

The video-recordings of the Nanoscience Club periods and the project team's visits to schools are the third source of the data in the current research. For the analysis of data coming from the video-recordings, Miles, Huberman and Saldaña (2014) suggest to transfer them into textual summaries. The video-recordings of observations in schools, which lasted 18h 38′ in total, were transcribed into clear textual summaries of the core ideas in totally 88 pages including few images. Then, content analysis was performed regarding the research questions. The themes obtained with the analysis of data coming from video-recordings are organized in tables.

The weekly logs that filled by the students and teachers were used as additional data source for RQ2 and RQ5, which are about practical approaches of students and teachers in the exhibit development process. They were also used to contribute to data analysis done for RQ3 and RQ6, which aims to explore the benefits and difficulties of exhibit development for students and for teachers, who guided the process. The codes determined in the analysis of weekly logs were classified under the themes, which are identified in the content analysis of other data sources used for investigation of RQ2, RQ3, RQ5 and RQ6. The themes addressed in weekly logs are presented in tables.

Finally, the video-recordings of the workshop on exhibition and two CoL meetings in the exhibit development process were analyzed for further investigation of any instants or ideas addressing RQ2, RQ3, RQ5 and RQ6. These video recordings, which took 6h 40′, were textually summarized totally in 17 pages and content analysis was conducted. The codes and themes originated in this final source of data are introduced in tables.

The researcher benefitted from color coding for the analysis of all data sources. Three colors are used to highlight the identified quotations with respect to the research questions. The green color covers the benefits of the exhibit development process and the exhibition for students and teachers, while the red color highlights the difficulties they faced in these stages, and the yellow color, on the other hand, signs the practical approaches of students and teachers in these phases.

5.6. Credibility and Reliability

The nature of validation in qualitative research differs from the validation in quantitative research and therefore alternative terms such as *trustworthiness, credibility* and *authenticity* are used instead of validity (Creswell, 2013). In this research, the term "credibility" is used to refer the validity. Creswell (2013) considers credibility as "an attempt to assess the accuracy of the findings, as best described by the researcher and the participants" (p.249) and he describes several strategies to establish credibility.

The first strategy is "*prolonged engagement and persistent observation*" implying a long-term and close presence within the field, and learning about the ongoing process by earning trust of participants (Creswell, 2013, p.251). In this study, the researcher gained the trust of participants through introducing herself, explaining the purpose of the study, ensuring confidentiality, anonymity and volunteer participation, and made observations in the field for 5-6 weeks and recorded field notes relevant to the purpose of the study.

The second strategy is "*triangulation*", which refers to use of various sources and methods of collecting data, and presenting "evidence to a code or theme in different sources" (Creswell, 2013, p.251). In the current study, the sources of data are the interviews, the field notes, video-recordings and weekly logs, and varying data sources are addressed for particular codes and themes.

The third strategy is "*negative case analysis*", which implies that the researcher should include negative evidence if any as well as positive ones (Creswell, 2013, p.251). In this research, the researcher presents commonalities in the data as well as some specific exceptions by referring them through quotations.

Another strategy used to establish credibility in the current study is "*rich, tick description*" of the participants, settings and cases so that readers can decide about transferability of the findings in their cases (Creswell, 2013, p.252). Participants of the study, school cultures of the participants and settings of the study were described in detail in this research (See Section 5.2. and 5.3. for full descriptions about the participants and settings of the study).

Another strategy used to ensure credibility is "*clarifying researcher bias*" (Creswell, 2013, p.251). In the current study, the researcher

- introduced herself and her background (See Section 5.3.2.)
- discussed how her background may affect the study (See Section 5.3.2.)
- described her role in the particular stages of the study (See Section 5.3.2., Section 5.4. and Section 5.5.)

In addition, after developing the interview protocols, the researcher sent these protocols to the two science education experts from the Project IRRESISTIBLE team in Turkey, for revision and modified the protocols through the feedback of the experts.

On the other hand, "*member checking*", which implies the participants' judgement on the credibility of the data, data analysis, and conclusions drawn, was not performed and might be a threat to the credibility of this research because member checking is a technique that improves the accuracy of their response.

Creswell (2013) defines the reliability in a qualitative study as "the stability of responses to multiple coders of data sets" (p.253). Reliability of a qualitative research is reinforced when the field notes are detailed, voice-recordings or audio-recordings are good quality and transcribed or reflected on (Creswell, 2013). However, the main indicator of a qualitative study's reliability is "*intercoder agreement*" which refers to analysis of the transcribed data through multiple coders (i.e. computer programs or multiple individuals) (Creswell, 2013, p.253). Creswell (2013) suggests to comparison of the text parts that the coders assign codes rather than exact lines or phrases. Minimum 80% agreement shows the reliability of the study. In this study, intercoder agreement is performed by a graduate of Secondary School Science and Mathematics Education Master Program of Boğaziçi University with a Mathematics Education and Science, Technology, Engineering, and Mathematics (STEM) Education background. Transcriptions of interviews with one of the teacher-participants and one of the student-participants were chosen randomly and then analyzed with respect to research questions of the study by regarding the themes and sub-themes identified by the researcher. As a result, above 90% agreement is established.

6. ETHICAL CONSIDERATIONS

While conducting a qualitative research, there are many ethical aspects that should be addressed (Creswell, 2013; Mile *et al.,* 2014). In this study, before the data collection the purpose of the study is explained to the participants. Then, the researcher asked permissions of the participants for interviewing with them and regarded the voluntariness of participants.

At the beginning of the data collection, participants were informed about the confidentiality and anonymity such that the data sources would be kept in encrypted file and only the researcher could identify the responses of each participants. Another ethical concern that should be considered from the beginning is the *reciprocity* of the study implying the mutual gain of the participants as well as the researcher from the study (Creswell, 2013; Miles *et al.,* 2014). Participating in this study provides the participants with doing a self-reflection about what they gain from the process, how their knowledge improved, what kind of process they went through and quality of their exhibit.

During the data collection, the researcher asked permissions of the participants for audio-recording the interviews, and the interview protocols were shared with the participants before making interviews to let them know what kind of questions they will answer. In a phenomenological study, the researcher should not share any personal experience with the participants in order to avoid affecting their responses (Creswell, 2013). In this study, the researcher did not mention about any experiences that might destroy the originality of participants' answers while collecting data. The researcher also asked permissions of teachers and students for observing the Nanoscience Club periods while they were developing and designing science exhibits. In the observations, the researcher did not insert any participant' name and avoided an attitude that may lead a participant to think the researcher is recording something about him/her while taking the field notes. Videos recordings of the Nanoscience Club periods were avoided to focus specifically on any participant's face.

7. RESULTS AND CONCLUSIONS

In this study, the in-detail report of results and conclusions starts with describing previous experiences of participants about exhibitions to give reader an insight about participants' background and to support the researcher's conclusions addressing the participants' past experiences. Subsequently, the exhibits developed by students are described including quotations from the interviews that reflects the students' own perspectives on their works. Finally, the results and conclusions, based on the researcher's analysis of varying data sources with respect to the research questions, are presented.

7.1. Previous Experiences of Participants About Exhibitions

In a study with a qualitative approach, it might be efficient to mention about the participants' backgrounds that may have an impact on their current experiences under investigation. From this point of view, the researcher finds it meaningful to make a brief summary on the participants' previous experiences about exhibition including how often the participants visit an exhibition, if they have experience about interactive exhibitions, science exhibitions or student-created exhibitions. Besides, students' history of developing an exhibit and teachers' history of guiding students along developing an exhibiting an exhibit are clarified.

The pre-interview with teachers reveal that they visit exhibitions in their daily life, they at least heard about interactive exhibition, they visited a sort of science exhibition before and they all visited student-created exhibition. In addition, they all have experience in guiding students along exhibit development at different levels, i.e., local level, national level and international level as seen in Table 7.1.

On the other side, the pre-interview with students shows that only four of them visit exhibition time to time, while the other four visits exhibitions rarely. The rest of the students has never been in an exhibition or has visited once. Secondly, most of them have not heard about interactive exhibition and have visited a sort of science exhibition. Besides, most of them have experience in developing and exhibiting their exhibits. The Table 7.2. shortly summarizes each students' experiences about exhibitions and exhibit developing.

Table 7.1. Previous experiences of teachers about exhibitions.

	SH1T1	**SH2T1**	**SH3T1**
Visiting exhibitions in daily life	Sometimes	Often	Often
Experience of interactive exhibition	Heard before	Heard before and visited	Heard before
Experience of science exhibition	Visited a science center and a science fair	Visited science museum, science center, science fairs and science project contests	Visited science center and science exhibition
Experience of student-created exhibitions	Visited	Visited	Visited
Experience of guiding students along developing an exhibit	Guiding students: - Developing science projects several time - Making poster presentation in an international science exposition	Guiding students: - Developing science projects several time - Participating in science fairs - Participating in science project contests	Guiding students: - Developing science projects for one time - Exhibiting them in school exhibition

Table 7.2. Previous experiences of students about exhibitions.

	SH1S1	SH1S2	SH1S3	SH1S4	SH1S5	SH2S1	SH2S2	SH3S1	SH3S2	SH3S3	SH3S4	SH3S5	SH3S6
Visiting exhibitions in daily life	Rarely	Often	Sometimes	Rarely	Rarely	Sometimes	Often	Never	Once	Rarely	Sometimes	Never	Once
Experience of interactive exhibition	Heard before and visited	Not heard before	Heard before	Heard before	Not heard before	Not heard before	Not heard before	Not heard before	Not heard before	Not heard before	Not heard before	Not heard before	Not heard before
Experience of science exhibition	Visited a science museum and science fair	Visited a science project contest	Visited a science center	Visited space camp exhibition	Visited a science center and science fair	Visited space camp exhibition and a science museum	Visited a science exhibition	Visited a science exposition	Visited a science museum	Not visited	Visited a science museum and science fair	Not visited	Visited a science fair
Experience of student-created exhibitions	Visited	Visited	Visited	Visited	Visited	Visited	Visited	Not visited	Not visited	Not visited	Visited	Not visited	Visited
Experience of developing an exhibit	Developed an exhibit for a science fair Group work	Developed an art work and a science project for school exhibitions Individual work	Developed an exhibit for a science fair Group work	Developed an art work for a school exhibition Individual work	Developed an exhibit about literature for a school exhibition Group work	Developed a science exhibit but exhibition was cancelled Group work	Developed science exhibits for different science project contests	Not developed	Developed a science project for a term project. Individual work	Not developed	Developed an exhibit for a science fair Group work	Not developed	Developed a science project for a term project. Individual work

7.2. The Exhibits of Students

This section aims to introduce the exhibits developed in each school under investigation in this study. The exhibits are described in terms of the theme of exhibits, the purpose of exhibits, the interactive elements used in the exhibits and the integration of RRI in exhibits. The given group names are determined accordingly with the student-participants' codes for the ease of the reader. For instance, while the group involving SH1S1 is called as SH1G1 (School 1 Group 1), the group SH1S5 participated is named as SH1G5. If a group includes more than one participant of this study, the group is named after the student, whom code is coming first. For example, the group, which includes both SH1S2 and SH1S3, is presented as SH1G2. On the other hand, the exhibit names are given in order of presentation in this study by including schools' codes such that the first exhibit addressed in this research is referred as SH1E1 (School 1 Exhibit 1), while the second exhibit is given as SH1E2. The exhibits' names start from the number 1 again, when the school under investigation changes. For instance, the first exhibits of the SH2 and SH3 are called as SH2E1 and SH3E1 respectively.

The first exhibit of SH1 (SH1E1) belongs to the group SH1G1, which is group of 5 including the participant SH1S1. The Nanoscience and Nanotechnology (NST) theme of SH1E1 is "The use of Nanotechnology in water treatment process". SH1G1 modelled a water treatment process involving filtration of nanoparticles by using a group of beads and filters with pores in different sizes as seen in Figure 7.1. The smallest beads represent nanoparticles and the filter with the smallest pores represents "nano-filters" that can filter nanoparticles. The turning mechanism ensures to reset the exhibit by reversing the filtration. SH1S1 explains their purpose in developing this exhibit as the following:

> "We tried to keep it simple because we wanted to introduce nanoscience and Responsible Research and Innovation (RRI) to every segment of the society and people of all ages from children to adults. Our exhibit idea came out of the size and scale concept, which is the basic and an unknown property of nanoscience. We wanted to integrate this concept in our exhibit, and thought about nanoparticles and how we can show them. Then, we came up with the idea of water treatment process" (SH1S1-Post).

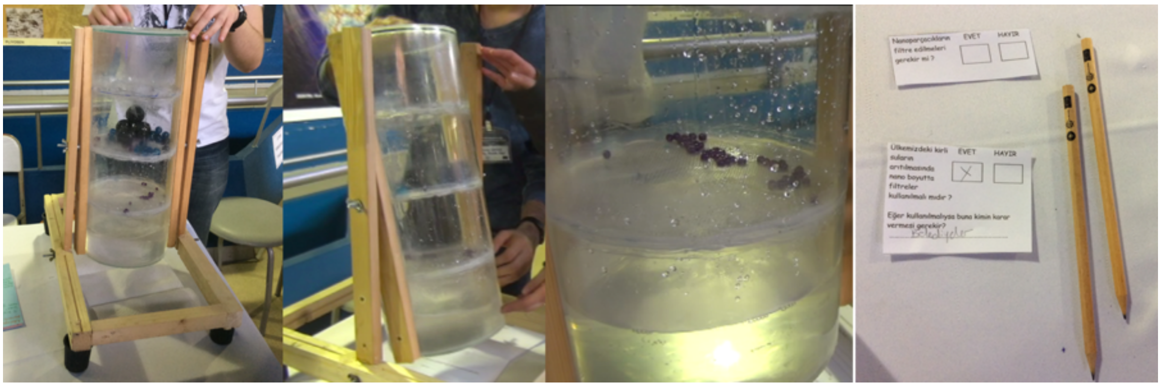

Figure 7.1. SH1E1.

SH1S1 describes two aspects of the exhibit SH1E1 making it interactive:

> "Visitors touched the exhibit and turned the tube upside down. Besides, they filled a questionnaire and placed it in a box. In the second day of the exhibition, we reported visitors the results of questionnaire answered a day before" (SH1S1-Post).

SH1G1 integrated RRI in their exhibit with items of the survey. They prepared questions for each RRI dimensions (See the Section 2.7.4.) such as "Do nanoparticles damage the environment?", "Should our country use the nano-filters in the water treatment process?" and "Who should decide to use of nano-filters?".

The group SH1G1 also developed the second exhibit SH1E2. The NST theme of this exhibit is "Atomic Force Microscope (AFM) and Scanning Electron Microscope (SEM)". This exhibit comprises of two sections as seen in Figure 7.2. Bottom section models the AFM and has three sub-sections including beads with different sizes in each, while the top section represents the SEM. The surface images in AFM model is built by visitors relatively after they scan the three sub-sections with a stick with a very thin tip. On the other hand, the surface image in SEM model is given on a cell phone screen. In addition, SH1G1 prepared an image sorting game, in which some images of living and non-living entities are matched with the three types of microscope the images taken: optic microscope, AFM and SEM. SH1S1's explanation for aim of SH1G1 in developing the exhibit SH1E2 is very similar to their purpose in making the first exhibit SH1E1. What SH1S1 says additionally is as follows:

> "We aimed to give visitors an insight about nanoparticles in the simplest way. It was an exhibit that they can easily interact with and that can stick in their mind" (SH1S1-Post).

Figure 7.2. SH1E2.

The exhibit SH1E2 provides visitors with various interactive components such as scanning the surfaces with a stick, drawing surface images on a paper and sorting image cards according to the types of microscopes. SH1S1 summarizes the interactive elements of their exhibit SH1E2 as the following:

> "Visitors touched and examined the microscopes. We also had a game about it" (SH1S1-Post).

Similar to the integration of RRI in their first exhibit, the group SH1G1 integrated RRI in SH1E2 with a questionnaire including ten yes/no questions, in which the visitors remarked their opinions by signing the options "yes" or "no".

The third exhibit SH1E3 was developed by the group SH1G2, which is a group of 6, involving the participants SH1S2, SH1S3 and SH1S4. The NST theme of this exhibit is "The use of NST in cancer treatment". SH1G2 modelled the use of polymerized medicine produced for drug-delivery in cancer treatment. SH1S2 describes their exhibit seen in Figure 7.3. as follows:

> “The chemotherapy drugs are widely used in cancer treatment. The chemotherapy drugs can reach healthy cells as well as cancer cells and therefore have side effects such as color change in skin, hair fall or weakening of the immune system. The space between cancer cells are larger than the space between healthy cells. In our exhibit we modelled the polymer attached chemotherapy drugs, which can only reach in cancer cells and keep healthy cells safe. We represented veins with tubes. We used small iron beads to represent usual chemotherapy drugs and used larger ones to represent polymerized chemotherapy drugs. There is an electric circuit behind the exhibit and iron beads complete the circuit. Firstly, we put the small iron beads in tubes and so, all lights turn on after circuits are completed, which means all the cells are damaged. Then, we empty the tubes and send the larger iron beads, which turn the lights on in the upper section meaning destruction of only the cancer cells” (SH1S2-Post).

The group SH1G2 also prepared a knowledge test, which comprises of 10 questions about NST and RRI, and gives feedback right after any incorrect answers.

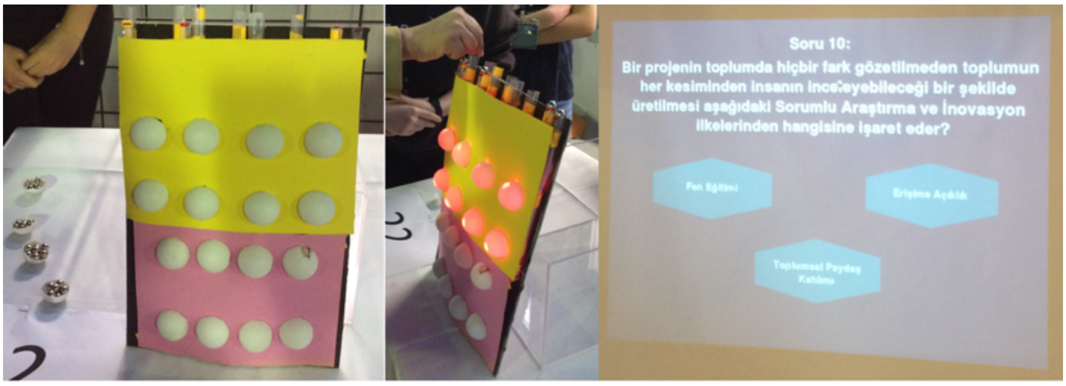

Figure 7.3. SH1E3.

SH1S3 explains the purpose of group SH1G2 in developing the exhibit SH1E3 as the following:

> “The purpose of computer-based knowledge test was to be informative and instructive. There was no scoring. Visitors would learn from their mistakes if there were any. On the other side, we aimed to inform visitors about the use of nanoparticles in cancer treatment with our model. This is a research currently in progress and we inform visitors about it” (SH1S3-Post).

While identifying the interactive features of their exhibit, SH1S2, SH1S3 and SH1S4, firstly, point out placing iron beads in tubes. SH1S3 also draws attention to visitors’ freedom in asking questions to learn more about the exhibit. Besides, SH1S4 mentions about the visitors’ self-testing of their knowledge while answering the questions in the knowledge test. On the other hand, while explaining the integration of RRI in the exhibit SH1E3, all of the participants, contributing the development of it, agree on it was ensured with some of the questions in the knowledge contest such as “Which RRI dimension does support having mutual role of both male and female researchers in the development of a project?" and "Which RRI dimension does support the sharing and presentation of research results in accessible media?". SH1S4 explains the role of knowledge test as follows:

> "RRI was integrated directly within the questions of the knowledge test. In this sense, the model and knowledge test completed each other" (SH1S4-Post).

The last exhibit of the school SH1 (SH1E4) in the scope of this study belongs to the group SH1G5, which is group of 4, including the participant SH1S5. The theme of the exhibit SH1E4 is "The color change in gold nanoparticles depending on size". SH1G5 modelled how color of gold colloids change as the size of gold nanoparticles increase. They also verbally explained how gold nanoparticles are used for cancer detection and treatment. Besides, the exhibit consists of two different card matching games as seen in Figure 7.4. The first one includes questions and answers about the exhibit theme such as "What are the applications of color change in gold nanoparticles depending on size?" and "Which size of gold nanoparticles does make their solution red in color?". The second card matching game is about RRI.

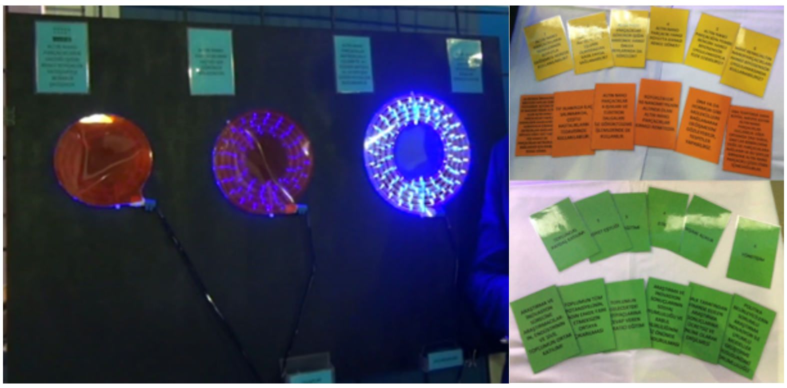

Figure 7.4. SH1E4.

SH1S5 explains what was their aim in developing the exhibit SH1E4:

> "We wanted to develop a colorful and dimensional model, which is catchy and not very didactic. We thought it would be nice to make an exhibit that is understandable for all visitors and direct them to think by keeping information minimum. Besides, we use gold nanoparticles in daily life a lot such as in DNA tests or pregnancy tests. We wanted to show it people and wanted people to say like "Oh! See? It is also used in these areas"" (SH1S5-Post).

SH1S5 describes few interactive characteristics of their exhibits:

> "We prepared card matching game, which includes some questions and answers cards. We asked them to match the questions and answers by thinking what they learned from our exhibit and reading the cards. Similarly, we prepared card matching game for RRI" (SH1S5-Post).

For the integration of RRI, the group SH1S5 prepared card matching game. They prepared one concept card and one statement card for each RRI aspect. For instance, the corresponding statement for "engagement" dimension of RRI is "Joint participation of researchers, industry and civil society in the research and innovation process".

The exhibit SH2E1 is the first exhibit developed by all 8 students in the school club, which is SH2G1, including the participants SH2S1 and SH2S2. SH2E1 is an exhibit in form of knowledge test including statements or facts about NST and RRI such as "The nanometer is the unit of length that is the one billionth of the meter" and "Nanoscience examines the properties and dynamics of the matters that can be seen with naked eye". Visitors state their opinions as true or false for the statements by positioning the switch to the true or false side. LED lights turn on after visitors specified their opinions for all the statements. Lights turn on in green or red color depending on the correctness of the answer as seen in Figure 7.5. SH2G1 developed two sets of quiz board so that visitors can compete with each other simultaneously. SH2S2 explains their purpose while developing a knowledge test as follows:

> "We tried not to include very specific statements, but rather general statements that all can have an opinion or thought about it" (SH2S2-Post).

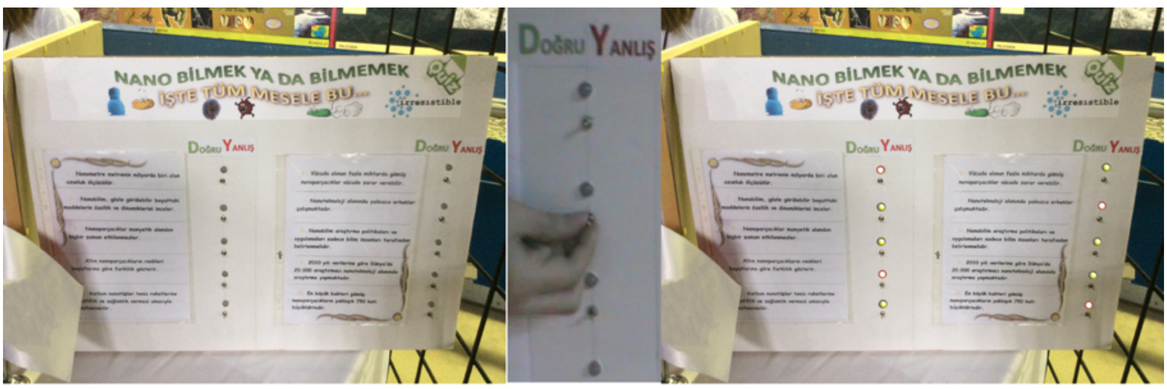

Figure 7.5. SH2E1.

While defining the interactive aspects of the exhibit both SH2S1 and SH2S2 agree that making the knowledge test ensures the interaction of visitors with the exhibit. Furthermore, RRI is integrated within the statements of the exhibit SH2E1. Similar to the items about NST, visitors state their opinions about RRI statements in the exhibit. SH2S1 and SH2S2 point out how they integrated RRI in their exhibit and gives an example as follow:

> “We integrated RRI within the scope of NST. For example, we included an item as *Nanoscience research politics and applications should be determined only by the scientists*” (SH2S2-Post).

> “We related RRI with the nanotechnology. For instance, there was a statement like *Silver nanoparticles are harmful for human beings and the nature*” (SH2S1-Post).

Similar to the exhibit SH2E1, the second exhibit of SH2 (SH2E2) was developed by the contribution of all 8 students. The theme of this exhibit is “The antibacterial effect of silver nanoparticles”. The group SH2G1 modelled this phenomenon by producing a mobile three dimensional printed bacteria, in which some electric components attached, and two static model of silver nanoparticle as seen in Figure 7.6. The fimbriae of bacteria are represented with pins attached to the model. In this way, the bacteria can burst the balloons, which represents the cells. The LED lights on the bacteria shows whether it is alive or dead. When, the bacteria contacts with the silver nanoparticles they attach each other and it dies. So, the LED lights on the bacteria turn off. SH2S1 explains their purpose in developing a model like the exhibit SH2E2 as follows:

> “We wanted to develop an exhibit that can draw visitors’ attention from a distance and arise curiosity to visit our exhibit. It actually did. Many visitors came and asked about our exhibit” (SH2S1-Post).

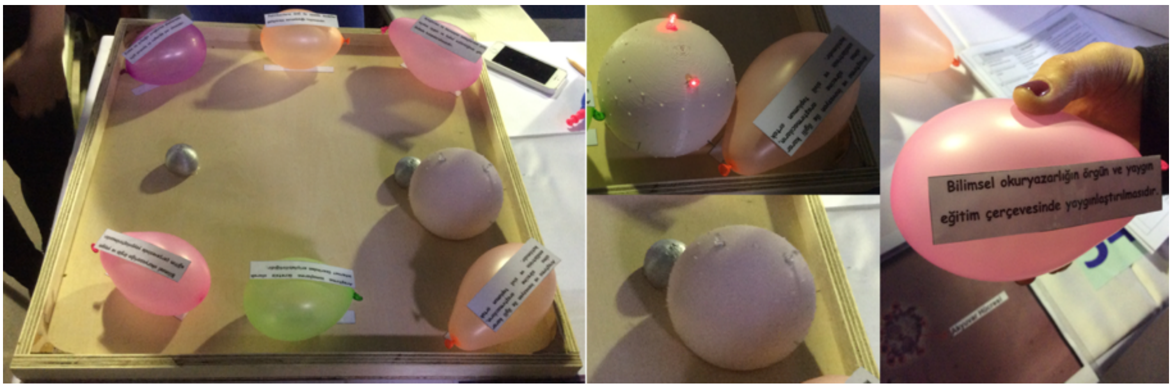

Figure 7.6. SH2E2.

SH2G1 prepared a matching game for integration of RRI. SH2S1 explains how they integrated RRI in the exhibit as follows:

> "We tried to integrate RRI in our exhibit for introducing it to visitors. We prepared statements that can present RRI. Visitors were matching the RRI dimensions with (the items on) balloons representing cells" (SH2S1-Post).

SH1G1 wrote a statement for each RRI aspect. For example, for the "governance" dimension of RRI, the corresponding statement is "The responsibility of policy makers to develop harmonious models for RRI".

The first exhibit in SH3 (SH2E1) was developed individually by the participant SH3S1. The theme of the exhibit is "Biosensor applications of gold nanoparticles". The participant SH3S1's exhibit is a model, in a game format, modelling the use of gold nanoparticles for drug-delivery in a body. The five different spots in the labyrinth board seen in the Figure 7.7. represent different organs or parts of a body. The ball represents the gold nanoparticles carrying drugs. Besides, the participant SH3S1 prepared a question for each spot.

Figure 7.7. SH3E1.

SH3S1 expresses the interactive aspects of the exhibit SH3E1 as the following:

> "My exhibit drew visitors' interest because they were manipulating the labyrinth themselves. Besides, they were thinking on the questions (I ask). I think it could interact with visitors" (SH3S1-Post).

The integration of RRI was provided with preparing some questions about it. When the ball is reached to a certain spot in the labyrinth, a question is asked to visitor. SH3S1 summarizes the RRI integration in the exhibit SH3E1:

> "I integrated RRI in the exhibit with some questions. There were 5 questions in total and 3 of them were about RRI. I was posing visitor a question and keeping record of the answer in a table" (SH3S1-Post).

The exhibit SH3E2 was developed by the group SH3G2, which is a group of 2, involving SH3S2 and SH3S5. The NST theme of the exhibit is "The use of gold nanoparticles in cancer treatment". SH3G2 modelled the applications of biosensor and photo-thermal property of gold nanoparticles in cancer treatment. The model consists of a main vein opens to an ill-shaped cancer cell and six capillary vessels open to healthy cells as seen in Figure 7.8. A toy ball, which opens up in magnetic field, is used to represent the cancer detection. SH3G2 verbally explains how photo-thermal effect of gold nanoparticles is used to destroy cancer cells.

Figure 7.8. SH3E2.

SH3S2 and SH3S5 explain why they came up with such an exhibit idea:

> “We covered the cancer cells in the Biology lessons one or two week ago starting to develop an exhibit. Both me and my group friend are planning to study genetic engineering in the future for mainly our interest in cancer. Therefore, we discussed and decided to develop this exhibit idea” (SH3S2-Post).

> “I was impressed from the article we read about gold nanoparticles in one of the chapters we covered (in the nano school club). I imagined this in my mind and then decided to do it (as an exhibit)” (SH3S5-Post).

When describing the interactive characteristics of the exhibit SH3E2, both of the participants SH3S2 and SH3S5 agree that the interaction of visitors with the exhibit was provided with visitors’ throwing the ping pong balls through capillary vessels while playing the matching game prepared for RRI. SH3S5 describes how they integrated RRI in their exhibit as follows:

> “We prepared capillary vessels and ping pong balls, which one of the RRI dimensions is written on. There was a text related with each RRI aspect (on the healthy cells that capillary vessels open to). We were giving a ball at a time and asking visitors to send the ball through the vessel they think matches correctly (with the dimension written on the ball)” (SH3S5-Post).

The third exhibit in SH3 (SH3E3) belongs to the group SH3G3, including the participants SH3E3 and SH3E4. The theme of the exhibit is “The impact of cosmetics including nanoparticles on environment”. SH3G3 modelled how the silver nanoparticles used in cosmetics is decreasing in the product in time and mixing in waste waters after each washing. The combs with droppers represent a product with silver nanoparticles that can heal the dandruff health problem in hair. Food coloring is used to represent the silver nanoparticles. Three sets of beaker and comb with dropper, seen in the Figure 7.9., are used to compare the increasing amount of contamination with the raising number of washing. Besides, the group SH3G3 prepared a survey of three questions about RRI and a brochure informing about silver nanoparticles. SH3S3 and SH3S4 explain their aim in developing the exhibit SH3E3 as following:

> “We wanted to enrich the visitors and be able to create questions about nanotechnology in their minds after they visit our exhibit such as “Where does nanotechnology is used?”, “Are there any risks besides the benefits?”. We wanted to make visitors think about such aspects” (SH3S3-Post).

> “We wanted to reflect the damaging potential of nanoparticles in our exhibit and thought on products that requires contact with human body” (SH3S4-Post).

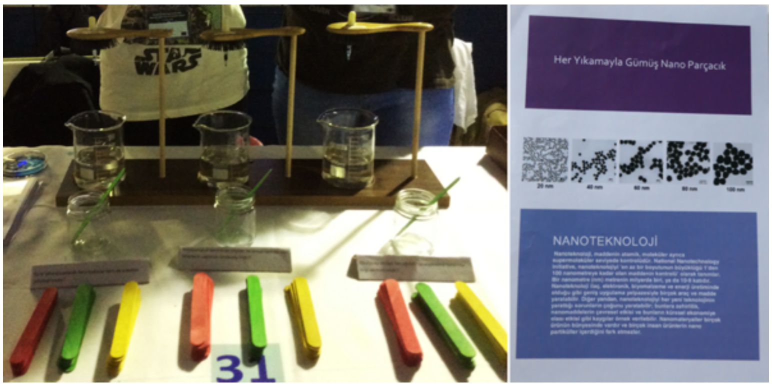

Figure 7.9. SH3E3.

While identifying the elements of their exhibit that make it interactive, both SH3S3 and SH3S4 agree that visitors' use of droppers on the combs and answering the survey questions are the ways how visitors interact with the exhibit SH3E3. Besides, SH3S4 remarks two more factors that making their exhibit interactive:

> "We thought that just informing the visitors may be boring and instead we wanted to be in conversation with them. We integrated the interaction within our conversation" (SH3S4-Post).
>
> "They (visitors) were seeing (the results) by doing themselves" (SH3S4-Post).

For integration of the RRI, SH3G3 prepared a survey including three questions: "Do you think both female and male researchers should work in laboratories?", "Do you think people, who directly contacts with nanoparticles, are at risk?" and "Do you think science education in schools includes nanotechnology?". SH3G3 also included popsicle sticks in three different colors, which visitors pick and place in a jar for stating their opinions. SH3S3 explains how they integrated RRI in the exhibit SH3E3 as follows:

> "We wrote three questions. One of them was about gender equality, another of them was about ethics and the last one was about science education. Each one has three options as *Yes, No* and *I don't know*" (SH3S3-Post).

SH3S4 adds two more aspects for integration of RRI in their exhibit:

> "We acted ethically when presenting our exhibit by mentioning about risks as well as benefits (of silver nanoparticles). Besides, we prepared brochures including references and explained that we developed this exhibit within the scope of these information. So, we integrated open access as well" (SH3S4-Post).

The final exhibit (SH3E4) within the scope of this study is the individual work of the participant SH3S6. The theme of this exhibit is “The use of gold nanoparticles in drug-delivery”. This exhibit consists of two sections: a mobile round plate with a triangular slit, which SH3S6 calls it as “wheel”, and a bottom part including six RRI dimensions as seen in Figure 7.10. The upper section has information about gold nanoparticles on it.

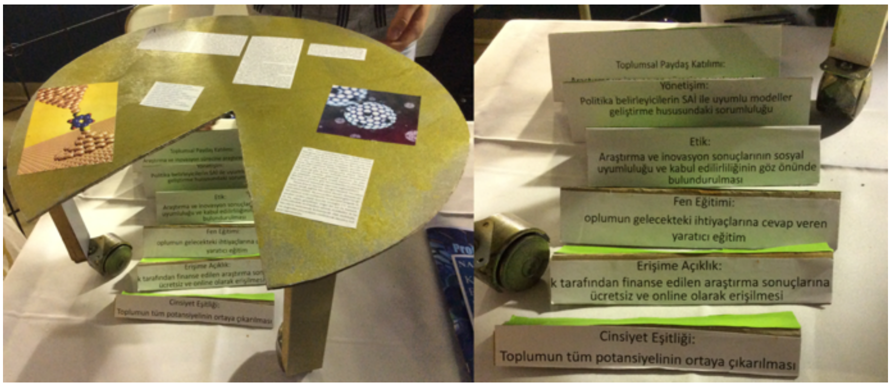

Figure 7.10. SH3E4.

SH3S6 explains why he came up with this exhibit idea as the following:

> “We read an article about gold nanoparticles. When we talked with SH3S1 (about exhibit idea), we thought the most applicable and feasible property of gold nanoparticles is its use for drug-delivery. Therefore, we addressed this property” (SH3S6-Post).

SH3S6 points out the interactive characteristics of the exhibit SH3E4 as follows:

> “I asked visitors to pick an RRI dimension. After they chose one of the RRI aspects, they were turning the wheel. These were the interactions” (SH3S6-Post).

SH3S6 describes how the RRI is integrated in the exhibit SH3E4:

> “The bottom part (of the exhibit) includes 6 RRI dimensions. First, visitors were reading the information on the wheel. Then, I was asking them to choose a card, which a RRI dimension is written on and saying them to regard it as cancer cell. Then, the wheel’s slit was spotting that card after turning. In this way, I was also describing the use (of gold nanoparticles) in drug-delivery” (SH3S6-Post).

Table 7.3. The basic information about the exhibits.

The Exhibit	**Group/ Individual Work**	**Participant(s) Involved**	**Format of the Exhibit**	**The Theme of the Exhibit**
SH1E1	Group of 5	SH1S1	Model-Survey	The use of nanotechnology in water treatment process
SH1E2	Group of 5	SH1S1	Model-Game	Atomic Force Microscope (AFM) and Scanning Electron Microscope (SEM)”.
SH1E3	Group of 6	SH1S2 SH1S3 SH1S4	Model-Knowledge Test	The use of NST in cancer treatment
SH1E4	Group of 4	SH1S5	Model-Game	The color change in gold nanoparticles depending on size
SH2E1	Group of 8	SH2S1 SH2S2	Knowledge Test	Facts about NST
SH2E2	Group of 8	SH2S1 SH2S2	Model-Game	The antibacterial effect of silver nanoparticles
SH3E1	Individual	SH3S1	Model-Survey	Biosensor applications of gold nanoparticles
SH3E2	Group of 2	SH3S2 SH3S5	Model-Game	The use of gold nanoparticles in cancer treatment
SH3E3	Group of 2	SH3S3 SH3S4	Model-Survey	The impact of cosmetics including nanoparticles on environment
SH3E4	Individual	SH3S6	Model	The use of gold nanoparticles in drug-delivery

7.3. Teachers' Descriptions of Exhibition, Interactive Exhibition and Science Exhibition

The purpose of the first research question (RQ1) of this study is examining how do teachers describe exhibition, interactive exhibition and science exhibitions before and after guiding students along developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications. For the analysis of RQ1, the pre-interviews and post-interviews with teachers were used. The analysis of each description, i.e., descriptions of exhibition, interactive exhibition and science exhibition, are presented in different sections following.

7.3.1. Exhibition Descriptions of Teachers

First of all, the analysis of exhibition descriptions of teachers was performed. From the 6 verbatim transcripts, 32 important statements were determined and clustered into 3 themes and 2 sub-themes, which are presented, explained and exemplified with quotations in Table 7.4. The *Exhibit* and *Theme of Exhibition* are first two themes identified, which covers any types or example of exhibits and specified theme of exhibition respectively. The last theme is *Role of Exhibition* including two sub-themes: (i) *Role of Exhibition for Exhibitor*, which comprises of any descriptions of exhibitions' role in regard of exhibitors as developers of exhibits in exhibitions or as a curator of an exhibition, and (ii) *Role of Exhibition for Visitor*, which covers statements about role of exhibition in regard of visitors coming to exhibitions. The categories corresponding for each description of the teachers SH1T1, SH2T1 and SH3T1 are reported in Table 7.5. Any categories addressed by teachers in their descriptions are remarked in grey color.

The first remarkable change from the pre-descriptions to the post-descriptions is that some codes under the themes of *Exhibit* and *The Theme of Exhibit* disappeared, while new codes were identified under the sub-themes of *Role of Exhibition for Exhibitors* and *Role of Exhibition for Visitors* such as "Evaluation" and "Drawing attention". The Figure 7. 11. shows the changing number of teachers, who addressed the themes, in their former and latter exhibition descriptions.

Table 7.4. Themes identified for exhibition descriptions of teachers.

Theme and Sub-theme	Explanation	Example
1. Exhibit	Description of exhibition consists of types of exhibit or some specific examples of exhibits.	It is advertising a work with visuals or demonstrations (SH3T1-Pre). The word “exhibition” may come after many things and many sort of products such as artefacts or handicrafts (SH2T1-Post).
2. Theme of Exhibition	Description of exhibition includes an exhibition theme.	It can be an art exhibition but my current perception is science exhibitions about Physics, Chemistry or Science in general (SH2T1-Pre).
3. Role of Exhibition		
3a. Role of Exhibition for Exhibitors	Description of exhibition involves role of exhibitions specifically for the exhibitors or the exhibit owners.	It is a display of models designed for a purpose to put emphasis on it (SH3T1-Post)
3b. Role of Exhibition for Visitors	Description of exhibition involves role of exhibitions specifically for the visitors.	It is a temporary activity providing visitors’ learning by involvement (SH2T1-Pre). It is a display of exhibits in somewhere for other people to see (SH1T1-Pre). (Addresses both 3a and 3b)

Table 7.5. Corresponding themes and codes for exhibition descriptions of teachers.

	Theme	Sub-theme	Code	SH1T1	SH2T1	SH3T1
PRE-DESCRIPTIONS	1. EXHIBIT		Designed/made exhibits			
			Demonstrations			
			Experiments			
	2. THE THEME OF EXHIBITION		Art			
			Science			
	3. ROLE OF EXHIBITION	3a. Role of Exhibition for Exhibitors	Public display of exhibits			
		3b. Role of Exhibition for Visitors	Public involvement			
			Public learning			
	Theme	**Sub-theme**	**Code**	SH1T1	SH2T1	SH3T1
POST-DESCRIPTIONS	1. EXHIBIT		Designed/made exhibits			
	2. THE THEME OF EXHIBITION		Art			
	3. ROLE OF EXHIBITION	3a. Role of Exhibition for Exhibitors	Public display of exhibits			
			Drawing attention			
			Getting evaluation and self-evaluation			
		3b. Role of Exhibition for Visitors	Public involvement			
			Public learning			
			Making evaluation and self-evaluation			

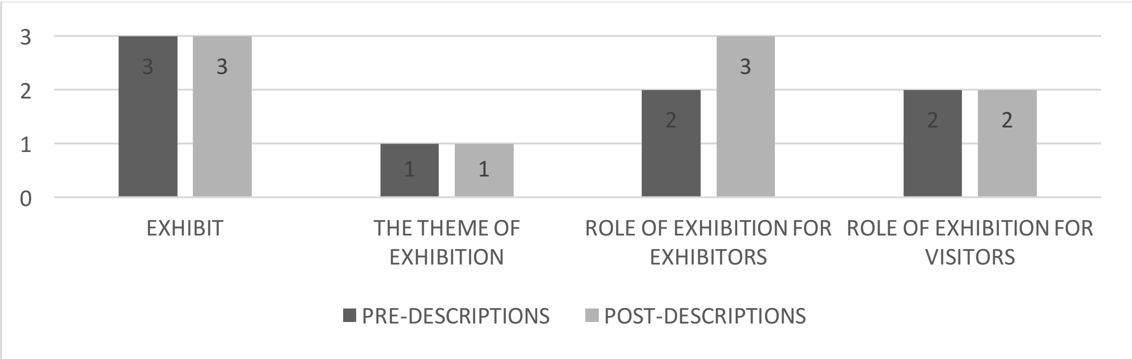

Figure 7.11. The number of teachers addressing the themes and sub-themes identified under their exhibition descriptions.

The reason behind the disappearance of codes under the first two themes in the later descriptions is that the teacher-participants, in their post-interviews, described exhibition in a broader sense in terms of exhibits and the theme of exhibitions. The descriptions of the teacher SH2T1 at pre and post-interviews can be given as an example:

> "It can be an art exhibition including paintings of an artist, but my current perception is science exhibitions about Physics, Chemistry or Science in general which includes interactive experiments. On the other hand, we can describe exhibition as temporary activities with narrow-scope or at a certain theme providing visitors' learning by involvement" (SH2T1-Pre).
>
> "Exhibition is a platform at which things, in an extensive meaning, are shared with visitors. The word "exhibition" may come after many things and many sort of products such as artefacts or handicrafts. There are exhibits drawing attention and people having interest of. You display and share your exhibits with target population, which can be large or small as well" (SH2T1-Post)

After guiding students along exhibit developing and exhibiting processes, there was a considerable increase in describing the exhibition with regard to role of exhibitions, especially the role of exhibitions for exhibitors. Besides, a new significant role of exhibition was pointed out, which is about evaluative aspect of exhibitions. The pre and post-descriptions of the teacher SH2T1 can be given as an example:

> "It is a display of exhibits in somewhere for other people to see" (SH1T1-Pre).
>
> "Exhibition is informing visitors about exhibit developed or about a certain topic. It provides you with public display of your exhibit and getting comment about it. It makes you to understand whether you did a good job or not while you explain your exhibit to a visitor. Therefore, keeping it (your exhibit) to yourself doesn't reflect what you know or not" (SH1T1-Post)

The first-hand experience of being a part of an exhibition, which includes their students' exhibits, might be lead teachers to gain more insight about the role of exhibition.

7.3.2. Interactive Exhibition Descriptions of Teachers

Secondly, the analysis of interactive exhibition descriptions of the teachers was carried out. From the analysis of 6 interview transcriptions, 39 significant statements were obtained and categorized into 5 themes and 5 sub-themes, which are presented, explained and exemplified with quotations in Table 7.6. The Figure 7.12 shows the changing number of teachers, who addressed the themes, in their former and latter descriptions of interactive exhibition. The themes and sub-themes with corresponding codes are given in Table 7.7, and the ones addressed in each description of teachers are remarked in grey color.

Table 7.6. Themes identified for interactive exhibition descriptions of teachers.

Theme and Sub-theme	Explanation	Example
1. Type of Interaction		
1a. Physical Interaction	Description of interactive exhibition addresses physical interaction with an exhibit such as pushing a button.	…letting them to touch or work on the exhibit…(SH1T1-Post) (Addresses both 1a and 2a)
1b. Verbal Interaction	Description of interactive exhibition addresses interaction with an exhibit or exhibitor through words such as establishing a dialog.	…We can think it as dialogs between participants or forming interactions with exhibitors besides interacting with parts of exhibits…(SH2T1-Post) (Addresses both 1b and 2b)
1c. Mental Interaction	Description of interactive exhibition addresses interactions promoting visitors' intellectual activity such as answering a question or making inferences.	…It can be in the form of question-answer done with the exhibitor… (SH2T1-Pre) (Addresses both 1b, 1c and 2b)
2. Direction of Interaction		
2a. Visitor-Exhibit Interaction	Description of interactive exhibition involves interaction of visitor with exhibit.	…It is an exhibition where exhibits on display can be involved in and resulting change can be observed… (SH3T1-Post) (Addresses both 2a and 1c)
2b. Visitor-Exhibitor Interaction	Description of interactive exhibition involves interaction of visitor with exhibitor.	…We can think it as dialogs between participants or forming interactions with exhibitors besides interacting with parts of exhibits…(SH2T1-Post) (Addresses both 2b and 1b)

Table 7.6. Themes identified for interactive exhibition descriptions of teachers. (cont.)

Theme and Sub-theme	Explanation	Example
3. Example of Interaction	Description of interactive exhibition includes specific examples of interactive elements of an exhibit	… For example, let's say, you'll prepare an exhibit about solution of salt in water. You (visitor) observe the solution of salt by doing yourself… (SH1T1-Pre)
4. Benefits of Interactive Exhibition	Description of interactive exhibition refers a benefit of it.	…It is more efficient. At least visitors don't get bored…(SH2T1-Post)
5. Alternative Conceptions of Interactive Exhibition	Description of interactive exhibition includes any alternative ideas about it.	…Besides, sometimes huge and interesting demonstrations are done for big population of audiences in exhibitions…(SH2T1-Pre)

The analysis of pre-descriptions of teachers shows that teachers had an idea about what interactive exhibition is before the process of guiding students in developing an interactive exhibit. In the pre-interviews, the teachers SH1T1 and SH3T1 state that they heard of interactive exhibition before but did not visit any, while SH2T1 states he had experience. On the other hand, some alternative conceptions about interactive exhibition are identified in descriptions of SH1T1 and SH2T1 such as "introducing a phenomenon with an animation", "an exhibit being visually attractive" or "making big demonstrations". A part from description of SH1T1 can be given as example. The alternative conception is presented in italic form:

> "… For example, let's say, you'll prepare an exhibit about solution of salt in water. You (visitor) observe the solution of salt by doing yourself or *you watch an animation showing it…*" (SH1T1-Pre)

First important difference in the latter descriptions of teachers is the elimination of "alternative conceptions of interactive exhibition (IE)" determined in the pre-descriptions as seen in Figure 7. 12. The post-description of SH1T1 can be given as an example:

> "I had an idea what an interactive exhibition is more or less before, but I had no experience. Now, I got experience in developing one. It is providing visitors with learning about the subject you want by letting them to touch or work on the exhibit you developed and so raising their curiosity (about it)" (SH1T1-Post).

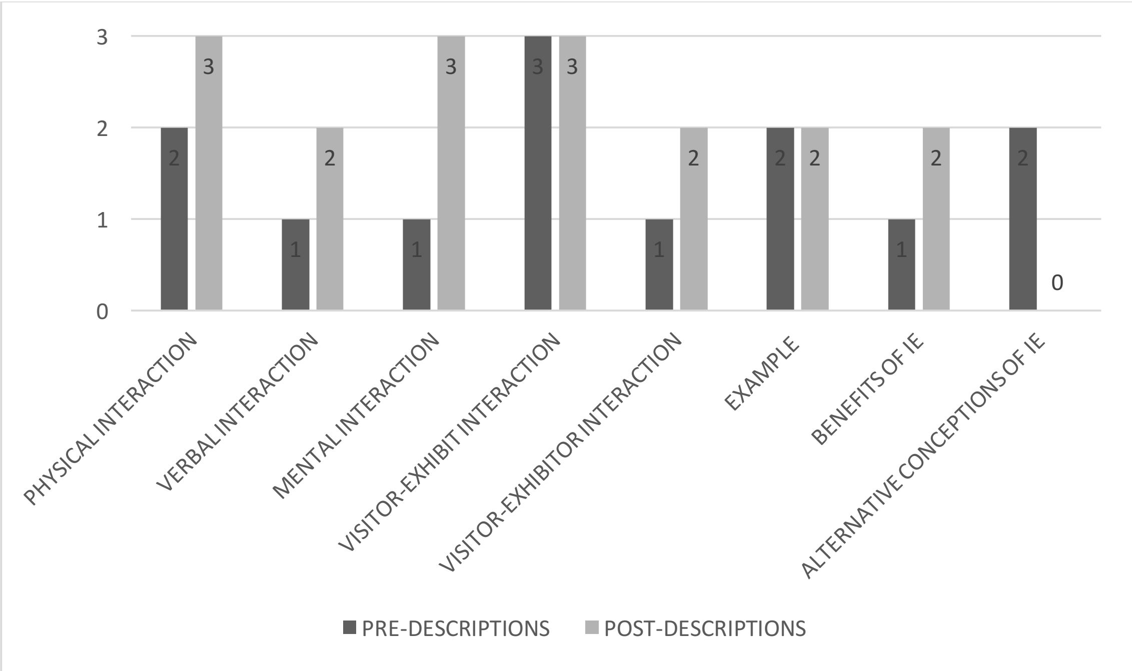

Figure 7.12. The number of teachers addressing the themes and sub-themes identified under their interactive exhibition descriptions.

Another considerable change from the pre-descriptions to post-descriptions of teachers is the increase in the "types of interaction" addressed. In the first descriptions of interactive exhibition, two teachers covered only physical interaction and a teacher covered other two types, i.e., verbal interaction and mental interaction. On the other hand, in the post-descriptions, two teachers included three different types of interaction and a teacher addressed two types of interaction as seen in Table 7.7. The pre and post-descriptions of teacher SH3T1 can be given as example:

> "I heard it before but I didn't attend. You are involving in exhibits in an exhibition. You contribute in a part of application (in/of an exhibit)" (SH3T1-Pre).

> "I think I have learned more about it during this project. It is an exhibition where exhibits on display can be involved in and resulting change can be observed. It is a kind of communicating with exhibit or talking with exhibit in a form of question and answer. Affecting it… I mean touching and make a change in exhibit by involving in it physically" (SH3T1-Post).

Table 7.7. Corresponding themes and codes for interactive exhibition descriptions of teachers.

	Theme	Sub-theme	Example Codes	SH1T1	SH2T1	SH3T1
PRE-DESCRIPTIONS	1. TYPE OF INTERACTION	1a. Physical Interaction	Touching, making, trying exhibit			
		1b. Verbal Interaction	Dialogue			
		1c. Mental Interaction	Answering a question			
	2. DIRECTION OF INTERACTION	2a. Visitor-Exhibit Interaction	Visitor's involvement in exhibit			
			Reciprocity of action			
		2b. Visitor Exhibitor Interaction	Visitors' interaction with exhibitor			
	3. EXAMPLE OF INTERACTION		Making experiments			
	4. BENEFITS OF INTERACTIVE EXHIBITIONS		Interesting			
	5. ALTERNATIVE CONCEPTIONS OF INTERACTIVE EXHIBITIONS		Introducing a phenomenon with an animation			
			Visually attractive exhibits, big demonstration			
POST-DESCRIPTIONS	1. TYPE OF INTERACTION	1a. Physical Interaction	Touching, making, trying exhibit			
		1b. Verbal Interaction	Dialogue			
		1c. Mental Interaction	Learning by doing, exchange of ideas, answering a question			
	2. DIRECTION OF INTERACTION	2a. Visitor-Exhibit Interaction	Visitor's involvement in exhibit			
			Reciprocity of action			
		2b. Visitor Exhibitor Interaction	Visitors' interaction with exhibitor			
	3. EXAMPLE OF INTERACTION		Simulation, computer game			
	4. BENEFITS OF INTERACTIVE EXHIBITIONS		More efficient, visitors don't get bored			

The reason behind in raising number of "types of interaction" referred in the post-descriptions might be the fact that teacher got first-hand experience in developing an interactive exhibit and participating in an interactive exhibition as the teachers SH1T1 and SH3T1 mentioned in their post-descriptions. Seeing numerous interactive exhibits developed by other students in the exhibition might be enriched teachers' perceptions of interactive exhibitions.

7.3.3. Science Exhibition Descriptions of Teachers

The last analysis done for the RQ1 is the analysis of science exhibition descriptions of teachers. From 6 transcripts, 38 important statements were obtained, and classified into themes and sub-themes. Four themes and 8 sub-themes are identified under pre-descriptions, while the same four themes with varying 8 sub-themes are determined under post-descriptions, which are presented, explained and exemplified with quotations in Table 7.8. The first two themes, namely *Science-based Exhibits* and *Exhibition with a Scientific Theme*, cover two basic aspects of science exhibitions. The third theme identified is the *Role of Science Exhibitions*, which brings the participants' statements about roles of science exhibition together. It consists of 7 sub-themes: 4 common sub-themes for pre and post-descriptions and 3 separate sub-themes: (i) Informing, (ii) Presenting Empirical Evidence, (iii) Raising Curiosity and Interest, (iv) Science Education, (v) Eliminating Prejudice Against Science, (vi) Introducing Tentative Nature of Science, and (vii) Self-evaluation of Knowledge. The last theme determined under descriptions of science-exhibition is *Methods Used in Science Exhibitions*, which includes 3 sub-themes: (i) Letting visitors to experience, (ii) Scientific method and (iii) Modelling. The corresponding categories for each description of the teachers are presented in Table 7.9. and remarked in grey color. Besides, The Figure 7.13 shows the changing number of teachers, who addressed the themes, in their former and latter descriptions of science exhibition.

The analysis of teachers' pre-descriptions of science exhibition reveals that teachers had a pre-knowledge about science exhibition addressing its role and the methods used in it besides the characteristics of exhibit and the theme of exhibition. Their backgrounds about science exhibitions might be coming from their previous experiences because they all had visited different sorts of science exhibitions, including science museums, science centers and science fairs, before their current experience as seen in Table 7.1. reporting previous experiences of teachers about exhibitions. The first description of the teacher SH2T1 can be given as example:

> "Science exhibition might have a certain theme, but its aim is presenting scientific evidence based on empirical methods. This is most basic difference of it (from other types of exhibitions). You don't expect evidence in everything, but in science, you expect a modelling or a study building cause-effect relation. These modellings are more interesting and effective. A poster as an exhibit, for instance, may be developed with endeavor, but it can attract visitors only who have a special interest on it. Otherwise, it may not be interesting for a 5 years old child. As I said, it is modelling and presenting cause-effect relations in science through empiric ways" (SH2T1-Pre).

Interestingly, although the themes identified are the same in analysis of pre-descriptions and post-descriptions, there is a decrease in the number of frequencies of themes addressed in the latter descriptions. The reason behind such result might be the fact that teachers, in their previous descriptions of science exhibitions, were making an explanation about science exhibitions regarding different types of it, while they might be focusing around science fairs in their post-descriptions after guiding students along development and exhibiting of a science exhibit. The science exhibition descriptions of teacher SH3T1 can be given as example:

> "Of course, I think that it has a purpose and it seeks for changing perspective. I think it may eliminate prejudices against science. It may break down the prejudice of science is understandable for people with high-level (of knowledge). It may present empirical evidence through simple ways rather than complex one or it may shed some light on our observation upon findings" (SH3T1-Pre).

> "Its aim is making visitors inquire, making them curious and leaving some room for the fact that it (science) can be improvable…Besides, the exhibits like a painting is stable, but ours (current exhibits developed) are not like that. In our case, it should be rather like "We could do it (exhibit) like that" or "We could change it in this way"" (SH3T1-Post).

Table 7.8. Themes identified for science exhibition descriptions of teachers.

Theme and Sub-theme	Explanation	Example
1. Science-based Exhibits	Description of science exhibition addresses science-related exhibits.	…Science exhibition is a kind of exhibition including experiments and exhibits built on a scientific background and scientific method (SH2T1-Post). (Addresses both 1 and 4b)
2. Exhibition with a Scientific Theme	Description of science exhibition addresses scientific theme of exhibition.	Science is a very broad topic. It (exhibition) has to reflect the theme very good. For example, if it is about chemistry or nanotechnology, visitors who don't have pre-knowledge of it should be able to learn about it… (SH1T1-Post) (Addresses both 2 and 3d)
3. Role of Science Exhibitions	Description of science exhibition addresses role of it.	
(Common in Pre & Post-Descriptions) 3a. Informing	Giving visitors information	…It is more informative when it includes exhibits around a certain theme…(SH1T1-Pre)
3b. Presenting Empirical Evidence	Presentation of empirical evidence to verify a scientific phenomenon	Science exhibition might have a certain theme, but its aim is presenting scientific evidence based on empirical methods…(SH2T1-Pre) (Addresses both 3b and 4b)
3c. Raising Curiosity and Interest	Raising curiosity and interest of visitors towards science	…For example, if you want to search about environmental wastes or if there are exhibits about it, you learn about them or become curious about it when you see them (SH1T1-Pre) (Addresses 3c, 2 and 3d)
3d. Science Education	Science learning of visitors from varying ages	… For example, if it is about chemistry or nanotechnology, visitors who don't have pre-knowledge of it should be able to learn about it or the ones with pre-knowledge should be able to improve their knowledge about it… (SH1T1-Post) (Addresses both 3d and 2)

Table 7.8. Themes identified for science exhibition descriptions of teachers. (cont.)

Theme and Sub-theme	Explanation	Example
(Identified only in Pre-Descriptions) 3e. Eliminating Prejudice Against Science	Breaking down the prejudices against science	…I think it also seeks for changing perspective. I think it may eliminate prejudices against science…(SH3T1-Pre)
(Identified only in Post-Descriptions) 3e. Introducing Tentative Nature of Science	Introducing that scientific laws and theories are not concrete and can be modified or replaced	…Its aim is making visitors inquire, making them curious and leaving some room for the fact that it (science) can be improvable… (SH3T1-Post) (Addresses 3e, 3c and 4b)
3f. Self-evaluation of Knowledge	Visitors' self-evaluation of their knowledge	…It (makes you) not only seeing what you know, but also realizing what you don't know. (SH1T1-Post)
4. Methods Used in Science Exhibitions	Description addresses a method or approach used in science exhibitions.	
(Common in Pre & Post-Descriptions) 4a. Self-experience	Letting visitors to experience a scientific phenomenon by themselves.	It bases on a scientific background. It is an occasion, where someone else can gather the same scientific evidence through testing and experiments…(SH2T1-Post) (Addresses 4a, 4b and 3b)
4b. Scientific Method	Using and reflecting scientific method in exhibits	…You don't expect evidence in everything, but in science, you expect a modelling or a study building cause-effect relation…(SH2T1-Pre) (Addresses 4b, 4c and 3b)
(Identified only in Pre-Descriptions) 4c. Modelling	Modelling scientific phenomena	

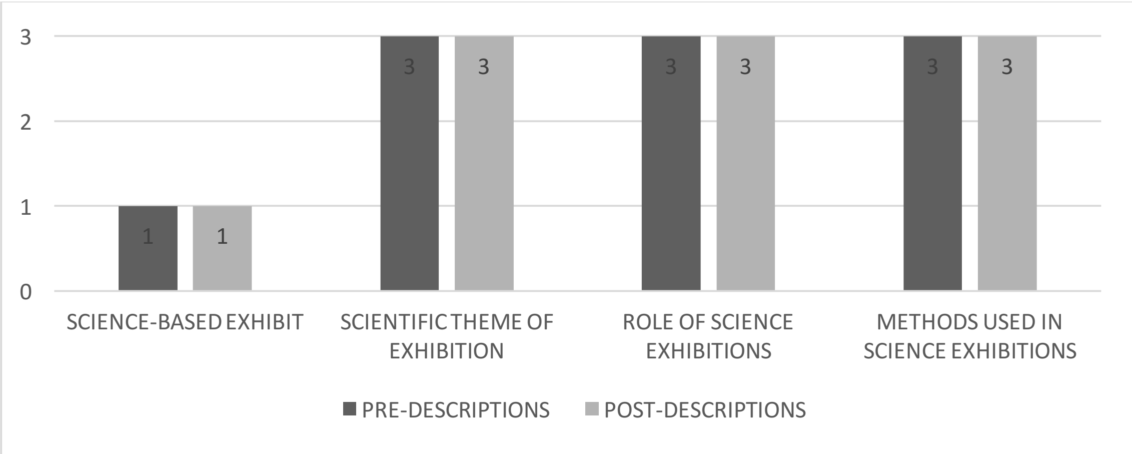

Figure 7.13. The number of teachers addressing the themes and sub-themes identified under their science exhibition descriptions.

Another distinction determined in the teachers' latter descriptions of science exhibition is the inclusion of "Self-evaluation" under the theme of *Role of Science Exhibition*. Both of the teachers SH1T1 and SH3T1 pointed out the self-evaluation of knowledge or performance in science exhibitions as follows:

> "…It (makes you) not only seeing what you know, but also realizing what you don't know" (SH1T1-Post).
>
> "…Besides, the exhibits like a painting is stable, but ours (current exhibits developed) are not like that. In our case, it should be rather like "We could do it (exhibit) like that" or "We could change it in this way"" (SH3T1-Post).

On the other hand, the teacher SH2T1 didn't touch to such aspect of science exhibition in his description as given below:

> "Science exhibition bases on a scientific background. It is an occasion, where someone else can gather the same scientific evidence through testing and experiments. It is a kind of exhibition including experiments and exhibits built on a scientific background and scientific method" (SH2T1-Post).

The reason behind that the description of SH2T1 doesn't include "self-evaluation", while the SH1T1's and SH3T1's do is might be the fact that one of the exhibits (SH2E2) developed by students of SH2T1 has ranked first in the overall evaluation, and therefore, he is satisfied with the exhibit and performance of his students. On the other hand, SH1T1 and SH3T1 might be engaged in a more critical and reflective perspective regarding their students' exhibits and performance. The emphasis that SH1T1 put on evaluative role of exhibitions in her post-description of exhibition may also support this interpretation:

> "…It makes you to understand whether you did a good job or not while you explain your exhibit to a visitor. Therefore, keeping it (your exhibit) to yourself doesn't reflect what you know or not" (SH1T1-Post).

The overall analysis of data with respect to RQ1 exploring teachers' descriptions of exhibition, interactive exhibition and science exhibition reveals that there is a remarkable improvement in teachers' conceptions of exhibition, especially in terms of roles of exhibition. Likewise, there is an important transformation in teachers' understandings of interactive exhibition, especially regarding the type of interaction and elimination of alternative conceptions about it. On the other side, there is a slight difference in their descriptions of science exhibitions which might be based upon the existence of their previous multi-experiences about science exhibitions and a minor shift in their descriptions towards describing their current experience of science fair as discussed before.

Table 7.9. Corresponding themes and codes for science exhibition descriptions of teachers.

	Theme	Sub-theme	Example Codes	SH1T1	SH2T1	SH3T1
PRE-DESCRIPTIONS	1. SCIENCE-BASED EXHIBIT		Scientific models, Scientific studies			
	2. EXHIBITION WITH A SCIENTIFIC THEME		A certain discipline, Science in general			
	3. ROLE OF SCIENCE EXHIBITIONS	3a. Informing	Giving information, elaborating knowledge			
		3b. Presenting Empirical Evidence	Experimental evidence, empirical evidence, testing			
		3c. Raising Curiosity and Interest	Raising interest, curiosity, eager to learn more			
		3d. Science Education	Science for all			
			Science learning			
		3e. Eliminating Prejudice Against Science	Changing perspectives, breaking down prejudices			
	4. METHODS USED IN SCIENCE EXHIBITIONS	4a. Self-experience	Letting visitors to experience a phenomenon by themselves			
		4b. Scientific Method	Empirical base, testing			
			Observation			
			Building cause-effect relation			
		4c. Modelling	Modelling scientific phenomena			
POST-DESCRIPTIONS	1. SCIENCE-BASED EXHIBIT		Experiments, scientific studies			
	2. EXHIBITION WITH A SCIENTIFIC THEME		A certain discipline, Science in general			
	3. ROLE OF SCIENCE EXHIBITIONS	3a. Informing	Giving information, elaborating knowledge			
		3b. Presenting Empirical Evidence	Experimental evidence, empirical evidence, testing			
		3c. Raising Curiosity and Interest	Raising interest, curiosity, eager to learn more			
		3d. Science Education	Science learning			
		3e. Introducing Tentative Nature of Science	Scientific conclusion, theories can be modified or replaced			
		3f. Self-evaluation	Making judgements about self-knowledge or performance			
	4. METHODS USED IN SCIENCE EXHIBITIONS	4a. Self-experience	Letting visitors to experience a phenomenon by themselves			
		4b. Scientific Method	Empirical base, testing			
			Making inquiry			

7.4. Students' Descriptions of Exhibition, Interactive Exhibition and Science Exhibition

This section of the study reports the data analysis done with respect to the RQ4 which aims to explore how students describe exhibition, interactive exhibition and science exhibition before and after developing and exhibiting RRI integrated interactive science exhibits on nanotechnology applications. For the analysis of the RQ4, the pre-interviews and post-interviews of student-participants were used. The analysis of each description, i.e., descriptions of exhibition, interactive exhibition and science exhibition, are presented in different sections.

7.4.1. Exhibition Descriptions of Students

The first analysis performed for the RQ4 is the analysis of students' descriptions of exhibition. From the 26 verbatim transcripts, 105 significant statements were obtained and clustered into 3 themes and 2 sub-themes under the pre-descriptions and the post-descriptions, which are presented, explained and exemplified with quotations in Table 7.10.

The identified themes and sub-themes for the students' descriptions of exhibition are the same with the ones obtained from the teachers' descriptions with a few changes in codes such as the code "Bringing items together" under the sub-theme of *Role of Exhibition for Exhibitor* and the code "Collection of objects" under the theme of *Exhibit* as seen in Table 7.11. The differences in codes may stem from variations in responses of higher number of student-participants compared to number of teacher-participants. Besides, the categories relating with the students' descriptions of exhibition are shown in Table 7.11. Any categories addressed by students are remarked in grey color.

The considerable change from the students' pre-descriptions to the post-descriptions is the increasing trend in inclusion of role of exhibition for visitors in the post-descriptions. This transformation in students' descriptions is presented in Table 7.11 and Figure 7.14. which shows the changing frequencies of number of students addressing the themes and sub-themes identified under their exhibition descriptions.

Table 7.10. Themes identified for the students' descriptions of exhibition.

Theme and Sub-theme	Explanation	Example
1. Exhibit	Description of exhibition consists of types of exhibit or some specific examples of exhibits.	It is a display of a group of exhibits such as researches at a certain topic or products based on research results (SH1S2-Pre). It is a place where a group of projects or artefacts are brought together and are displayed for other people (SH2S1-Post).
2. Theme of Exhibition	Description of exhibition includes an exhibition theme.	It is display of developed exhibits based on art or science (SH1S1-Pre).
3. Role of Exhibition 3a. Role of Exhibition for Exhibitors 3b. Role of Exhibition for Visitors	Description of exhibition involves role of exhibitions specifically for the exhibitors or the exhibit owners. Description of exhibition involves role of exhibitions specifically for the visitors.	It is a place, where we can display our works throughout the year in an organized way (SH1S5-Pre). It is a medium where people introduce their works, and others visit and get varying information from them (SH3S1-Post) (Addresses both 3a and 3b). It is a public display of a collection of works for drawing attention, giving information and taking positive or negative criticism (SH1S4-Post) (Addresses both 3a and 3b).

The former and latter exhibition descriptions of the participants SH3S1, SH1S5 and SH1S3 can be given as examples for how some students involved the role of exhibition for visitors in their second descriptions:

> "Exhibition is a place, where the various products developed are introduced and presented" (SH3S1-Pre).
>
> "It is a medium where people introduce their works, and others visit and get varying information from them" (SH3S1-Post).
>
> "It is a place, where we can display our works throughout the year in an organized way" (SH1S5-Pre).
>
> "Exhibition is a medium, where we can display our works throughout the year and share them with other people. We can make visitors to think (on exhibits) by informing them" (SH1S5-Post).

"Exhibition is a place, where the exhibits developed at a certain theme are displayed" (SH1S3-Pre).

"Exhibition is a place, where the exhibits developed at a certain theme are displayed and public has access to it" (SH1S3-Pre).

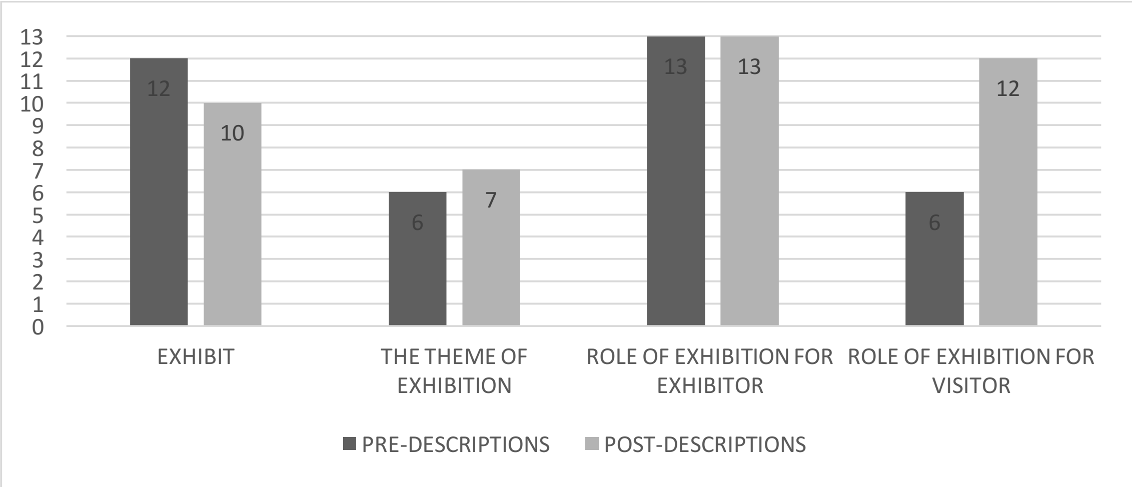

Figure 7.14. The number of students addressing the themes and sub-themes identified under their exhibition descriptions.

The analysis of exhibition descriptions also showed that there is a slight decrease in number of descriptions including specific types of exhibits. Besides, although the frequencies of *The Theme of Exhibition* theme has no difference in pre and post-descriptions, one of the codes under this theme disappeared in the analysis of post-descriptions as seen in Table 7.11. Similar to the case in exhibition descriptions of teachers, the reason of this decrease might be describing exhibition in a broader sense in terms of exhibits and the theme of exhibitions. The exhibition descriptions of the participant SH1S1 can be given as example:

"Exhibition is display of developed exhibits based on art or science" (SH1S1-Pre).

"Exhibition is display of a group of things for the public, for the visitors coming" (SH1S1-Post).

The last aspect of analysis of the students' exhibition descriptions is a new category identified under the sub-theme of *Role of Exhibition for Exhibitor*, which is "Changing opinions", in the post-descriptions. This category is worth including in the analysis although it was addressed by a very limited number of participants, because it brings an important role of exhibition forward.

Table 7.11. Corresponding themes and codes for exhibition descriptions of students.

	Theme	Sub-theme	Code	SH1S1	SH1S2	SH1S3	SH1S4	SH1S5	SH2S1	SH2S2	SH3S1	SH3S2	SH3S3	SH3S4	SH3S5	SH3S6
PRE-DESCRIPTIONS	1. EXHIBIT		Designed/made exhibit	■		■		■		■	■	■	■	■		
			Collection of objects				■		■							■
			Research-based exhibits	■	■											
	2. THE THEME OF EXHIBITION		Art, science, history	■	■	■			■			■				■
	3. ROLE OF EXHIBITION	3a. Role of Exhibition for Exhibitor	Public display of exhibits	■	■	■	■	■	■	■	■	■	■	■		■
			Drawing attention				■								■	
			Bringing items together						■			■				
			Evaluation										■			
		3b. Role of Exhibition for Visitor	Public involvement	■						■			■	■	■	■
			Public learning							■					■	■
POST-DESCRIPTIONS	1. EXHIBIT		Designed/made exhibit		■		■	■	■	■	■	■				■
			Collection of objects	■		■	■		■							
	2. THE THEME OF EXHIBITION		Art, science, history		■	■			■	■		■		■		■
	3. ROLE OF EXHIBITION	3a. Role of Exhibition for Exhibitor	Public display of exhibits	■	■	■	■	■	■	■	■	■	■	■	■	■
			Drawing attention				■	■								
			Bringing items together						■			■				
			Evaluation				■									
			Changing opinions												■	
		3b. Role of Exhibition for Visitor	Public involvement	■	■	■	■	■	■	■	■		■	■	■	■
			Public learning				■	■		■	■		■	■	■	

7.4.2. Interactive Exhibition Descriptions of Students

The second analysis conducted for the RQ4 is the analysis of students' interactive exhibition descriptions. From the analysis of 26 verbatim transcriptions, 110 significant statements were determined and classified into 5 themes and 5 sub-themes, which are presented, explained and exemplified with quotations in Table 7.12. The Figure 7.15. shows the changing number of students, who addressed the themes, in their former and latter descriptions of interactive exhibition. Finally, the themes and sub-themes with corresponding codes are given in Table 7.13.

The analysis of pre-interviews with students reveals that only two of them had heard the concept of "interactive exhibition" and one of among them had visited such an exhibition before. The rest of the students stated that they didn't heard this concept before, but some of among them made an estimation about what interactive exhibition can be, based on its name, including some "alternative conceptions of interactive exhibition (IE)".

Table 7.12. Themes identified for the students' descriptions of interactive exhibition.

Theme and Sub-theme	Explanation	Example
1. Type of Interaction		
1a. Physical Interaction	Description of interactive exhibition addresses physical interaction with an exhibit such as pushing a button.	…It might be a type of exhibition where visitors can touch exhibits (SH3S5-Pre).
1b. Verbal Interaction	Description of interactive exhibition addresses interaction with an exhibit or exhibitor through words such as establishing a dialog.	…Visitor may push a button or may answer a question. (SH3S3-Post)
1c. Mental Interaction	Description of interactive exhibition addresses interactions promoting visitors' intellectual activity such as answering a question or making inferences.	…the interaction doesn't have to be physical. It can be in the form of quiz… (SH2S1-Post)
2. Direction of Interaction		
2a. Visitor-Exhibit Interaction	Description of interactive exhibition involves interaction of visitor with exhibit.	…It is a kind of exhibition, where visitors learn about exhibits more by doing themselves… (SH1S5-Post) (Addresses 1c and 2a)

Table 7.12. Themes identified for the students' descriptions of interactive exhibition. (cont.)

Theme and Sub-theme	Explanation	Example
2b. Visitor-Exhibitor Interaction	Description of interactive exhibition involves interaction of visitor with exhibitor.	…If we (as an exhibitor) are able to have a conversation with visitor, it is also an interactive exhibition… (SH3S4-Post)
3. Example of Interaction	Description of interactive exhibition includes specific examples of interactive elements of an exhibit	…There was an earthquake room simulating earthquake… (SH1S1-Pre)
4. Benefits of Interactive Exhibition	Description of interactive exhibition refers a benefit of it.	…It is more instructive and inclusive compared to the normal exhibitions… (SH1S3-Post)
5. Alternative Conceptions of Interactive Exhibition	Description of interactive exhibition includes any alternative ideas about it.	It is probably an organization, which includes more than one exhibiting-team…(SH1S2-Pre)

The first significant transformation took place in the post-descriptions of students compared to their pre-descriptions is a major increase in "the types of interaction" addressed, namely, *Physical Interaction*, *Verbal Interaction* and *Mental Interaction*. In addition, students were able to give more examples of interactions in the latter descriptions. These improvements are seen in Table 7.13 and Figure 7. 15.

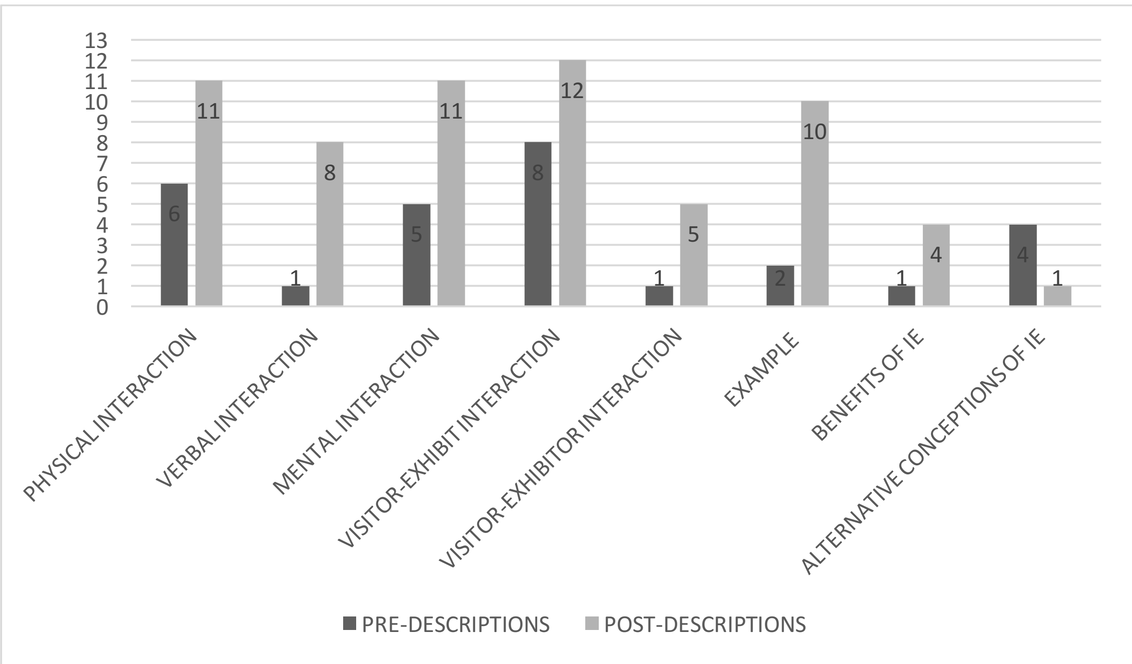

Figure 7.15. The number of students addressing the themes and sub-themes identified under their interactive exhibition descriptions.

The reason behind this trend, which is similar to change in teachers' descriptions, might be students' experience in developing their own interactive exhibits as well as visiting other interactive exhibits in the exhibition and examining them. The interactive exhibition descriptions of participants SH1S4 and SH3S6 can be given as example for indicating how students' descriptions improved from pre to post-description:

> "I haven't heard it or visited such an exhibition before. But if I would make a guess on it, it might be including things (exhibits) that visitors can practice or test by themselves" (SH1S4-Pre).
>
> "I think interactive exhibition is a kind of exhibition, where visitors can interact with exhibits and get first-hand experience. They do something on it (an exhibit) and see the resulting change by themselves. They experience it without needing anybody to explain it for them. When you develop an interactive exhibition, it appeals all the senses of visitors by letting them touch, hear and involve in it. At the same time, it is applicable for visitors' varying levels of knowledge, it tests and contributes in them. The exhibits on display makes it easier to understand by directing visitors to involve in them" (SH1S4-Post).
>
> "I didn't hear it before. But visitors might be getting in contact with exhibit" (SH3S6-Pre).
>
> "Interactive exhibition is a kind of exhibition, where visitors involve in exhibits. There must be an interaction between visitors and the exhibit on display. The (ways of) interaction may vary. For example, I went to a space exhibition, when I was a child. We were examining galaxies; the ones we were choosing. It can be this kind of interaction. Besides, there can be different kinds of interaction because it changes depending on the answers visitors give to questions" (SH3S6-Post).

The second improvement the analysis of the students' post-descriptions reveals is the raising number of students, who addressed "visitor-exhibit interaction" and "visitor-exhibitor interaction" as seen in Table 7.13 and Figure 7.15. In the latter descriptions, almost all students pointed out the visitor-exhibit interaction and half of them touched upon the visitor-exhibitor interaction. Another difference between students' former and latter descriptions is the number of "benefits of interactive exhibition" mentioned. Some benefits covered by students are as the following:

> "…It appeals all the senses of visitors by letting them touch, hear and involve in it…" (SH1S4-Post).
>
> "…The activations of exhibits provide a better comprehension of information…" (SH1S1-Pre).
>
> "…It is more instructive and inclusive compared to the normal exhibitions…" (SH1S3-Post).
>
> "…It is more fun for visitors…" (SH1S5-Post).
>
> "…It provides you to present the theme of the exhibit a way better…" (SH3S1-Post).

Table 7.13. Corresponding themes and codes for interactive exhibition descriptions of students.

	Theme	Sub-theme	Example Codes	SH1S1	SH1S2	SH1S3	SH1S4	SH1S5	SH2S1	SH2S2	SH3S1	SH3S2	SH3S3	SH3S4	SH3S5	SH3S6
PRE-DESCRIPTIONS	1. TYPE OF INTERACTION	1a. Physical Interaction	Touching, pushing													
		1b. Verbal Interaction	Dialogue													
		1c. Mental Interaction	Testing, making inference													
	2. DIRECTION OF INTERACTION	2a. Visitor-Exhibit Interaction	Visitor's involvement in exhibit													
		2b. Visitor Exhibitor Interaction	Visitors' interaction with exhibitor													
	3. EXAMPLE OF INTERACTION		Earthquake simulator room													
	4. BENEFITS OF IE		Better comprehension													
	5. ALTERNATIVE CONCEPTIONS OF IE		Animation, multi-exhibitor													
POST-DESCRIPTIONS	1. TYPE OF INTERACTION	1a. Physical Interaction	Touching, using													
		1b. Verbal Interaction	Dialogue													
		1c. Mental Interaction	Testing, making inference													
	2. DIRECTION OF INTERACTION	2a. Visitor-Exhibit Interaction	Visitor's involvement in exhibit													
			Reciprocity of action													
		2b. Visitor Exhibitor Interaction	Visitors' interaction with exhibitor													
	3. EXAMPLE OF INTERACTION		Throwing a ball, matching items													
	4. BENEFITS OF IE		Better understanding, inclusive, fun													
	5. ALTERNATIVE CONCEPTIONS OF IE		Presenting exhibit													

Final change from pre-descriptions to post-descriptions is the decrease in number of students having "alternative conceptions of interactive exhibition". In the first interviews, four students included some alternative conceptions in their descriptions such as presenting with an animation, inclusion of more than one exhibiting-team or presentation of an exhibit. In the post-descriptions, only one student addressed an alternative conception, which is presentation of exhibit by exhibitor. This conception is defined as alternative conception instead of verbal interaction because it is a one-way explanation rather than a conversation. The reason of building such a conception about interactive exhibition might be the fact that in the exhibition, students sometimes explained their exhibits to visitors besides providing them with a sort of interaction with the exhibit.

7.4.3. Science Exhibition Descriptions of Students

The last analysis done with respect to RQ4 is the analysis of science exhibition descriptions of students. From the 26 interview transcripts, 107 important statements were identified and categorized into 6 themes and 12 sub-themes, which are presented, explained and exemplified with quotations in Table 7.14. The first theme determined is the *Science-Related Exhibit*, which covers types of exhibits in different formats addressed in the descriptions. The second theme, namely *The Theme of Science Exhibition*, which refers to themes that are idiosyncratic to science exhibitions, has two sub-themes: (i) Science and (ii) Mathematics. The third theme is *Role of Science Exhibitions,* which, as the name implies, consists of any role of science exhibitions mentioned in participants' descriptions. It has 5 sub-themes in total, varying under pre and post-descriptions: (i) Informing, (ii) Raising Curiosity and Interest, (iii) Science Education, (iv) Presenting Scientific Evidence, and (v) Changing Views and Opinions. Another theme is the *Methods Used in Science Exhibitions*, which includes 5 sub-themes: (i) Letting Visitors to Experience, (ii) Scientific Method, (iii) Guiding Visitors, (iv) Display of Exhibits in a Certain Arrangement, and (v) Modelling. The fifth theme identified in the analysis is the *Specific Examples*, which comprises of specific examples of science exhibition or exhibits, addressed by participants and has 2 sub-themes: (i) Science Exhibition Example and (ii) Exhibit Example. The last theme is named after exact responses of participants as *No Idea/No Difference*, which implies that a participant has no idea or sees no difference of science exhibition compared to other types of exhibitions.

The analysis of the first science exhibition descriptions of students revealed that most of students had an idea about science exhibitions to some degree except two students, who see no difference from other exhibitions or have no idea. These two students had no experience about science exhibitions as they stated in their pre-interviews. On the other hand, about half of the students addressed a role of science exhibitions or a method used in science exhibitions in their descriptions.

The first remarkable transformation from the students' former descriptions of science exhibitions to their latter descriptions is the increase in the number of students, who address the role of science exhibitions, and increase in the variety of roles described. This transformation in descriptions has led to increase in the frequency of the theme *Role of Science Exhibition* in post-descriptions. The Figure 7.16. also shows the increasing number of students, who addressed the role of science exhibitions, in their latter descriptions of science exhibition. The roles addressed in the former descriptions were classified under 3 sub-themes, which are Informing, Raising Curiosity and Interest, and Science Education. In the analysis of post descriptions, on the other hand, two additional role of science exhibitions were identified, namely Presenting Scientific Evidence, and Changing Views and Opinions, but the majority of students addressed the other three sub-themes as seen in Table 7.15, which presents the categories relating with the students' descriptions of science exhibition. The science exhibition descriptions of SH1S1, SH3S1 and SH1S5 can be given as example:

> "It gives people information about what happened in the past and what can be in the future. But it gives information with respect to science like how they formed or how they will be in the future" (SH1S1-Pre).
>
> "It tries to transfer information. I mean it tries to create awareness and enlighten people. It has such purpose. It presents something more objective, but not subjective. Usually, there are science-based evidences. Besides it is more open to interaction compared to other (types of) exhibitions" (SH1S1-Post).

> "I haven't visited any science exhibition before. So, I may not realize any difference of it from other types of exhibitions, but I think there is no difference" (SH3S1-Pre).
>
> "Differently from other types of exhibitions, it mainly aims to give visitors information. It gives visitors varying point of views" (SH3S1-Post).

> "I have visited a science center long time ago. There was a big DNA model… Well… In a science exhibition, we see more objectivity and more generally accepted particular things, while in an art exhibition, people (the exhibitors) reflect their own world" (SH1S5-Pre).
>
> "First of all, if I would compare science exhibitions with art exhibitions, we give information (in science exhibitions). In art exhibitions, everybody can perceive different things sentimentally or get a different meaning from the things they see. But in science exhibitions, there is a certain accuracy and we have a teaching purpose" (SH1S5-Post).

Table 7.14. Themes identified for the students' descriptions of science exhibition.

Theme and Sub-theme	Explanation	Example
1. Science-Related Exhibit	Description of science exhibition addresses science-related exhibits.	I think the materials used in models reflect that it is a science exhibition… (SH3S4-Post)
2. The Theme of Science Exhibition 2a. Science 2b. Mathematics	Description of science exhibition addresses possible theme of science exhibitions.	…There were projects on Physics, Chemistry and Biology. Projects on varying ideas. Some were theoretical studies, which is on Mathematics… (SH1S2-Pre) (Addresses 2a, 2b and 1)
3. Role of Science Exhibitions	Description of science exhibition addresses role of it.	
(Common in Pre & Post-Descriptions) 3a. Informing	Giving visitors information	It mainly aims to give visitors information… (SH3S1-Post)
3b. Raising Curiosity and Interest	Raising curiosity and interest of visitors towards science	…The main objective of a science exhibition is introducing science and make it fun for the public by making interesting modules. (SH2S1-Post)
3c. Science Education	Science learning of visitors	…There is a kind of teaching purpose, science education. (SH1S3-Post)
(Identified only in Post-Descriptions) 3d. Presenting Scientific Evidence	Presentation of empirical evidence to verify a scientific phenomenon	…Usually, there are science-based evidences… (SH1S1-Post)
3e. Changing Views and Opinions	Giving visitors a different point of view	…It gives visitors varying point of views… (SH3S1-Post)
4. Methods Used in Science Exhibitions	Description addresses a method or approach used in science exhibitions.	
(Common in Pre & Post-Descriptions) 4a. Self-experience	Letting visitors to experience a scientific phenomenon by themselves.	…There were simulators. We were able to simulate flight (with space craft) as if we were in it. (SH1S4-Pre) (Addresses 4a and 1)

Table 7.14. Themes identified for the students' descriptions of science exhibition. (cont.)

Theme and Sub-theme	**Explanation**	**Example**
4b. Scientific Method	Using and reflecting scientific method in exhibits	…In a science exhibition it is aimed to get information such as from results of a chemical reaction, cause-effect relations or (by thinking) why it reacts. (SH1S4-Post)
4c. Guiding Visitors	Providing visitors with a kind of guide to reinforce their learning from exhibits	…It was more fun in terms of display of exhibits. There were a staff guiding us and giving historical explanations… (SH1S4-Pre)
(Identified only in Pre-Descriptions) 4d. Display of Exhibits in a Certain Arrangement	Display of exhibits in a specific arrangement	…In general, the exhibition is visited on a path and in a chronological order… (SH2S1-Pre)
(Identified only in Post-Descriptions) 4e. Modelling	Modelling scientific phenomena	…We are modelling something scientific such as an atomic model… (SH3S4-Post) (Addresses 4e, 5b, 1)
5. Specific Examples 5a. Science Exhibition Example	Description includes a specific example of science exhibition	I have gone to ITU Science Center a long time ago… (SH1S5-Pre)
5b. Exhibit Example	Description includes a specific example of exhibit	…I have watched (a program on) exhibition about space crafts on television. The most participants (the exhibitors) of the exhibition were people , who developed their own rockets…(SH3S2-Pre)
6. No Idea/No Difference	Participant has no idea or sees no difference in science exhibitions compared to other types of exhibitions.	I have no idea. (SH3S5-Pre) It is not different (than other exhibitions). (SH3S1-Pre)

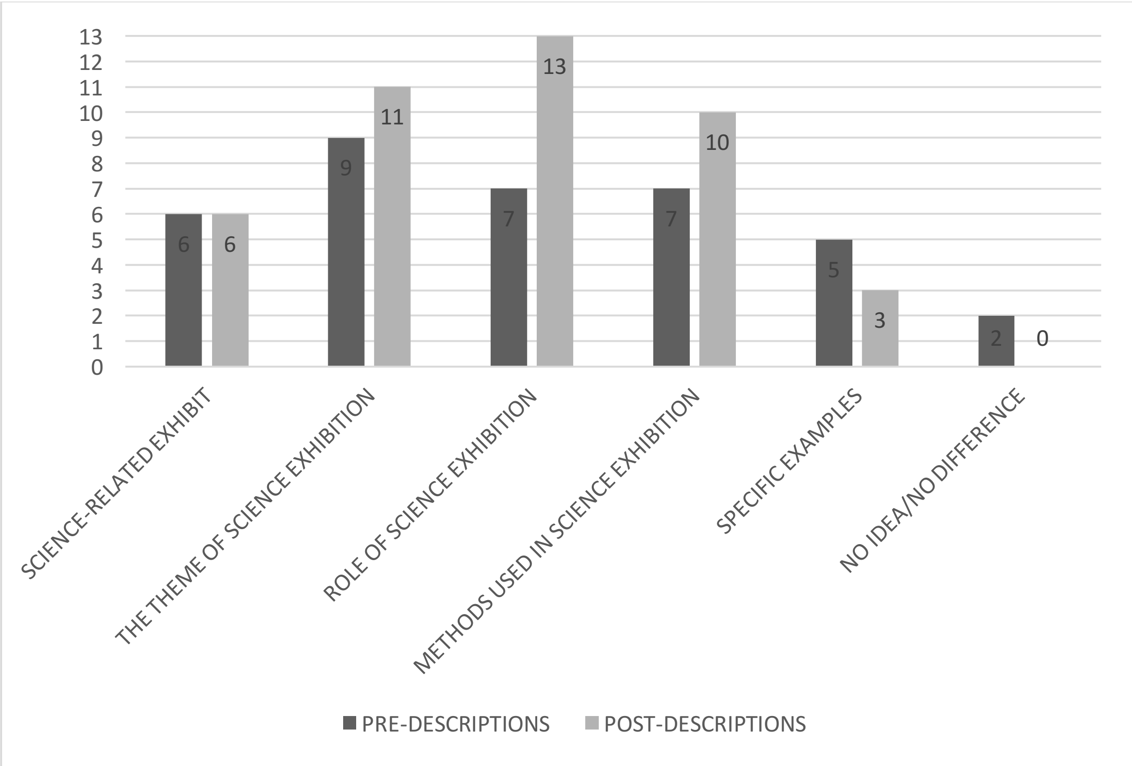

Figure 7. 16. The number of students addressing the themes and sub-themes identified under their science exhibition descriptions.

Another change identified within the analysis of students' science exhibition descriptions is the raising number of students, who mention about a method used in science exhibitions such as letting visitors to experience a scientific phenomenon, doing modellings and building cause-effect relations. This improvement is seen as an increase in number of students addressing the related theme in Figure 7.22 and seen as growing number of students referring the related theme and sub-themes in Table 7.15. The science descriptions of SH1S3 and SH3S4 can be given as example:

> "I think I have gone to a science exhibition a few years ago. There were exhibits about different subjects. It was for informing about new things and the things displayed there" (SH1S3-Pre).
>
> "First of all, science exhibition aims to give information about certain topics in science and to share the studies done. There is a kind of teaching purpose, science education (purpose). In terms of presentation…For example, in contrary to an art exhibition, which consists of paintings, there must be a demonstration or explanation in a science exhibition. Because it is usually about something new or an innovation, it needs to be informative in terms of what is new, what it bases on, how it is developed and where it is used in our lives" (SH1S3-Post).

Table 7.15. Corresponding themes and codes for science exhibition descriptions of students.

	Theme	Sub-theme	Example Codes	SH1S1	SH1S2	SH1S3	SH1S4	SH1S5	SH2S1	SH2S2	SH3S1	SH3S2	SH3S3	SH3S4	SH3S5	SH3S6
PRE-DESCRIPTIONS	1. SCIENCE-RELATED EXHIBIT		Theoretical Studies, Space Crafts		■	■	■	■	■			■				
	2. THE THEME OF SCIENCE EXHIBITION	2a. Science	Physics, Chemistry, Biology, Space Science	■	■	■	■	■	■	■		■				■
		2b. Mathematics	Mathematics		■											
	3. ROLE OF SCIENCE EXHIBITIONS	3a. Informing	Informing about current developments	■		■			■				■			■
		3b. Raising Curiosity and Interest	Amazement, raising interest				■						■			
		3c. Science Education	Learning science						■	■						
	4. METHODS USED IN SCIENCE EXHIBITIONS	4a. Self-experience	Letting visitors to examine		■		■					■				
		4b. Scientific Method	Objectivity					■								
			Observation		■											
		4c. Guiding Visitors	Audio guide, Explanatory board				■			■						
		4d. Display of Exhibits in a Certain Arrangement	Chronological ordering, labyrinth form						■					■		
	5. SPECIFIC EXAMPLES	5a. Science Exhibition Example	NASA Space Craft Exhibition, TUBITAK Science Project Contest		■		■	■	■							
		5b. Exhibit Example	DNA model, rocket		■		■	■	■			■				
	6. NO IDEA/ NO DIFFERENCE		No idea, no difference from other exhibitions								■				■	

Table 7.15. Corresponding themes and codes for science exhibition descriptions of students. (cont.)

	Theme	Sub-theme	Example Codes	SH1S1	SH1S2	SH1S3	SH1S4	SH1S5	SH2S1	SH2S2	SH3S1	SH3S2	SH3S3	SH3S4	SH3S5	SH3S6
POST-DESCRIPTIONS	1. SCIENCE-RELATED EXHIBIT		Models, scientific equipment		■	■	■		■					■		■
	2. THE THEME OF SCIENCE EXHIBITION		Science, Chemistry, Physics, Space Science	■	■	■	■	■	■			■	■	■	■	■
	3. ROLE OF SCIENCE EXHIBITIONS	3a. Informing	Informing about a scientific study	■	■	■	■	■	■		■	■	■		■	■
		3b. Raising Curiosity and Interest	Interesting modules, raising curiosity				■		■						■	
		3c. Science Education	Learning science	■	■	■		■		■		■				
		3d. Presenting Scientific Evidence	Evidence-based things	■										■		
		3e. Changing Views and Opinions	Giving a point of view								■					
	4. METHODS USED IN SCIENCE EXHIBITIONS	4a. Self-experience	Letting visitors to observe											■		
		4b. Scientific Method	Objectivity	■				■		■						
			Observation											■		
			Making Inquiry													■
			Making inferences											■		
			Building cause-effect relation				■									
		4c. Guiding Visitors	Audio guide, Explanatory board		■	■							■		■	■
		4d. Modelling	Modelling a scientific phenomenon											■		
	5. SPECIFIC EXAMPLES		Exhibit Example		■		■							■		

> "In most of the science exhibitions, at least in the ones I saw on television, the exhibition area was organized in the form of labyrinth. If the exhibition is about art and includes visuals, they are just hanged on wall. It (science exhibition) is different in terms of arrangement (of exhibition area)" (SH3S4-Pre)

> "I think the materials used in models reflect that it is a science exhibition. For example, we may see test tubes or atomic models because we are modelling and line up with something scientific. It (the exhibit) visually points out science exhibition. When someone visits the exhibition we created, s/he can tell that it is a science exhibition. We build understanding through examining and observing" (SH3S4-Post)

The reason behind the improvements in science exhibition descriptions of students after they exhibited the exhibits they developed in a science exhibition may be the fact that they obtained first-hand experience in a science exhibition not only as exhibitors of their exhibits, but also as visitors of other exhibits developed by students from other schools. Having both roles in a science exhibition may have deepened the students' understandings of science exhibition with respect to its role and the methods used in it. Besides, with the experience they acquired, both of the students, who were not able to describe science exhibition in the pre-interviews, now are capable of explaining it regarding varying aspects of it.

On the other hand, the analysis reveals that there is a decrease in the frequencies of two themes in the post-descriptions, namely *Science-Related Exhibit* and *Specific Examples* covering exhibit examples and science exhibition examples. The cause of such trend in descriptions might be the fact that after gaining more insight about science exhibitions through self-experience, students had a chance to internalize roles of it and ways used for realizing them. Because of this reason, the latter science exhibition descriptions of students might be focusing mainly around roles and methods rather than exhibits and the theme of exhibitions.

The overall analysis of data regarding RQ4, which explores students' descriptions of exhibition, interactive exhibition and science exhibition reveals that there is a remarkable improvement in students' understandings of exhibition, interactive exhibition and science exhibition. Students, in their latter descriptions of exhibition, addresses more about role of it, especially roles of exhibition for visitor. Likewise, there is a considerable transformation in students' conceptions of interactive exhibition, especially regarding the types of interaction, direction of interaction, benefits of interactive exhibition and elimination of alternative conceptions about it. Finally, although most students had a background about science exhibition based on their self-experiences, there is a remarkable difference in their post-description of science exhibition with respect to its role and methods used in science exhibitions.

7.5. Practical Approaches of Teachers in Guiding Students Along the Exhibit Development and Exhibition Processes

Apart from examining any improvement in the knowledge of participants about exhibitions, another purpose of this study is to explore the participants' practical approaches in the exhibit development and exhibition processes, which was defined as "practical applications, which base on their existing experiences, ideas and theoretical knowledge, in managing, handling or guiding a situation" before. This section of the study reports the analysis of data with respect to RQ2, which is about the practical approaches of the teacher-participants in guiding students along developing a RRI integrated interactive science exhibit on NST, and exhibiting them. For identifying teachers' practical approaches in the process, different data sources were analyzed including the interviews, video recordings of school observations, weekly logs, field notes and video recordings of CoL meetings in the exhibit development process.

The practical approaches of teachers were classified under four categories regarding the stages in the exhibit development and exhibition processes: (i) Practical Approaches in Pre-Production Stage, (ii) Practical Approaches in Production Stage, (iii) Practical Approaches in Managing the Overall Process, and (iv) Practical Approaches in Exhibition Stage. These four stages comprise of 6 themes and 9 sub-themes, which are named after practical approaches at a certain phase of exhibit development or at a certain task, as presented, explained and exemplified with quotations in Table 7.16.

The first category, namely "Practical Approaches in Pre-Production Stage", consists of three themes and two sub-themes: 1. *Practical Approaches in Preparing for Exhibit Development Process*, 2. *Practical Approaches in Finding an Exhibit Idea*, 3. *Practical Approaches in Planning of Exhibits* with the sub-themes 3a. Practical Approaches in Planning of Exhibit Designs and 3b. Practical Approaches in Planning of Materials.

Secondly, the category of “Practical Approaches in Production Stage” includes the fourth theme *Practical Approaches in Production of Exhibits* and four relating sub-themes: 4a. Practical Approaches in Making of Exhibits, 4b. Practical Approaches in Integration of RRI, 4c. Practical Approaches in Making Exhibits Interactive, and 4d. Getting Support in Production of Exhibits. The third category, which is “Practical Approaches in the Overall Process”, comprises of the fifth theme *Practical Approaches in Managing the Overall Process* and three corresponding sub-themes: 5a. Practical Approaches for Motivating Students, 5b. Role of Teacher, and 5c. Organizational Approaches. Final category is about exhibition stage and it involves the sixth theme, namely *Practical Approaches in The Exhibition*.

The practical approaches under each theme and sub-theme are reported in the following sections examined under each of the four categories. Different practical approaches of teachers are identified as well as their common practical approaches through the analysis of varying data sources aforementioned.

Table 7.16. Themes and sub-themes identified for the practical approaches of teachers.

	Themes and Sub-themes	Explanation	Example
PRACTICAL APPROACHES IN PRE-PRODUCTION STAGE	1. Practical Approaches in Preparing for Exhibit Development Process	Practical approaches of teachers in making students ready for exhibit development process.	Giving students extra materials about exhibitions on NST (SH2T1)
	2. Practical Approaches in Finding an Exhibit Idea	Practical approaches of teachers in guiding students along gathering an exhibit idea.	Revising what is learned in the field trip to university laboratories (SH1T1, SH2T1, SH3T1) Inviting another school in the project to discuss all together (SH3T1)
	3. Practical Approaches in Planning of Exhibits	Practical approaches of teachers in exhibit planning.	
	3a. Practical Approaches in Planning of Exhibit Designs	Practical approaches of teachers in guiding students along planning of their exhibit designs.	Directing students to do modelling (SH3T1) Showing an old student project as an example for exhibit design (SH1T1)
	3b. Practical Approaches in Planning of Materials	Practical approaches of teachers in guiding students along planning materials of their exhibits.	Suggesting students to consult their acquaintances about materials (SH1T1, SH3T1) Benefitting from the materials in the laboratory (SH1T1, SH2T1)
PRACTICAL APPROACHES IN PRODUCTION STAGE	4. Practical Approaches in Production of Exhibits	Practical approaches of teachers in production stage.	
	4a. Practical Approaches in Making of Exhibits	Practical approaches of teachers in guiding students along exhibit making.	Asking students to give feedback each other's exhibit in progress (SH1T1) Asking students to discuss about missing parts of each exhibit (SH3T1)
	4b. Practical Approaches in Integration of RRI	Practical approaches of teachers in guiding students along integrating RRI in their exhibits.	Reminding the meaning of each RRI dimension (SH1T1) Giving students examples of thinking RRI with respect to NST (SH2T1)
	4c. Practical Approaches in Making Exhibits Interactive	Practical approaches of teachers in guiding students along making their exhibit interactive.	Reminding students interactive exhibits in the science center (SH1T1)

Table 7.16. Themes identified for the practical approaches of teachers. (cont.)

	Themes and Sub-themes	Explanation	Example
	4d. Getting Support in Production of Exhibits	Practical approaches of teachers for getting support in guiding students along the production of exhibits.	Consulting the Science Project Coordinator (SH2T1) Inviting volunteer students, who are not from the nanoscience school club, for taking support in exhibit development (SH2T1) Getting support from the engineering club of the school (SH1T1)
PRACTICAL APPROACHES IN THE OVERALL PROCESS	5. Practical Approaches in Managing the Overall Process of Exhibit Development:	Practical approaches of teachers in overall process management.	
	5a. Practical Approaches for Motivating Students	Practical approaches of teachers for motivating students in exhibit development process.	Encouraging students to develop all of the exhibit ideas they came up with (SH1T1) Complimenting about strong sides of an exhibit to encourage improvement of weak sides (SH3T1)
	5b. Role of Teacher	Practical approaches reflecting the role of teacher in guiding students along the exhibit development.	Directing students by asking them questions (SH1T1, SH2T1, SH3T1) Providing source and creating opportunities (SH1T1, SH2T1)
	5c. Organizational Approaches	Organizational approaches of teachers in the exhibit development process.	Letting students to decide about forming group dynamics (SH1T1) Suggesting students to work on exhibit development in laboratory at lunch breaks (SH1T1, SH2T1)
PRACTICAL APPROACHES IN EXHIBITION STAGE	6. Practical Approaches in The Exhibition	Practical approaches of teachers in the exhibition event.	Encouraging students to evaluate their own exhibits (SH1T1) Contributing the students' presentation of their exhibits in the first day of exhibition (SH3T1) Interacting with colleagues (SH1T1)

7.5.1. Practical Approaches of Teachers in Pre-Production Stage

7.5.1.1. Preparing for Exhibit Development Process. The first theme in the pre-production stage category covers teachers' practical approaches to orient students through exhibit development process and make them ready for it. The common practical approaches shown with this purpose are informing students briefly about the exhibit development and exhibition processes, putting emphasis on learning of module topics well to eliminate lack of information, asking students to brainstorm on exhibit idea at semester holiday and asking students to make an internet search for the exhibit ideas before the exhibit development process starts as seen in Table 7.17. Statements of SH3T1 and SH1T1 given below are examples of practical approaches under the first theme:

> "I had an expectation from students, which I put emphasis on it: Which information do we have? We should know them very well so that we don't lack in information. We have "nanotechnology" and we shouldn't leave our knowledge on it incomplete" (SH3T1-Post).

> "I suppose that you have made search on what kind of exhibit you may develop because we don't have Internet access in here. I had asked you to do it before" (SH1T1 in SH1O1_Textual Sum.).

Most of the practical approaches identified are common among teachers, but SH2T1 took different approaches as well. The teacher SH2T1 had two additional approaches for preparing students for the exhibit development. The first one is reminding students that they will go through an exhibit development process, time to time while teaching the module. The second practical approach, which was taken before a very short period of time to the beginning of exhibit development, is giving students extra materials about exhibitions on NST to familiarize students with nano-themed exhibits and exhibitions. Statement in the below can be given as example of a practical approach of SH2T1 under the first theme:

> "Teacher asked students whether they examined the reading he gave them before. It is about a web site including ideas for nano-exhibitions" (SH2T1 in SH2O1_Textual Sum.)

7.5.1.2. Practical Approaches in Finding an Exhibit Idea. The second theme in the pre-production stage consists of teachers' practical approaches in guiding students along finding an exhibit idea. Most of the practical approaches identified are common among teachers, but each teacher has different approaches, either. The common practical approaches of teachers in finding an exhibit idea are revising what is learned in the field trip to university laboratories, revising what is learned in the module and module materials, directing students to make a search on the Internet, evaluating practicability of students' exhibit ideas, brainstorming and discussing with students on their exhibit ideas, directing students to pick a nanoparticle and its specific property, reminding students that developing an exhibit individually is an option to increase the number of exhibits, asking each group to give feedback for exhibit ideas of other groups, and directing students about exhibit ideas by asking questions. The statements below can be given as examples of practical approaches under the second theme:

> "While we were searching about what can be done (as exhibit) we learned about exhibits (about NST) developed before and usage area of different nanoparticles regarding how it is used and where it is used" (SH1T1-Post).
>
> "I am planning to evaluate the practicability of exhibit ideas" (SH1T1-WeeklyLog#1)
>
> "They all revise the topics learned in the module while trying to find an exhibit idea" (SH2O1_FieldNotes).
>
> "I asked students to pick a nanoparticle and decide which property of it they want to model. We spent too much time for it" (SH3T1-Post).

Differently from other two teachers, SH1T1 had two practical approaches in the phase of gathering an exhibit idea. The first one is directing students to discuss exhibit idea first in groups, then all together through a feedback mechanism. The following statements can be given as examples of SH1T1's practical approaches under the second theme:

> "They got each other's opinions while discussing on their exhibit ideas. It seems like an exhibit is developed by 3-5 students, but actually all 21 of them have contribution in it" (SH1T1-Post).
>
> "Teacher asked students to listen each groups' ideas and think on each group's exhibit idea(s) all together to contribute them by regarding how the idea can be improved and how they can help each other" (SH1T1 in SH1O1_Textual Sum.).

Other practical approach of SH1T1 is regarding the originality of exhibit ideas. The statement of SH1S5 is addressing this approach:

> "Teacher told us this idea is not original and done before. So we changed it and now we think on new idea" (SH1S5 in SH1O3_Textual Sum.).

The practical approaches of SH2T1, which are different from others, are consulting the Science Project Coordinator in the school, giving students examples of nano-products, regarding limited time, and discussing all together for finding an exhibit idea. The following statements can be given as example of SH2T1's approaches under the second theme:

> "Teacher told students that they can find products like hydrophobic fabrics and gave few examples of nano-products" (SH2T1-SH1O1_FieldNotes)
>
> "We have a "Science Project Coordinatorship" in school. The head of this department is an expert about electronics, robotics. We will consult him and get support on next Monday. He designs robots with sensors. Students will consult him about if their ideas about robotics are applicable or not" (SH2T1 in CoL_Meeting#2).

Similar to other two teachers, SH3T1 also had some varying practical approaches in process of exhibit idea gathering. These approaches are inviting another school in the project to discuss all together, asking students to think on an exhibit idea individually to increase the variety of exhibit ideas, suggesting students to read extra materials, and discussing the exhibit ideas of groups or individuals all together. The following statements can be given as example of SH3T1's practical approaches under the second theme:

> "I asked students to think exhibits individually because they were not present in club hours all together at the same time. I thought, they will be more brave (about ideas) in this way" (SH3T1-Post).
>
> "Teacher had invited neighbor school, which is also in the project, for benefit of all of them. Students of SH3 have chance to learn about other students' ideas of exhibits. This can be inspirational for them and enlarge their visions" (SH3O1-Textual Sum.)

<u>7.5.1.3. Practical Approaches in Planning of Exhibits.</u> The third theme in the pre-production stage involves teachers' practical approaches in guiding students along planning of exhibit designs and materials. Practical approaches taken with these intentions were analyzed and classified under two sub-themes including planning of exhibit designs and planning materials phases. Most of the practical approaches identified under this theme are common among teachers, but each teacher has different approaches as well.

The practical approaches shown by all three teachers in planning of exhibit designs are asking students to draw their exhibit design plans, reminding students to regard integration of RRI and interactivity of exhibits, suggesting students to think on sustainability of the exhibit mechanism, directing students to revise their exhibit design after the project team's feedbacks, and discussing all together about exhibit designs (Please see Table 7.17 for full list of practical approaches).

Table 7. 17. The practical approaches of teachers in the pre-production stage of exhibit development process.

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PREPARING FOR EXHIBIT DEVELOPMENT PROCESS		Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Informing students briefly about the exhibit development and exhibition processes (SH1T1, SH2T1, SH3T1) Asking students to brainstorm on exhibit idea at semester holiday (SH1T1, SH2T1, SH3T1) Putting emphasis on learning of module topics well (SH1T1,SH3T1) Asking students to make an internet search for the exhibit ideas before the exhibit development process starts (SH1T1, SH3T1)
							SH1T1	-
							SH2T1	Reminding students the exhibit development process time to time while teaching the module Giving students extra materials about exhibitions on NST
							SH3T1	-
PRACTICAL APPROACHES IN FINDING AN EXHIBIT IDEA		Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Revising what is learned in the field trip to university laboratories (SH1T1, SH2T1, SH3T1) Revising what is learned in the module and module materials (SH1T1, SH2T1, SH3T1) Directing students to make a search on the Internet (SH1T1, SH2T1, SH3T1) Evaluating practicability of students' exhibit ideas (SH1T1, SH2T1, SH3T1) Brainstorming and discussing with students on their exhibit ideas (SH1T1, SH2T1, SH3T1) Directing students about exhibit ideas by asking questions (SH1T1, SH2T1, SH3T1) Directing students to pick a NP and its property (SH1T1, SH3T1) Reminding students developing an exhibit individually is an option to increase the number of exhibits (SH1T1, SH3T1) Asking each group to give feedback for exhibit ideas of other groups (SH1T1, SH3T1)
							SH1T1	Regarding originality of exhibit ideas Directing students to discuss exhibit idea first in groups, then all together through feedbacks
							SH2T1	Consulting the Science Project Coordinator in the school Giving students examples of nano-products Regarding limited time Discussing all together for finding an exhibit idea
							SH3T1	Inviting another school in the project to discuss all together Asking students to think on an exhibit idea individually to increase the variety of exhibit ideas Suggesting students to read extra materials Discussing the exhibit ideas of groups or individuals all together

Table 7.17. The practical approaches of teachers in the pre-production stage of exhibit development process. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN PLANNING OF EXHIBITS	PRACTICAL APPROACHES IN PLANNING OF EXHIBIT DESIGNS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Asking students to draw their exhibit design plans (SH1T1, SH2T1, SH3T1) Reminding students to regard integration of RRI (SH1T1, SH2T1, SH3T1) Reminding students to regard interactivity of exhibits (SH1T1, SH2T1, SH3T1) Suggesting students to think on sustainability of the exhibit mechanism (SH1T1, SH2T1, SH3T1) Directing students to revise their exhibit design after the project team's feedbacks (SH1T1, SH2T1, SH3T1) Discussing all together about exhibit designs (SH1T1, SH2T1, SH3T1) Asking students to pay attention to reflect the NST theme of exhibit good (SH2T1, SH3T1) Asking students to pay attention to plan exhibit designs that are coherent with their purposes. (SH2T1, SH3T1) Suggesting students to develop a prototype of their exhibit designs to see if it works (SH1T1, SH2T1) Deciding ultimate exhibit design plans through trial and error (SH1T1, SH2T1) Asking students to give feedback each group's exhibit design plans (SH1T1, SH3T1) Asking students to regard visuality of their exhibits (SH1T1, SH3T1) Asking students to regard visitor's understanding and learning (SH2T1, SH3T1) Asking students to regard scientific correctness while deciding on exhibit design plans (SH1T1, SH3T1) Consulting colleagues, technical staff or science project coordinator (SH1T1, SH2T1)
							SH1T1	Asking students to develop exhibits that is independent of the exhibit owner Revising the interactive exhibits they see in the field trip to science center Making suggestions about possible exhibit formats Showing an old student project as an example for exhibit design
							SH2T1	Directing students to avoid complex exhibit designs Regarding visitors' excitement
							SH3T1	Directing students to do modelling Inviting a volunteer student for taking suggestions in multi-media based exhibits
	PRACTICAL APPROACHES IN PLANNING OF MATERIALS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Asking students to consider alternative materials and test them (SH1T1, SH2T1, SH3T1) Suggesting students some materials (SH1T1, SH2T1, SH3T1) Benefitting from the materials in the laboratory (SH1T1, SH2T1, SH3T1) Suggesting students to consult their acquaintances about materials (SH1T1, SH3T1) Consulting colleagues, technical staff or science project coordinator (SH1T1, SH2T1) Asking each group to give suggestions of materials for other groups (SH1T1, SH3T1) Suggesting students some stores for materials (SH1T1, SH3T1) Learning about different materials (SH1T1, SH2T1) Suggesting students to benefit from durable materials (SH2T1, SH3T1) Directing students to gather the materials they need by themselves (SH1T1, SH3T1)
							SH1T1	Suggesting students to search materials on the Internet
							SH2T1	Supplying materials for students
							SH3T1	Suggesting students to benefit from materials used in daily life

The practical approaches taken by at least two teachers in the phase of students' planning of exhibit designs are asking students to pay attention to reflect the NST theme of exhibit good and plan exhibit designs that are coherent with their purposes, asking students to regard scientific correctness of their exhibits as well as its visuality, asking students to regard visitor's understanding and learning, asking students to give feedback each group's exhibit design plans, suggesting students to develop a prototype of their exhibit designs to see if it works, consulting someone (colleagues, technical staff or science project coordinator) for students' exhibit designs and deciding ultimate exhibit design through trial and error. The statements below can be given as example for teachers' practical approaches under this category:

> "SH1S4 tries to change his design in a way that he can use acid-base solutions and indicators to show any change and difference between healthy cells and cancer cells. SH1T1 suggests to test the idea before using it in the exhibit" (SH1O2-Textual Sum.).

> "I asked students to pay attention whether the exhibits are able to give our message clearly or if it is perceivable easily by visitors" (SH2T1-Post).

> "Students realized that their models didn't constitute an answer for some questions after we started to ask questions to each other. Then, they tried to transform their models in that way" (SH3T1-Post).

> "Teacher wants group SH1G2 to listen SH1G5's exhibit design idea and to give feedback them before leaving the nano school club" (SH1O3_Textual Sum.).

Apart from the common practical approaches, SH1T1 took some different approaches in guiding students along exhibit design planning. The first one is asking students to develop exhibits that is independent of the exhibit owner, which was challenging for students as it is discussed in Section 7.8.1. Other practical approaches of SH1T1 are revising the interactive exhibits they see in the field trip to science center, making suggestions about possible exhibit formats and showing an old student project as an example for exhibit design. The suggestion of SH1T1 for a group can be given as example for practical approaches of SH1T1 in planning of exhibit designs:

> "Design your exhibits in a way that visitors can infer that the one with nanotechnology has dirt-proof property. You may not stand next your exhibit all the time. For instance, although there wasn't any presenter for each exhibit in the ITU Science Center, we were able to figure it out by ourselves" (SH1T1 in SH1O1-Textual Sum.).

> "Teacher brought the blood circulation model in the laboratory. It is developed by a student as a term project" (SH1O3-Post).

Differently from other two teachers, the practical approaches shown by SH2T1 are directing students to avoid complex exhibit designs because of limited time and suggesting students to regard visitors' excitement. The statement of SH2T1 can be given as example for his practical approaches in planning of exhibit designs:

> "We tried to avoid any exhibits that may challenge us heavily and consist of too much details" (SH2T1-Post).

Finally, the SH3T1's practical approaches, which are different from others, are directing students to do modelling specifically because students had seemed lost in deciding what kind of exhibits they can develop, and inviting a volunteer student, who are not from the nanoscience school club, for taking suggestions if a student or group want to make a multi-media based exhibit. The statement of SH3T1 can be given as example for the first approach she took:

> "Firstly, students thought that they need to invent something new. So, I told them that we will do an exhibit, we will do modelling" (SH3T1-Post).

Another category of teachers' practical approaches under the phase of planning exhibits is guiding students through planning of materials. Likewise, in the planning of exhibit designs, most of the practical approaches in this stage are common, and only one different approach was identified for each teacher as seen in Table 7.17. The common practical approaches, which are taken by all three teachers, are asking students to consider alternative materials and test them, suggesting students some materials and benefitting from the materials in the laboratory. The practical approaches taken by at least two teachers in the phase of material planning are suggesting students to consult their acquaintances about materials; consulting colleagues, technical staff or science project coordinator; asking each group to give suggestions of materials for other groups, suggesting students some stores for materials, learning about different materials, suggesting students to benefit from durable materials and directing students to gather the materials they need by themselves. The statement below can be given as example for teachers' practical approaches in material planning:

> "Students had difficulty in deciding and finding the right materials for their exhibits. We asked suggestions of acquaintances and staff (in stores). They consulted their families. We shared our opinions with colleagues and asked theirs" (SH1T1-Post).

> "…Besides, we used the 3-d printer in the school (Technology and Design Laboratory). Sometimes, we benefitted from the facilities of our laboratory (Chemistry Lab.)" (SH2T1-Post).

> "Teacher. asks science project coordinator. about type of magnets that can attach to inner walls of robot shells" (SH2O6_Textual Sum).

> "Can't you make it with toy blocks so that you can plug and unplug it easily. There may be magnets in laboratory. You may borrow magnet for weekend. There were different types of magnets in the Physics Laboratory" (SH3T1 in SH3O2-Textual Sum.)

The different practical approach of SH1T1 in planning of materials is suggesting students to search materials on the Internet. Differently from others, SH3T1 suggested students to benefit from materials used in daily life. She explains her approach as the following:

> "Sometimes, students wanted to buy ready-products. But, I said that we can use the materials we have. Then, they started to observe their environment more carefully" (SH3T1-Post).

> "I asked students to use the materials they possess. I mean (materials like) pen cases, pen, domestic wastes or something from recycle bins in their home" (SH3T1-Post)

On the other hand, unlike the other two teachers, SH2T1 bought materials from a store to supply materials readily for students. The statements below might be examples for teachers' different practical approaches in this manner:

> "I tried to direct students to buy materials after they decided completely" (SH1T1-Post).

> "Materials were bought by students, who reside close to the stores" (SH1T1-Post).

> "…Besides, (we used) the materials I bought from the market such as LED lights, magnets…" (SH2T1-Post).

The overall analysis of teachers' practical approaches in the pre-production stage, which were categorized under three themes, namely *Practical Approaches in Preparing for Exhibit Development Process*, *Practical Approaches in Finding an Exhibit Idea* and *Practical Approaches in Planning of Exhibits*, reveal that teachers took mostly common practical approaches as well as different ones. One of the reasons behind the commonalities in approaches might be the fact that teachers were guided along the exhibit development process starting with a workshop and continuing with in-process CoL meetings. The statements from a CoL meeting and a common practical approach of two teachers can be given as example:

> "Choosing a theme is important like choosing a specific NP or a nanotechnology theme such as AFM" (Project Coordinator in CoL_Meeting#2).

> "I asked students to pick a nanoparticle and decide which property of it they want to model. We spent too much time for it" (SH3T1-Post).

> "After SH1S5 explains her exhibit idea. SH1T1: It may be; but does it give any idea about nanoparticles to visitors?" (SH1T1 in SH1O1-Textual Sum.)

On the other side, the differences in practical approaches in the pre-production stage might stem from the changing experiences of teachers in guiding students through exhibit development. For instance, SH1T1 and SH2T1, who have several experiences in exhibit development with students, seem to collaborate more with colleagues or technical staff to consult them in the exhibit planning phase compared to the teacher SH3T1, who had an only experience, as seen in Table 7.17. Another reason of teachers' varying practical approaches in the pre-production stage might be changing facilities and opportunities of the school they work. For instance, SH2T1, who works in a private school, has Technology and Design Laboratory or Science Project Coordinator in their school; while the teachers SH1T1 and SH3T1, who works in public school, don't have such opportunities.

7.5.2. Practical Approaches of Teachers in Production Stage

<u>7.5.2.1. Practical Approaches in Making of Exhibits.</u> The first sub-theme in the production stage consists of teachers' practical approaches in building of exhibits by students based on their exhibit design plans. The common practical approaches of teachers taken in this direction are answering students' questions about making their exhibits, letting students to decide for what to do by trial and error, revising the finished parts of the exhibits all together, discussing with students on missing parts of their exhibits, not having hand work contribution in exhibit making, but rather guiding students through asking questions and giving feedback for exhibits on progress as seen in Table 7.18. The statements below can be given as example for common approaches of teachers in making of exhibits:

> "While students were developing their exhibits, I didn't reveal my ideas too much. I wanted them to have their own ideas. I mean, I didn't interrupt. After they made their exhibits, I asked them questions like "Could it be like this?", "Could it be better in this way?"" (SH1T1-Post).

> "SH2T1: Will you put a separate brain (electrical component) in circuit? SH2S1: We don't need a separate brain (electrical component). I can do it by using only cables and keys" (SH2O4_Textual Sum.).

Table 7.18. The practical approaches of teachers in the production stage of exhibit development process.

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN PRODUCTION OF EXHIBITS	PRACTICAL APPROACHES IN MAKING OF EXHIBITS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Answering students' questions about making their exhibits (SH1T1, SH2T1, SH3T1) Letting students to decide for what to do by trial and error (SH1T1, SH2T1, SH3T1) Revising the finished parts of the exhibits all together (SH1T1, SH2T1, SH3T1) Discussing with students on missing parts of their exhibits (SH1T1, SH2T1, SH3T1) Not having hand work contribution in exhibit making (SH1T1, SH2T1, SH3T1) Guiding students in making exhibits through asking questions (SH1T1, SH2T1, SH3T1) Giving feedback on exhibits on progress (SH1T1, SH2T1 SH3T1) Directing students to develop a prototype of their exhibits (SH1T1, SH2T1) Directing students to give feedback for each other's exhibits (SH1T1, SH3T1) Regarding each student for having role in production of exhibits (SH1T1, SH2T1) Regarding safety while students work on exhibits (SH1T1, SH2T1)
							SH1T1	Encouraging students to collaborate and help students in other groups
							SH2T1	-
							SH3T1	Suggesting students to be careful about the trustworthiness of the information on the Internet Directing students to ask questions each other about exhibits to see their deficiencies Asking students to record a video including the presentation of completed exhibits and share it with others
	PRACTICAL APPROACHES IN INTEGRATION OF RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Trying to motivate students for integration of RRI (SH1T1, SH2T1, SH3T1) Trying to make students understand and internalize the RRI dimensions by explaining each dimension (SH1T1, SH2T1, SH3T1) Giving students some format idea about integration of RRI (SH1T1, SH2T1, SH3T1) Giving students specific examples for integration of RRI (SH1T1, SH2T1, SH3T1) Giving students question examples relating RRI and NST (SH1T1, SH2T1, SH3T1) Discussing on possible ways of integrating RRI in each exhibits (SH1T1, SH2T1, SH3T1) Taking suggestions from the project team for possible ways of RRI integration in exhibits (SH1T1, SH2T1, SH3T1) Concentrating more on RRI after completing exhibit's design (SH1T1, SH2T1, SH3T1) Discussing on RRI issues (SH1T1, SH3T1) Suggesting students to make search about RRI on the web (SH1T1, SH3T1) Asking students to regard RRI dimensions themselves while developing an exhibit (SH1T1, SH3T1) Asking students to listen other groups' ideas to get idea about integration of RRI (SH1T1, SH3T1) Providing students with extra reading materials about RRI (SH2T1, SH3T1) Suggesting students to use their own words while integrating RRI (SH2T1, SH3T1)
							SH1T1	Asking students to integrate some of the RRI dimensions instead of integrating all of them Asking students find an integration way that directs visitors to make inferences about RRI dimensions by themselves

Table 7.18. The practical approaches of teachers in the production stage of exhibit development process. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN PRODUCTION OF EXHIBITS	PRACTICAL APPROACHES IN INTEGRATION OF RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	SH2T1	Giving students brochures of the module to examine Opening some documents on board that can help students to write questions
							SH3T1	Providing students with a reading material relating RRI and NST, and reading and discussing on it Suggesting students to revise the module activities to relate the RRI and NT Relating some RRI dimensions with the nano club periods Asking students to print the materials they benefit from for "open access" and emphasizing the importance of showing references Asking students to share the sources they found with others so that they can benefit from them
	PRACTICAL APPROACHES IN MAKING EXHIBITS INTERACTIVE	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Playing the video, which includes examples of interactive exhibits, addressed in the module (SH1T1, SH2T1, SH3T1) Informing students about what interactive exhibition is (SH1T1, SH2T1, SH3T1) Taking suggestions from the project team about ways of making exhibits interactive (SH1T1, SH2T1, SH3T1)
							SH1T1	Reminding students interactive exhibits in the science center Asking students to share their experiences about interactive exhibit Asking students the advantages and disadvantages of the interactive exhibits
							SH2T1	-
							SH3T1	Giving tips for making exhibits interactive
	GETTING SUPPORT IN PRODUCTION OF EXHIBITS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Taking support in technical aspects of exhibits (SH1T1, SH2T1) Creating opportunities for contribution of students out of the nanoscience club (SH1T1, SH2T1)
							SH1T1	Taking support from students of the engineering club in school Taking support from technician of the school
							SH2T1	Taking support from science project coordinator Taking support from Technology and Design teacher Taking support from two students out of the nanoscience school club
							SH3T1	-

> "SH3T1: You may attach capillary vessels to main vessel and put some questions on them to get visitors making inquiry on this topic. Do you know what happens if NPs reaches to healthy cells instead of cancer cells?" (SH3O3_Textual Sum.).

> "Teacher asked SH3S6 what the missing part of his exhibit is. SH3S6 answered as "The upper part of the wheel. I completed this part. Now I need to write information (on wheel). Teacher asked whether he decided what to write. SH3S6 answered as "Information about navigation property of gold nanoparticles"" (SH3O5_Textual Sum.)

The practical approaches shown by at least two of the teachers in guiding students along exhibit making are regarding each student for having role in production of exhibits, directing students to develop a prototype of their exhibits, regarding safety while students work on exhibits and directing students to give feedback for each other's exhibits. The statement below can be given as examples:

> "Teacher wants SH2S1 to connect motors to robot shell (bacteria model) and he suggests him to try and see the motion" (SH2O4_Textual Sum.).

> "First of all, I asked them not to harm themselves or others while making their exhibits" (SH1T1-Post).

> "They listened each other and made comments about the deficiencies of the exhibits" (SH3T1-Post)

Besides the common approaches, teachers SH1T1 and SH3T1 had different practical approaches in making of exhibits. For example, SH1T1 were encouraging students to collaborate with other groups, especially when there is a need for technical support. The statement below can be given as example for SH1T1's such approach:

> "Everybody searched on his/her task and then, did it. Meanwhile, they helped another groups if they needed." (SH1T1-Post).

On the other hand, the practical approaches of SH3T1, which are different from other two, are suggesting students to be careful about the trustworthiness of the information on the Internet, directing students to ask questions each other about exhibits to see their deficiencies, and asking students to record a video including the presentation of completed exhibits and share it with others. The statements in the below can be given as examples:

> "Teacher asks at which website a student have searched from and emphasized the importance of open access and trustworthiness of the information written in a website" (SH3O3_Textual Sum.).

> "I had told them to record a video about their exhibits and send it to me" (SH3T1-Post).

> "We will record a video after we make our exhibits" (SH3S3-WeeklyLog#2).

7.5.2.2. Practical Approaches in Integration of RRI. Integration of Responsible Research and Innovation (RRI) in exhibits is another aspect of the exhibit development process in this study. While guiding students through RRI integration, teachers took many common practical approaches as well as the different ones. First of all, although teachers had suggested students to regard RRI in their exhibits and made few discussions on it in the phase of finding idea, they actually started to focus on it after students finished the making of their exhibits. The statement of SH1T1 in a CoL meeting can be given as example of teachers' this practical approach:

> "Students may integrate RRI more easily, after the models (exhibits) are developed. They might think on it better after they touch it" (SH1T1 in CoL_Meeting#3).

The common practical approaches of teachers after concentrating on RRI integration are trying to motivate students for integration of RRI, trying to make students understand and internalize the RRI dimensions by explaining each dimension, giving students some format idea about integration of RRI, giving students specific examples for integration of RRI, giving students question examples relating RRI and NST, discussing on possible ways of integrating RRI in each exhibits, and taking suggestions from the project team for possible ways of RRI integration in exhibits. The statement below can be given as example for the tips given by the project team for integration of RRI:

> "For instance, the antibacterial effect of Ag NP. Integration of RRI is possible with questions like "How to know about it, which addresses science education", "Should it be shared with public or not, which refers to open access", "Should we use these products or not, which is about engagement" or "who should decide this (its use), which points out governance"" (A Science Education Expert in CoL_Meeting#2).

The practical approaches shown by at least two teachers are discussing on RRI issues, suggesting students to make search about RRI on the web, asking students to regard RRI dimensions themselves while developing an exhibit, asking students to listen other groups' ideas to get idea about integration of RRI, providing students with extra reading materials about RRI, and suggesting students to use their own words while integrating RRI. The statements below taken from varying data sources can be given as example of teachers' common practical approaches in guiding students along the integration of RRI in their exhibits:

"Sometimes, students dwelled on RRI integration and said "We will integrate RRI, but how? Is it really meaningful?" I tried to encourage them by telling that they can do it if they really think on it and tried to support them by telling the idea came in to my mind" (SH1T1-Post)

"RRI came to the fore more at the final lesson (of the module). What did we do for it in the following process? First, we tried to internalize it and then, we looked through its integration in our models" (SH2T1-Post)

"I tried to make them think on RRI from the beginning. We discussed on it. I tried to carry out them (making exhibit and RRI integration) together" (SH3T1-Post)

"I told students that they can regard the RRI themselves, while they develop their exhibits. I asked them to be responsible" (SH3T1-Post)

"You seem so tired and actually seem like don't have too much idea about RRI. Let's leave this part to next week; but please make an Internet search on it" (SH1O1_Textual Sum.)

"Teacher gave importance of politicians' involvement in the process of doing science as an example. She also exemplified the importance of public involvement in this process as a future user of the products" (SH1O1_Textual Sum.).

"Let's let each group to explain their ideas. It was very beneficial for each group last week. You can get idea about integration of RRI dimensions from the ideas coming from each group" (SH1T1 in SH1O2_Textual Sum.).

"Teacher asks: "Whether is the exhibit you develop beneficial for human being or not? Are there any disadvantages of this exhibit in the long term?"" (SH1T1 in SH1O2_Textual Sum.)

"Teacher gave an example of True-False question: Do nano-products have impact on environmental pollution? Teacher gave another example: "In what degree does it lead to environmental pollution? For instance, presence of heavy metals in waste water"" (SH2O1_Textual Sum.).

"Teacher said "If you integrate the aspects we discussed on into your exhibits, visitors may also see not only its one side, right?" Students shook their head to confirm" (SH3O1_Textual Sum.).

"Teacher gave an example: "There was a product of a known brand, carpet/rug washing machine. It was written on the box that the machine is powered with nanoparticles, but we couldn't see any explanation about it in the user manual. So, we may say there is no "open access" in it" (SH3O1_Textual Sum.).

After reading a text about RRI, teacher said "You can decide what to write (on informing cards) after reading such articles. You don't need to write the same things but rather you need to write sentences with your own words. It doesn't have to be a sentence, actually. It can be a slogan. It depends on your creativity" (SH3T1 in SH3O5_Textual Sum.).

"We brainstormed on RRI with students. We realized that we need to understand it more. We planned to separate more time on Internet search about it" (SH1T1-WeeklyLog#1).

"We will try to integrate RRI dimensions as mini messages" (SH3T1 in CoL_Meeting#2).

Differently from the common practical approaches, SH1T1 had two separate approaches while guiding students in RRI integration. For example, to familiarize the students with RRI more, SH1T1 asked students find an integration way that directs visitors to make inferences about RRI dimensions by themselves rather than explaining them directly. The statement below can be given as example of SH1T1's practical approach in this direction:

> "A student from SH1G5 thinks that they can explain RRI dimensions in a poster. Teacher suggested that they can find an integration way that directs visitors to reach to conclusion themselves and make them think on RRI dimensions" (SH1O2_FieldNote).

Besides, SH1T1 suggested students to integrate few of the RRI dimensions instead of all of them after students struggled in integration of each RRI dimension in their exhibits. SH1T1 explains her approach as the following:

> "Students had concerns about what if they can't (integrate RRI). They were saying "We are expected to integrate all RRI dimensions. We can show one or two; but how can we integrate all?" I encouraged them for trying to integrate at least three of them" (SH1T1-Post).

The difference in practical approaches of SH2T1 in RRI integration arouse in how he provided students with reading materials about RRI, which is actually among the common approaches. For helping students to write questions relating RRI and NST, SH2T1 gave students brochures of the module and opened some documents on board. The statement from textual summary of one of the school observations reflects SH2T1's this approach:

> Teacher opened some documents on smart board and asked SH2S2 to examine them to form questions for nano quiz. Then, teacher said "We are expected to integrate RRI dimensions in our questions to give messages to visitors" (SH2T1 in SH2O6_Textual Sum.).

On the other side, teacher SH3T1 used a different strategy while providing students with extra reading materials. A section from textual summary of one of the school observation shows how her approach differs from SH2T1's:

> "Teacher said that she found when she searched on the Internet about RRI and she printed it to show it as an example. They started to reading it. Each part was read by a different student. The text includes the ethical aspects of some possible disadvantages of using nanoparticles in health sector, references for multiple sources, which teacher relates with "open access" dimension of RRI, the date this text was updated, possible ecological effects of nanoparticles and their impact on human health, and current regulations about use of nanoparticles. Teacher related last two of them with "engagement" and "governance" dimensions of RRI. Text also mentions about some applications of nanotechnology in medicine. Teacher relates these applications with themes of students' exhibits" (SH3O5_Textual Sum.).

Other original practical approaches of SH3T1 in RRI integration are suggesting students to revise the module activities to relate the RRI and NST, relating some RRI dimensions with the nano school club periods, asking students to print the materials they benefit from for "open access" and emphasizing the importance of showing references, and asking students to share the sources they found with others so that they can benefit from them.

The analysis of teachers' practical approaches through students' integration of RRI in their exhibits reveals many common approaches besides the peculiar ones. Nevertheless, there is no common practical approach shown only by SH1T1 and SH2T1, who have multiple experience in exhibit development with students. Interestingly, SH3T1, who had only one experience in guiding students along exhibit development, took the higher number of different practical approaches in RRI integration compared to two others. This situation might stem from the fact that guiding students about RRI was a brand new experience for all of the teachers and therefore, their experience in exhibit development with students didn't make a difference at all. In addition, some reasons for SH3T1 to have more varying number of practical approaches in RRI integration might be her particular interest in such topics or the fact that struggle her students have in integrating RRI in their exhibits, which is discussed in Section 7.8.1, might be led her to take more action in this sense.

<u>7.5.2.3. Practical Approaches in Making Exhibits Interactive.</u> Another facet of guiding students along the exhibit development process in this study is that directing them through making of their exhibits interactive. The analysis of varying data sources reveals that practical approaches of teachers with this purpose vary depending on how much they followed the "Week-1" section of the module worksheet (See Appendix A). For example, the first common practical approach is playing the video, which includes examples of interactive exhibits, addressed in the module. The statement of SH2T1 can be given as example for this approach:

> "Our exhibits will not be as professional as the ones in the video we watched; but we will make an interactive modelling" (SH2T1 in CoL_Meeting#2).

Another common practical approach in guiding students about interactive exhibits is taking suggestions from the project team about ways of making exhibits interactive. The tips given below by the project coordinator in a CoL meeting can be given as example:

> "If the presentation of student be shorter, it could be better. Not keeping the students' telling long is better. Visitor should be in interaction. If somebody tells about the poster, the amount of interaction decreases. It could be in the form of treasure hunt game. Visitors may examine or search for something in the poster; then, s/he may answer questions" (The Project Coordinator in CoL_Meeting#2).

The last common approach is informing students about what interactive exhibition is. However, teachers' way of informing varies. For instance, the teachers SH2T1 and SH3T1 informed students by describing what interactive exhibition is. In addition, SH3T1 gave students some tips for making an exhibit interactive. The statement below is an example of her practical approach in this manner:

> "Visitors should be able to observe or interact with each step of work done in your exhibits as you did while developing your exhibit. For example, visitors may push a button, turn the wheel and see the card, s/he will have initiative to open the card or not. Interactive means visitors be able to make it (the exhibits' functioning) together with you. So your exhibits should be three dimensional" (SH3T1 in SH3O1_Textual Sum.).

On the other hand, SH1T1 began with reminding students the exhibits they saw in the field trip to the ITU Science Center. Then, she followed the module worksheet step by step and asked students to share their experiences about interactive exhibit and asked them the advantages and disadvantages of interactive exhibits. The following statements taken from varying data sources can be given as example for SH1T1's different practical approaches:

> "We got idea what an interactive exhibit is while we visited ITU Science Center and some of you had visited an interactive exhibition before" (SH1O1_Textual Sum.).
>
> "Students were talking about their experiences in interactive exhibitions. Then, they shared their experiences with class" (SH1O1_FieldNote).
>
> "SH1S4 says "I hadn't gone to an interactive exhibition before our visit in ITU Science Center". Teacher asks "What were you expecting an interactive exhibit to be by just inferring from its name?" SH1S4 answers as "While the owner of exhibit informs the visitor, somehow, visitor can also involve in this process"" (SH1O1_Textual Sum.).

The analysis of practical approaches of teachers in making exhibits interactive shows that the number of approaches are quite lower than the number of practical approaches shown in RRI integration as seen in Table 7.18. The reason behind it might be the fact that making exhibits interactive was an easier task for the participants compared to integrating RRI in their exhibits, which is discussed in the Section 7.7.1 and the Section 7.8.1.

<u>7.5.2.4. Getting Support in Production of Exhibits.</u> The final sub-theme identified under the analysis of teachers' practical approaches in the production of exhibits reveals why, how and from who the teachers SH1T1 and SH2T1 got support in this phase. The first common approach of these teachers are taking support in technical aspects of exhibits. While the teacher SH1T1 consulted to the technician of the school, SH2T1 took support from the Science Project Coordinator (SPC), and Technology and Design teacher in the school during the development of exhibits. The statements below from varying data sources are some examples for teachers' getting support:

> "Students assembled the materials, but then we realized that it leaks water and the adhesive was dissolving in water. The technician of the school asked what we were doing. After we explained him, he told us "There is an aquarium adhesive and we can use it" (SH1T1-Post).
>
> "We consulted the SPC. He has expertise in robotics" (SH2T1-Post).
>
> "We will consult SPC one more time. After he explains how to do the electric circuit and shows us an example you can do it" (SH2T1 in SH2O4_Textual Sum).
>
> "SPC checked students' electric circuit connections" (SH2O6_Textual Sum.).

The second common practical approach of SH1T1 and SH2T1 in getting support is creating opportunities for contribution of students out of the nanoscience club. The following statements exemplify this approach of teachers:

> "We took support from students, who are in the engineering club of the school, when we needed to dig hole on a water pump and while doing the electric circuits" (SH1T1-Post)
>
> "There was a student, who gave us support in the project when he was finding time after his school club. He has a good background in electronics" (SH2T1-Post)
>
> "There are two students, who the researcher has never seen in the nano school club periods before. One of them asked SH2S1and another student if they need any help. Then, they all worked on electric circuits" (SH2O5_Textual Sum.)

On the other side, the teacher SH3T1 didn't get in-school support in guiding students in the production of exhibits. The reason might be the fact that it was her first year in this public school and therefore she may not know her colleagues or the other staff like technicians working in the school very well. Besides, unlike the private schools like SH2T1 works in, the public schools don't have staff, who are experts in science projects, robotics or 3-d printers. The analysis shows that this is an important factor affecting teachers' practical approaches while getting support.

7.5.3. Some Practical Approaches of Teachers in The Overall Process of Exhibit Development

7.5.3.1. Practical Approaches for Motivating Students. The first sub-theme identified under the category of managing the overall process of exhibit development is about teachers' practical approaches for motivating students through the process. The codes fit in this sub-theme come from four different data sources as seen in Table 7.19. The common practical approaches taken in this manner are mentioning about having a chance of participation in final exhibition of the project, which is in another country, and suggesting students to develop their exhibit as soon as possible so that they can see the missing parts and have time to fix them before the exhibition. Besides, the practical approaches shown by at least two of teachers are emphasizing students that the responsibility of developing an exhibit belongs to them, pointing out the strong sides of the exhibits to encourage students to improve the weak sides, underlying that the exhibit development is a team work for motiving students to fulfil their in-group tasks on time, and directing student to work on the deficiencies of the exhibits all together for encouraging inter-groups collaboration. The statements below can be given as example for teachers' common practical approaches for motivating students:

> "I told students that the exhibits belong them, not me and said "You can develop your exhibits as you want or model whatever you wish". (SH1T1-Post)
>
> "Please start to develop your exhibit as soon as possible so that you can see the parts not working. It doesn't need to be perfect. Later you can improve it" (SH3T1 in SH3O2_Textaul Sum.)
>
> "Students want to develop exhibits that can be chosen for the final exhibition" (SH1T1 in CoL_Meeting#2).

Differently from other two teachers, the teacher SH1T1 taken some practical approaches for motivating students against their initial concerns about ranking in the exhibition. To motivate students having such apprehension, first, teacher told students that it isn't an obligation and then, she reminded that their aim is sharing what they've learned (about NST) with visitors and giving them an insight about NST. Apart from the common approaches for motivating students through the production of exhibits, SH1T1 used informing students about the schools, which had finished their exhibit development as a motive for students to work harder on their exhibits. The following statement can be given as example for SH1T1's peculiar motivational practical approaches:

Table 7.19. The practical approaches of teachers in the overall process of exhibit development.

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN THE OVERALL PROCESS	PRACTICAL APPROACHES FOR MOTIVATING STUDENTS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Mentioning about having a chance of participation in final exhibition of the project (SH1T1, SH2T1, SH3T1) Suggesting students to develop their exhibit as soon as possible so that they can see the missing parts and have time to fix them before the exhibition (SH1T1, SH2T1, SH3T1) Emphasizing students that the responsibility of developing an exhibit belongs to them (SH1T1, SH3T1) Pointing out the strong sides of the exhibits to encourage students to improve the weak sides (SH1T1, SH3T1) Underlying that the exhibit development is a team work for motiving students to fulfil their in-group tasks on time (SH1T1, SH3T1) Directing student to work on the deficiencies of the exhibits all together for encouraging inter-groups collaboration (SH1T1, SH3T1)
							SH1T1	For motivating students against their concerns about ranking in the exhibition: - Telling students that it isn't an obligation - Reminding that their aim is sharing what they've learned (about NST) with visitors and giving them an insight about NST Informing students about the schools, which has finished their exhibit development to motive students to work harder on their exhibits.
							SH2T1	-
							SH3T1	Encouraging students for exhibit development by emphasizing that they can improve their exhibits in time once they start to develop it. For motivating students, who don't want to involve in exhibit development process: - Encouraging students to try to find an exhibit idea - Asking other students to support them in finding an exhibit idea - Suggesting to develop a poster - Directing them to make an Internet search - Telling that they can work on missing parts later on Asking students to share their progress in exhibit development through the nano school club group in a messenger app Encouraging students to ask questions each other for realizing the missing parts of their exhibits by reminding that visitors in the exhibition may ask similar questions Suggesting students to make a presentation in classes before the exhibition for encouraging them for the exhibition Reminding students that sharing their exhibits is a kind of social responsibility to motive students for the exhibition

Table 7.19. The practical approaches of teachers in the overall process of exhibit development. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN THE OVERALL PROCESS	ROLE OF THE TEACHER	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	GUIDING Trying to make students to come up with their own ideas by directing them through questions and avoiding to state their own opinions directly (SH1T1, SH2T1, SH3T1) COORDINATING Having coordinating/ organizing role in the process (SH1T1, SH2T1, SH3T1) Creating sources and opportunities (SH1T1, SH2T1) MOTIVATING Motivating and encouraging (SH1T1, SH2T1, SH3T1) SUPERVISING Answering students' questions (SH1T1, SH2T1, SH3T1) Supporting students in their struggles in the process (SH1T1, SH2T1, SH3T1) Following and checking students' progress to try to prevent any inconvenience (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	ACCOMPANYING Having an accompanying role in the process (SH3T1) GUIDING Having a more passive role compared to traditional education (SH3T1)
	ORGANIZATIONAL APPROACHES	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	GROUP FORMATION Leaving the group formation to students (SH1T1, SH2T1) Making directions about group formation in some cases (SH1T1, SH2T1) TASK SHARING Leaving task sharing to students (SH1T1, SH3T1) TIME MANAGEMENT Leaving to decide times for working on exhibits to students (SH1T1, SH3T1) Working on exhibits at the nano school club period (SH1T1, SH2T1) Suggesting students to work also at after school hours for exhibit development (SH1T1, SH2T1, SH3T1) Suggesting students to work on exhibit development at lunch breaks (SH1T1, SH2T1) Accompanying students, while they work on their exhibits in school after school hours (SH1T1, SH2T1) Guiding students in overall time management (SH1T1, SH2T1, SH3T1) WORKING PLACE Creating opportunity for students to work for exhibit development in the science laboratory of the school (SH1T1, SH2T1) FORMAL PROCEDURES Providing communication between school administration and students (SH1T1, SH2T1, SH3T1) Providing communication between the project team and students (SH1T1, SH2T1, SH3T1)

Table 7.19. The practical approaches of teachers in the overall process of exhibit development. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN THE OVERALL PROCESS	ORGANIZATIONAL APPROACHES	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	SH1T1	TIME MANAGEMENT: Taking students from some school courses to create extra time for working on exhibits (SH1T1)
							SH2T1	GROUP FORMATION: Directing students not to form groups but instead working all together (SH2T1) TASK SHARING: Making task sharing by regarding students' background, skills as well as their request (SH2T1) TIME MANAGEMENT: Determining times for working on exhibits by regarding students' free time (SH3T1) FORMAL PROCEDURES: Providing communication between the science project coordinator, technology and design teacher, and students (SH2T1)
							SH3T1	WORKING PLACE Suggesting students to work on exhibit development at home

> “I tried to relieve students (of their concerns) about selection of their products. I told them “It isn't an obligation. Our aim is sharing what we’ve learned (about NST) with visitors”” (SH1T1-Post)

On the other side, some students of SH3T1 were worried about participating in the exhibit development and therefore, she took some practical approaches for motivating students for this process. Encouraging students to try to find an exhibit idea, asking other students to support them in finding an exhibit idea, suggesting to develop a poster, which is a simpler exhibit format compared to models, directing them to make an Internet search, and emphasizing that they can improve their exhibits and work on missing parts in time once they start to develop it are the practical approaches of SH3T1 taken with this purpose. SH3T1 also have other different approaches such as asking students to share their progress in exhibit development through the nano school club group in a messenger app to make students see each other’s work and got encouraged for exhibit making, encouraging students to ask questions each other for realizing the missing parts of their exhibits by reminding that visitors in the exhibition may ask similar questions, suggesting students to make a presentation in classes before the exhibition for encouraging them for the exhibition and reminding students that sharing their exhibits is a kind of social responsibility to motive students for the exhibition. The following statement is an example for SH3T1’s different motivational practical approaches:

> “Teacher tries to motivate a student, who doesn’t want to involve in exhibit development process, for making an exhibit. Teacher suggested her to pick a nanoparticle and a property of it for finding an exhibit idea. Teacher asked all students to think an exhibit idea for her. Then, teacher suggested her to prepare a poster” (SH3O2_Textual Sum.).

<u>7.5.3.2. Role of the Teacher.</u> The second sub-theme defined under managing the overall process of exhibit development is about role of teachers, which includes both teachers’ own opinions about their roles and the researchers’ perspective depending on the school observations. The common roles, which at least two teachers had in the process, are collected under four categories, namely guiding, coordinating, motivating and supervising as seen in Table 7.19. Teachers guided students by trying to make students to come up with their own ideas by directing them through questions and avoiding to state their own opinions directly. They also had a coordinating role, which is described in detail in the following section. Besides, they also addressed their aforementioned motivating and encouraging role while describing their roles in the process. Finally, teacher described their supervising role by

referring following and checking students' progress to try to prevent any inconvenience, answering students' questions and supporting students in their struggles in the process. The following statements can be given as examples for teachers’ role in exhibit development process:

> “I tried to guide students in the process. When I saw a deficiency of an exhibit I asked them questions like “Can you add something else about it?” or “How can you make it more durable?” rather than giving directives like “This part is missing” or “Change this part”” (SH1T1-Post)

> “I was coordinator, material supplier and a supervisor. I was creating sources and opportunities, and meeting them with sources. Otherwise, I didn’t mount any part of the exhibits” (SH2T1-Post)

> “Teacher is following students’ progress in exhibit development by asking each student at which step s/he is” (SH3O1_Textaul Sum.).

Apart from the common approaches, the teacher SH3T1 described two other aspects of her role in the exhibit development process. She explained these aspects as the following:

> “I tried to reach students as a partner” (SH3T1-Post).
> “In my eyes, I was trying to be an accompanist. I didn’t want to be a director” (SH3T1-Post).

7.5.3.3. Organizational Approaches. The last sub-theme identified under the category of managing the overall process of exhibit development consists of teachers’ organizational approaches in this procedure. The organizational approaches of teachers were classified under five categories, which are group formation, task sharing, time management, working place and formal procedures. Teachers have common organizational approaches as well as different ones. Firstly, in group formation, the teacher SH2T1 directed students not to form groups but instead working all together for each exhibit, however the teachers SH1T1 and SH3T1 left it to students and just interfere in some particular cases such as bringing students, who have similar or complimentary exhibit ideas, together and separating too crowded groups. Secondly, the teacher SH2T1 made task sharing by regarding students' background, skills as well as their request, while the other teachers left task sharing to students. Thirdly, teachers guided students in time management, especially for having control on the time separated for varying phases of exhibit development. On the other hand, teachers’ guidance in this manner differ from each other’s. For instance, the teacher SH2T1 determined the times for working on exhibits by regarding students’ free times, while the other teachers left it to students. Besides, the teachers SH1T1 and SH2T1 directed students to develop their exhibits mostly in the Nano school club periods, however, SH3T1 directed students to work in their free times at the weekend mainly because the school had no particular time for school club periods. In addition, for creating extra time for students' making their exhibits, SH1T1 and SH2T1 suggested students to work after school hours and at lunch breaks. In some cases, the teacher SH1T1 took students from some school courses because of limited time. Fourthly, the teachers SH1T1 and SH2T1 created opportunities for students to work for exhibit development in the science laboratory of the school, while the SH3T1 suggested students to work at their homes. Final facet of organizational approaches is the formal procedures. Teachers provided the communication between school administration and students and also the communication between the project team and students. Apart from other two, the SH2T1 also provided the communication between the science project coordinator, technology and design teacher, and students.

The overall analysis of teachers' organizational approaches shows that the teacher SH2T1 used more initiative in group formation, task sharing and time management, while other two gave more responsibility to students in these manners. Furthermore, the analysis also reveals that teachers' organizational approaches vary depending on the facilities of the school like in the case of SH3T1, who doesn't have an official weekly school club period. It led her to organize students out of the school for exhibit development, which was a challenge for her as it is discussed in Section 7.7.1.

7.5.4. Practical Approaches of Teachers in The Exhibition

The final stage, in which the teachers' practical approaches are addressed, is the exhibition. The practical approaches in this phase base on teachers' descriptions as well as the researcher's observation as seen in Table 7.20. The first common practical approach is being available at their school's section in the exhibition area for visitors as well as for their students. The second practical approach taken by two teachers, is evaluating their own students' exhibits after seeing other students' exhibits as they described it as the following:

> "After we saw the other exhibits in the exhibition, we made comments like "We have misunderstood this" or "We could do this part like this"" (SH1T1-Post)

> "After I visited other exhibits in the exhibition, I reflected on the exhibitions. I thought like "We could do this part like this" or "This aspect of the exhibit is not very good. It could be done in another way"" (SH3T1-Post)

Table 7.20. The practical approaches of teachers in the exhibition.

Theme	Sub-theme	Type of Data Source					Participants	Practical Approaches
PRACTICAL APPROACHES IN THE EXHIBITION	-	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Evaluating their own students' exhibits after seeing other students' exhibits (SH1T1, SH3T1) Being available at their schools' section in the exhibition area for visitors as well as for their students (SH1T1, SH2T1, SH3T1)
							SH1T1	Listening other teachers' experiences in the process and trying to benefit from them (SH1T1) Encouraging students to evaluate their own exhibits after seeing other exhibits (SH1T1) - RRI integration - Interactivity - Covering the theme
							SH2T1	-
							SH3T1	Contributing to students' presentation of their exhibits in the first day of the exhibition Explaining the contribution for guiding students Letting students to have full control in their presentations in the second day of exhibition

Apart from the common practical approaches in the exhibition, the teacher SH1T1 had two different approaches. The first one is listening other teachers' experiences in the process and trying to benefit from them. The teacher SH1T1describes it as the following:

> "Apart from that, it was also nice to be with other colleagues, to see their (students') products, to listen their experiences and to compare them with ours" (SH1T1-Post).

The other one is encouraging students to evaluate their own exhibits after seeing other exhibits in terms of varying characteristics such as RRI integration and way of interaction.

Differently from the other two, the teacher SH3T1 had few additional practical approaches in the exhibition. The first two were peculiar to the first day of the exhibition and is about teacher's involvement in students' presentations, while the last one is about letting students to have full control in their presentations in the next day. Teacher SH3T1 describes this transformation in her practical approaches as the following:

> "For example, sometimes students delayed the interaction. In such cases, I interfered in their presentation. They also learned from this. I explained them why I involved in their presentation. It was the case in the first day (of the exhibition). I didn't intervene in the second day" (SH3T1-Post)

7.6. Practical Approaches of Students in the Exhibit Development and Exhibition Processes

Exploring the practical approaches of student participants in the exhibit development and exhibition processes is another scope of this study, which is examined under RQ5. For the RQ5, varying data sources were analyzed including, interviews, school observations, weekly logs and field notes. As a result of this analysis, similar to the practical approaches of teachers, students' practical approaches were classified under four categories regarding the stages in the exhibit development and exhibition processes: (i) Practical Approaches in Pre-Production Stage, (ii) Practical Approaches in Production Stage, (iii) Practical Approaches in Managing the Overall Process, and (iv) Practical Approaches in Exhibition Stage. These four stages comprise of 5 themes and 10 sub-themes, which are named accordingly with the practical approaches at a certain stage of exhibit development or at a specific task, as presented, explained and exemplified with quotations in Table 7.21.

The first category, which is "Practical Approaches in Pre-Production Stage", consists of two themes and two sub-themes: 1. *Practical Approaches in Finding an Exhibit Idea*, 2. *Practical Approaches in Planning of Exhibits* with the sub-themes 2a. Practical Approaches in Planning of Exhibit Designs and 2b. Practical Approaches in Planning of Materials. Second category is "Practical Approaches in Production Stage", which includes the third theme *Practical Approaches in Production of Exhibits* and four relating sub-themes: 3a. Practical Approaches in Making of Exhibits, 3b. Practical Approaches in Integration of RRI, 3c. Practical Approaches in Making Exhibits Interactive, and 3d. Getting Support in Production of Exhibits. The third category, which is "Practical Approaches in the Overall Process", comprises of the fourth theme, namely *Practical Approaches in Managing the Overall Process,* and two sub-themes: 4a. Role of Students and 4b. Organizational Approaches. Final category is about practical approaches in exhibition stage and it involves the fifth theme, which is Exhibition-Related Practical Approaches, and two corresponding sub-themes: 5a. Practical Approaches in Preparing for the Exhibition and 5b. Practical Approaches in The Exhibition.

The practical approaches under each theme and sub-theme are reported in the following sections examined under each of the four categories. Different practical

Table 7.21. Themes and sub-themes identified for the practical approaches of students.

	Themes and Sub-themes	Explanation	Example
PRACTICAL APPROACHES IN PRE-PRODUCTION STAGE	1. Practical Approaches in Finding an Exhibit Idea	Practical approaches of students in gathering an exhibit idea.	Trying to find an exhibit idea, which they can reflect disadvantages as well as advantages of NST (SH1, SH3) Revising the exhibit ideas based on feedbacks (SH1, SH2, SH3)
	2. Practical Approaches in Planning	Practical approaches of students in exhibit planning.	
	2a. Practical Approaches in Planning of Exhibit Designs	Practical approaches of students in planning of their exhibit designs.	Avoiding to use ready products (SH1, SH3)
	2b. Practical Approaches in Planning of Materials	Practical approaches of students in planning materials of their exhibits.	Making trial and error with alternative materials (SH1, SH2, SH3)
PRACTICAL APPROACHES IN PRODUCTION STAGE	3. Practical Approaches in Production of Exhibits	Practical approaches of students in production stage.	
	3a. Practical Approaches in Making of Exhibits	Practical approaches of students in exhibit making.	Developing a prototype of the exhibit (SH1, SH2) Benefitting from what is learned in school science lessons (SH1, SH3)
	3b. Practical Approaches in Integration of RRI	Practical approaches of students in integrating RRI in their exhibits.	Trying to prepare questions integrating RRI with respect to NST (SH1, SH2, SH3) Revising the module materials for integrating RRI (SH2, SH3)
	3c. Practical Approaches in Making Exhibits Interactive	Practical approaches of students in making their exhibit interactive.	Providing visitors an opportunity to make a change on exhibit (SH1, SH3) Providing visitors a feedback mechanism for checking correctness of their answers (SH1, SH2)

Table 7.21. Themes and sub-themes identified for the practical approaches of students. (cont.)

	Themes and Sub-themes	Explanation	Example
	3d. Getting Support in Production of Exhibits	Practical approaches of students in getting support for the production of exhibits.	Getting support for technical issues (SH1, SH2, SH3) Consulting the project team (SH1,SH2, SH3)
PRACTICAL APPROACHES IN MANAGING THE OVERALL PROCESS	4. Practical Approaches in Managing the Overall Process of Exhibit Development:	Practical approaches of students in overall process management.	
	4a. Role of Student	Practical approaches reflecting the role of students along the exhibit development.	Solving problems (SH1) Having the same contribution with other group members in all stages of the exhibit development (SH3)
	4b. Organizational Approaches	Organizational approaches of students in the exhibit development process.	Working on exhibits at lunch breaks (SH1, SH2) Doing task sharing all together in group (SH1, SH3)
PRACTICAL APPROACHES IN EXHIBITION STAGE	5. Exhibition-Related Practical Approaches	Practical approaches of students in preparation for the exhibition event and in the exhibition.	
	5a. Practical Approaches in Preparing for the Exhibition	Practical approaches of students in preparation for the exhibition presentation.	Making rehearsal for presentation (SH1, SH2, SH3) Checking the correctness of presented information about NST
	5b. Practical Approaches in the Exhibition	Practical approaches of students in the exhibition	Examining the other exhibits in the exhibition (SH1, SH2, SH3) Working on the deficiencies of the exhibit (SH1)

approaches of students are identified as well as their common practical approaches through the analysis of varying data sources aforementioned. The common and different approaches are presented in school base.

7.6.1. Practical Approaches of Students in Pre-Production Stage

7.6.1.1. Practical Approaches in Finding an Exhibit Idea. The first theme in the pre-production stage is about students' practical approaches in finding an exhibit idea. Most of the approaches are common among students, but there are also different practical approaches as seen in Table 7.22. The common practical approaches of students taken with this purpose start with revising what is learned in the field trip to the university laboratories, revising the module topics and materials, picking a nanoparticle and its specific property as an exhibit theme, thinking on simple exhibit ideas, improving the exhibit idea based on a simple idea, thinking on exhibit idea individually, then making in-group ad inter-group brainstorming and making an Internet search about nano-exhibits and different nanoparticles. After some exhibit ideas have started to emerge, the common practical approaches shown by students are making a list of exhibit ideas; choosing among them by regarding the difficulty level of practicability, limited time, possible profile of visitors, originality of the exhibit idea and visitors' learning; trying to find an exhibit idea, which they can integrate RRI and NST, which they can reflect disadvantages as well as advantages of NST and which can direct visitors to critical thinking; trying to find a catchy and interesting exhibit idea, which can raise visitors' curiosity; and merging similar ideas. Finally, the common approaches after the exhibit ideas were formed to a certain extend are consulting their teachers about the exhibit idea, giving feedback to each other's exhibit idea and revising the exhibit ideas based on feedbacks. The statements taken from varying data sources can be given as example for common practical approaches in this stage of exhibit development:

> "Two groups having similar exhibit idea have merged their ideas" (SH1O1_ FieldNote).
>
> "They revised what they learned from the module topics for finding an exhibit idea" (SH2O1_FieldNote)
>
> "They are examining the web site nisenet.org" (SH2O1_FieldNote)
>
> "We realized the missing parts of our exhibit idea with the help of the teacher and other club mates" (SH3S2-WeeklyLog#1)

Table 7.22. The practical approaches of students in the pre-production stage of exhibit development process.

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN FINDING EXHIBIT IDEA		Interviews	Observations	Weekly Logs	Field Notes	Common	IN THE BEGINNING OF EXHIBIT IDEA FINDING: Revising what is learned in the field trip to the university laboratories (SH1, SH2, SH3) Revising the module topics and materials (SH1, SH2, SH3) Picking a nanoparticle and its specific property as an exhibit theme (SH1, SH2, SH3) Starting with thinking on simple exhibit ideas (SH1, SH2, SH3) Improving the exhibit idea based on a simple idea (SH1, SH2, SH3) Starting to think on exhibit idea individually (SH1, SH3) Making in-group brainstorming (SH1, SH2, SH3) Making inter-group brainstorming (SH1, SH3) Making an Internet search (SH1, SH2, SH3) - Searching about nano-exhibits - Searching about usage area of different nanoparticles - Searching about the NST theme of the exhibit AFTER SOME EXHIBIT IDEAS STARTED TO EMERGE: Making a list of exhibit ideas (SH1, SH2) Regarding the difficulty level of practicability (SH1, SH2, SH3) Regarding limited time (SH1, SH2, SH3) Regarding possible profile of visitors (SH1, SH2) Regarding visitors' learning (SH1, SH2, SH3) Regarding the originality of the exhibit idea (SH1, SH2) Trying to find an exhibit idea, which they can integrate RRI and NST (SH1, SH3) Trying to find an exhibit idea, which they can reflect disadvantages as well as advantages of NST (SH1, SH3) Trying to find an exhibit idea, which can direct visitors to critical thinking (SH1, SH3) Trying to find a catchy and interesting exhibit idea, which can raise visitors' curiosity (SH1, SH2, SH3) Merging similar ideas (SH1, SH3) AFTER THE EXHIBIT IDEAS WERE FORMED TO A CERTAIN EXTEND: Consulting their teachers about the exhibit idea (SH1, SH2, SH3) Giving feedback to each other's exhibit idea (SH1, SH3) Revising the exhibit ideas based on feedbacks (SH1, SH2, SH3)
						SH1	Revising the key features of NST Revising current applications of NST Consulting acquaintances about the exhibit idea
						SH2	Relating what is seen on the website with the module activities and topics
						SH3	Benefitting from what is learned in school science lessons Trying to find an exhibit idea, which they can find a solution for a daily-life problem with NST Listening other school students' exhibit ideas Developing the idea given by teacher

Table 7.22. The practical approaches of students in the pre-production stage of exhibit development process. (cont.)

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN PLANNING OF EXHIBITS	PRACTICAL APPROACHES IN PLANNING EXHIBIT DESIGN	Interviews	Observations	Weekly Logs	Field Notes	Common	IN THE BEGINNING OF PLANNING EXHIBIT DESIGN: Making in-group discussions (SH1, SH2, SH3) Preferring simpler exhibit designs (SH1, SH2, SH3) Focusing on modelling a phenomenon (SH1, SH2, SH3) Regarding the practicability of the exhibit design plan (SH1, SH2, SH3) Regarding the limited time (SH1, SH2, SH3) Regarding the durability and sustainability of the exhibit's mechanism (SH1, SH2, SH3) Regarding visual aesthetics of exhibit design to be interesting (SH1, SH2, SH3) Regarding standards and scientific principles (SH1, SH2) AFTER SOME EXHIBIT DESIGN PLANS STARTED TO EMERGE: Planning a modular exhibit design (SH1, SH3) Avoiding to use ready products (SH1, SH3) Examining some examples of previous students' projects (SH1, SH2) Making an Internet search to decide exhibit mechanism (SH1, SH3) Preferring an exhibit format that they can integrate RRI (SH1, SH3) Preferring an exhibit format that reinforce visitors' learning (SH1, SH2, SH3) Including interactive elements in exhibits (SH1, SH2, SH3) Paying attention to reflect the NST theme of exhibit good (SH1, SH3) Trying to make exhibit independent of the exhibit owner and doesn't need control of him/her (SH1, SH2) GIVING THE FINAL FORM OF THE EXHIBIT DESIGN PLAN: Explaining the exhibit design ideas others by drawing it on board (SH1, SH2, SH3) Consulting the teachers about the exhibit design plan (SH1, SH2, SH3) Consulting the project team about the exhibit design plan (SH1, SH2, SH3) Giving feedback for other's exhibit design plans and taking feedback from them for own design plan (SH1, SH3) Revising the exhibit design plans based on feedbacks of other groups, teachers and the project team (SH1, SH2, SH3) Revising the exhibit design plans based on materials available (SH1, SH3) Developing prototypes for testing some parts of exhibit design (SH1, SH2) Revising the exhibit design plan based on how prototype functions (SH1, SH2) Determining the deficiencies of the exhibit design plans and revising it accordingly (SH1, SH2, SH3)
						SH1	Revising the exhibits seen in the science center and regarding the exhibit design's suitability for a science center Regarding the competencies and skills of group members and the cost of the exhibit design Making multiple exhibit design plans for the same idea and then choosing one among them
						SH2	Preferring to design models that can move itself Consulting SPC, and Technology and Design teacher about exhibit design plan Inspiring from the web 2.0 tools used in the module activities
						SH3	Inspiring from a game seen in a TV show Consulting acquaintances about the exhibit design plan

Table 7.22. The practical approaches of students in the pre-production stage of exhibit development process. (cont.)

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN PLANNING OF EXHIBITS	PRACTICAL APPROACHES IN PLANNING MATERIALS	Interviews	Observations	Weekly Logs	Field Notes	Common	Making in-group discussions (SH1, SH2, SH3) Regarding the ease of accessibility to materials (SH1, SH2, SH3) Determining materials under guidance of teachers (SH1, SH2, SH3) Consulting technical staff or science project coordinator in school (SH1, SH2) Planning to benefit from electronic components such as LED lights and circuit components (SH1, SH2) Planning to use basic stationary materials such as glue, cardboard and scissors (SH1, SH2, SH3) Planning to use laboratory materials such as magnets, beakers, iron beads and droppers (SH1, SH2, SH3) Planning to benefit from daily life materials such as ping pong ball and comb (SH1, SH3) Making trial and error with alternative materials (SH1, SH2, SH3) Revising material list after testing alternative materials (SH1, SH2, SH3) Supplying materials from varying stores (SH1, SH3) Getting help from teacher for material supply (SH2, SH3) Giving others suggestions for materials and taking material suggestions from them (SH1, SH3)
						SH1	Making an Internet search for alternative materials and their properties Helping each other for material supply
						SH2	Planning to benefit from 3d-printer Guiding other school club mates and teacher about electronic materials - Introducing materials - Introducing functions of materials
						SH3	Getting support from family members for material supply Consulting a carpenter

> "I thought this idea very fast. So, I really need your opinions to improve my idea" (SH1S4 in SH1O1).

> "I listened the all groups' exhibit idea and thought on what can be done to improve these ideas" (SH1S2-WeeklyLog#1).

Differently from the common practical approaches, there are some approaches identified only in the first school. These practical approaches are revising the key features of NST and current applications of NST and consulting acquaintances about the exhibit idea. The following statement can be given as example:

> "The exhibit idea came from the size and scale concept, which is the basic and not very well known feature of NST. We wanted to integrate it in our exhibits" (SH1S1-Post).

On the other side, the practical approach in gathering an exhibit idea determined as specific to the second school is relating what is seen on the website with the module activities and topics. The statement from a school observation can be given as example of this approach:

> "They started to watch a video called "Nano Food. It demonstrates an activity about Size and Scale concept (Increasing surface area). Students made connections with this and "The effect of surface area on the absorption or release of medicine" activity in the module" (SH2O1_Textual Sum.)

Finally, the practical approaches of students identified only in the third school (SH3) in finding an exhibit idea are benefitting from what is learned in school science lessons, trying to find an exhibit idea, which they can find a solution for a daily-life problem with NST, listening other school students' exhibit ideas and developing the idea given by teacher. The following statements can be given as examples:

> "We were covering the cancer cells in the biology lessons, while we began to exhibit development process. Besides me and my group friend are planning to study genetic engineering in the future" (SH3S2-Post).

> "I had dandruff problem in my hair when I was in the middle school. Then, I thought that there are shampoos for it, but can't we solve the problem with another personal care product such as comb. That was my inspiration" (SH3S4-Post).

<u>7.6.1.2. Practical Approaches in Planning of Exhibits.</u> The second theme in the pre-production stage of exhibit development is about students' practical approaches in planning of their exhibit, which were analyzed and classified under two sub-themes including planning of exhibit designs and planning materials. Most of the practical approaches

identified under this theme are common among students, but students in each school have different approaches as well.

The common practical approaches shown in planning the exhibit design by students from at least two different schools start with making in-group discussions, preferring simpler exhibit designs, focusing on modelling a phenomenon; regarding the practicability of the exhibit design plan, limited time, durability and sustainability of the exhibit's mechanism, visual aesthetics of exhibit design to be interesting, and standards and scientific principle. The practical approaches shown after the exhibit design plans have been started to emerge are planning a modular exhibit design, avoiding to use ready products, examining some examples of previous students' projects, making an Internet search to decide exhibit mechanism, preferring an exhibit format that students can integrate RRI and reinforce visitors' learning, including interactive elements in exhibits, paying attention to reflect the NST theme of exhibit good, and trying to make exhibit independent of the exhibit owner so that it doesn't need control of him/her. The common approaches taken for giving the final form of the exhibit design plan are explaining the exhibit design ideas others by drawing it on board, consulting the teachers and the project team about the exhibit design plan; giving feedback for other's exhibit design plans and taking feedback from them for own design plan; developing prototypes for testing some parts of exhibit design, revising the exhibit design plans based on feedbacks of other groups, teachers and the project team, materials available, how prototype functions and the deficiencies identified. The statements below from varying data sources can be given as example:

> “I will need to change the water in beaker for each visitor” (SH3S4 in SH3O2_Textual Sum.).
>
> “After the project team’s feedback, the group SH1G1 decided to make beads more invisible and increase the size difference between beads” (SH1O4_Textual Sum.)
>
> “First, we thought how we can transform the exhibit idea into an interesting and interactive exhibit (SH2S1-Post)

Differently from the practical approaches of students in SH2 and SH3, the approaches identified in the SH1 in planning of exhibit designs are revising the exhibits seen in the science center, regarding the exhibit design's suitability for a science center, regarding the competencies and skills of group members, regarding the cost of the exhibit design, and making multiple exhibit design plans for the same idea and then choosing one among them. The following statements can be given as example of SH1 students' different practical approaches in this manner:

> "We produced few alternative exhibit design ideas. We will choose one of them and follow it to make the required changes" (A student in SH1G2-WeeklyLog#1)

> "There was a spinning tornado simulation in ITU Science Center. I wanted our exhibit (mechanism) to be similar to that exhibits'" (SH1S1-Post).

Apart from the common approaches, three practical approaches were identified in SH2, which are preferring to design models that can move itself, inspiring from the web 2.0 tools used in the module activities, and consulting SPC, and Technology and Design teacher about exhibit design plan. The statements below can be given as example:

> "We consulted SPC for the mechatronics parts of our exhibits and brainstormed on it" (SH2S1-WeeklyLog#2).

> "A student suggested to prepare the quiz exhibit with "Kahoot". SH2S1 suggests to use "Quiz-Up"" (SH2O1_Textual Sum.).

Finally, the different practical approaches determined in SH3 are inspiring from a game seen in a TV show and consulting acquaintances about the exhibit design plan. Following statement from an interview can be given as example:

> "I was watching a competition programme. Then, I saw the labyrinth (game) and decided to do my exhibit like that" (SH3S1-Post).

Another category of students' practical approaches in the stage of planning exhibits is the approaches in planning of materials. Likewise, in the planning of exhibit designs, most of the practical approaches in this phase are common, but there are few different approaches identified in each school as well as seen in Table 7.22. The common approaches shown in the beginning of material planning are making in-group discussions, regarding the ease of accessibility to materials, determining materials under guidance of teachers, consulting technical staff or SPC in school, planning to benefit from electronic components such as LED lights and circuit components, planning to use basic stationary materials such as glue, cardboard and scissors, planning to use laboratory materials such as magnets, beakers, iron beads and droppers and planning to benefit from daily life materials such as ping pong ball and comb. After determining the materials to some degree, the common practical approaches taken are making trial and error with alternative materials, revising material list after testing alternative materials and giving others suggestions for materials and taking material suggestions from them. Finally, the common approaches after determination of materials to a large extend are supplying materials from varying stores and getting help from teacher for material supply. The following statement from varying data sources can be given as example of students' some common practical approaches in this stage:

> "You can represent vascular system with a transparent hose. You can simulate blood stream by using a syringe. Then, there can be vascular occlusion where the hose narrows down" (SH1S4 in SH1O1_Textual Sum.).
>
> "Firstly, we tried to build 3d-models with a Styrofoam. We tried to shape Styrofoam by using acetone. However, because we had put too much acetone, we couldn't control it" (SH2S2-Post)
>
> "After showing their exhibit design plan, SH3S2 and SH3S5 took material suggestion from the teacher" (SH3O2_FieldNote).

On the other side, there are two additional practical approaches shown by each school in the planning of materials. The different approaches in the SH1 are making an Internet search for alternative materials and their properties, and helping each other for material supply. The following statement of SH1S2 can be given as example:

> "We have gone through a long process of searching about which materials can provide better visuality and which materials can increase the effectiveness of our presentation" (SH1S2-Post).

The practical approaches identified only in SH2 are planning to benefit from 3d-printer and guiding other school club mates and the teacher about electronic materials by introducing materials and their functions. The following practical approach of SH2S1, who has background in electronics, can be given as example:

> "SPC introduced some electronic components like power supply and small motor torque. The teacher and students examined them. A student asked what they can do with it by pointing out small motor torque. SH2S1 replied as "We can use it to create motion (bacteria robots). Then, the student told they don't want them just turn around. Then, SH2S1 answered "You don't have to use it just for spinning. You can attach gear wheels and transfer that motion into something else" (SH2O2_Textual Sum.).

Finally, the additional practical approaches in the SH3 in planning materials are getting support from family members for material supply and consulting a carpenter about materials. The following statement can be given as example:

> "My group friend's father helped us to supply the beakers we need. But, I broke them by mistake. Then, my father helped us in finding new beakers. I really appreciate their support in that stage" (SH3S4-Post).

The overall analysis of students' practical approaches in the pre-production stage reveals that students mostly shown common approaches as well as few different ones, which were classified under two themes, namely *Practical Approaches in Finding an Exhibit Idea* and *Practical Approaches in Planning of Exhibits.* A reason behind the differences in students' practical approaches in this manner might be the differences in guidance of teachers in this stage. The following practical approach of the SH1T1 and the parallel approaches of students in SH1 in planning of exhibit design can be given as example:

> "Design your exhibits in a way that visitors can infer that the one with nanotechnology has dirt-proof property. You may not stand next your exhibit all the time. For instance, although there wasn't any presenter for each exhibit in the ITU Science Center, we were able to figure it out by ourselves" (SH1T1 in SH1O1-Textual Sum.).
>
> "First, we thought to use an application, but then, we gave up this idea because it might not be suitable for ITU Science Center" (SH1S5 in SH1O1_FieldNote).

The second reason behind the differences in practical approaches in pre-production stage might be the differences in the facilities and opportunities provided by the school. For example, as seen in Table 7.22., the students of the SH2, which is a private school planned to use 3-d printer in building of bacteria models because they have such opportunity and a teacher that can support them in this process. On the other hand, the school SH3's students, who have not such in-school opportunities, for instance, consulted people from out of school like carpenter or acquaintances for exhibit design and materials.

Another factor creating differences in approaches taken by students might be the students' backgrounds and pre-experiences in developing exhibits and projects for science fairs or a similar organization. For instance, the SH2S1, who had developed science projects before for multiple science project contests and have a background in electronics were able to guide his teacher and other students in benefitting from electronic components that were planned to use in their exhibits, while they were planning materials.

7.6.2. Practical Approaches of Students in Production Stage

7.6.2.1. Practical Approaches in Making Exhibits. The first sub-theme identified for students in the production stage is about their practical approaches in making their exhibits based on the planned exhibit design. It consists of two categories, which are building exhibit and preparing NST questions as seen in Table 7.23. The common practical approaches taken by students in building exhibits are developing a prototype of the exhibit, benefitting from what is learned in school science lessons for building exhibits, keeping following the other group members' progress in making exhibits for providing the integrity of the exhibits, getting feedback from other groups and the project team for improving the exhibits in progress and revising the exhibits through the feedbacks of other groups and the project team. The following statements can be given as example of students' common practical approaches in this direction:

> "We were learning about the electric circuits in the Physics lessons in school. We benefitted from them while working on some parts like resistance" (SH1S3-Post).
>
> "Everybody prepared a prototype of their exhibits" (SH1S2-Post).
>
> "We presented our exhibit to our school club mates with pictures. Then, we improved it with the contribution of their ideas" (SH3S5-Post).
>
> "They tried different tools and methods to dig hole on bacteria model. SH2S2 used pin and it worked" (SH2O6_Textual Sum.).

The students of the SH2 and SH3 showed additional practical approaches in the phase of building exhibits. For instance, the SH2 students discussed every aspects of the exhibits all together and had consensus on the next step before making a progress in exhibits. This situation stems from the differences in their organizational approaches, specifically the ones about not forming groups as it is discussed in Section 7.6.3.2. On the other side, differently from other school students, the SH3 students shared the pictures of exhibits in progress with other school club mates and the teacher through a messenger application and after completing their exhibit they brought them in school for getting feedback from others. Similar to the reason in the SH2, these different approaches of the SH3 students base on the differences in organizational approaches, specifically the ones about working place and time management.

Table 7.23. The practical approaches of students in the production stage of exhibit development process.

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN PRODUCTION OF EXHIBITS	PRACTICAL APPROACHES IN MAKING EXHIBITS	Interviews	Observations	Weekly Logs	Field Notes	Common	BUILDING EXHIBIT: Developing a prototype of the exhibit (SH1, SH2) Benefitting from what is learned in school science lessons (SH1, SH3) Getting feedback from other groups for improving the exhibits in progress (SH1,SH3) Getting feedback from the project team (SH1, SH2, SH3) Revising the exhibits through the feedbacks of other groups (SH1, SH3) Revising the exhibits depending on the feedback of the project team (SH1, SH2, SH3) To keep following the other group members' progress in making exhibits for providing the integrity of the exhibits (SH1, SH2, SH3) PREPARING NST QUESTIONS: Revising module for preparing questions about NST theme of the exhibit (SH1, SH2, SH3) Learning more about the NST theme of the exhibit: (SH1, SH2, SH3) - Internet search - Module materials Consulting teacher about the questions (SH1, SH2, SH3) Revising questions through the feedback of the project team (SH1, SH2, SH3)
						SH1	-
						SH2	Discussing every aspects of the exhibits all together and having consensus on the next step before making a progress in exhibits Preparing basic questions about NST so that visitors can make comment or make a guess
						SH3	Sharing the pictures of exhibits in progress with other school club mates and the teacher through a messenger application Bringing the exhibits in progress in school for getting feedback from others
	PRACTICAL APPROACHES IN INTEGRATION OF RRI	Interviews	Observations	Weekly Logs	Field Notes	Common	Focusing on integration of RRI after making the exhibits (SH1, SH2, SH3) Integrating RRI through questions with questionnaire or knowledge test (SH1, SH2, SH3) Preparing Likert type questions for assessing visitors' opinions on RRI (SH1, SH2, SH3) Integrating RRI through matching game (SH1, SH2, SH3) Keeping statistics of visitors' answers (SH1, SH3) Trying to prepare questions integrating RRI with respect to NST (SH1, SH2, SH3) Just giving conceptual explanation of each RRI dimension without relating it with NST (SH1, SH2, SH3) Revising the module materials for integrating RRI (SH2, SH3) Making an Internet search about RRI (SH1, SH2, SH3) Examining the extra materials offered by the teacher (SH2, SH3) Integrating all dimensions of RRI (SH1, SH2, SH3) Integrating some dimensions of RRI (SH1, SH2, SH3) Giving feedback each other about integration of RRI (SH1, SH3) Taking suggestions from the project team about RRI integration (SH1, SH2, SH3) Revising questions through the feedback of the project team (SH1, SH2, SH3)

Table 7.23. The practical approaches of students in the production stage of exhibit development process. (cont.)

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN PRODUCTION OF EXHIBITS	PRACTICAL APPROACHES IN INTEGRATION OF RRI	Interviews	Observations	Weekly Logs	Field Notes	SH1	Trying to keep it simple for understanding of visitors from varying ages
						SH2	-
						SH3	Reading the article, which teacher shared, aloud all together for learning and discussing more about RRI
	PRACTICAL APPROACHES IN MAKING EXHIBITS INTERACTIVE	Interviews	Observations	Weekly Logs	Field Notes	Common	Making discussions for possible ways of making exhibits interactive (SH1, SH2, SH3) Providing interactivity with integration of RRI in an interactive way (SH1, SH2, SH3) Preparing an exhibit format providing visitors an opportunity to experience to involve in exhibits by letting them to work on it (SH1, SH2, SH3) Preparing an exhibit format which lets visitors to touch the exhibit (SH1, SH2, SH3) Preparing an exhibit format providing visitors self-assessment of their knowledge like questionnaire or knowledge test (SH1, SH2, SH3) Preparing a game (SH1, SH2, SH3) Planning to have a conversation with visitors (SH1, SH2, SH3) Planning to let visitors to ask their questions (SH1, SH2, SH3) Trying to prepare an exhibit format aiming to direct visitors to critical thinking (SH1, SH3) Preparing an exhibit format providing visitors an opportunity to see the results of their actions on the exhibit (SH1, SH3) Preparing an exhibit format providing visitors an opportunity to make a change on exhibit (SH1, SH3) Preparing an exhibit format providing visitors a feedback mechanism for checking correctness of their answers (SH1, SH2) Planning to share statistics of the visitors' answers in the first day of exhibition with the visitors coming in the second day of exhibition (SH1, SH3)
						SH1	Sharing experiences about interactive exhibits Discussing the advantages and disadvantages of the interactive exhibits Addressing the interactivity of the exhibits seen in the field trip to the science center
						SH2	-
						SH3	-

Table 7.23. The practical approaches of students in the production stage of exhibit development process. (cont.)

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN PRODUCTION OF EXHIBITS	GETTING SUPPORT IN PRODUCTION OF EXHIBITS	Interviews	Observations	Weekly Logs	Field Notes	Common	GETTING SUPPORT FOR: Getting support for technical issues (SH1, SH2, SH3) Getting motivational support (SH1, SH2, SH3) Getting support for integration of RRI (SH1, SH2, SH3) GETTING SUPPORT FROM: Getting support from other nano school club mates (SH1, SH3) Getting support of students from other school clubs (SH1, SH2) Consulting other teachers in school (SH1, SH2) Consulting the project team (SH1,SH2, SH3) Consulting the teacher (SH1, SH2, SH3)
						SH1	Getting support from technical staff in the school
						SH2	Consulting science project coordinator Consulting Technology and design teacher
						SH3	Getting support from a carpenter Getting support from family members

Many of the exhibits prepared by students includes questions about NST as seen in Section 7.2. Students took varying practical approaches for writing these questions. The common practical approaches of students in this manner are revising module for preparing questions about NST theme of the exhibit, learning more about the NST theme of the exhibit through an Internet search and examining module materials, consulting teacher about the questions and revising questions through the feedback of the project team. The statements below can be example for some of these approaches:

> "The quiz questions were prepared by focusing on the antibacterial effect of silver nanoparticles" (SH2S1-Post).

> "Our teachers posed us some questions. I adapted these questions in my exhibit" (SH3S1-Post).

> "SH2S2 asked the teacher if he can write a true-false question like "Nanoparticles are bigger than bacteria in size. Is it true or false?"" (SH2O3_FieldNote).

> "The project team gave some suggestions for format of questions or their answers for the knowledge test developed by the group SH1G2" (SH1_The Project Team's School Visit).

> "Teacher asked students how they can arrange their exhibits in parallel with feedbacks the project team gave them. The SH1G2 students mentioned about revising questions of knowledge test" (SH1O4_Textual Sum.).

Differently from the common practical approaches, the approach identified in the SH2 in preparing NST questions is preparing basic questions about NST so that visitors can make comment or make a guess on it. SH2S2 explains this approach as the following:

> "We generally tried to prepare simple questions that can everybody has an opinion on it or can think on it rather than writing specific questions" (SH2S2-Post).

7.6.2.2. Practical Approaches in Integration of RRI. The integration of RRI was one of the facet asked from students to regard while developing their exhibits. Students mostly took common practical approaches with this purpose, but two additional approaches in total were identified in the SH1 and SH3 as seen in Table 7.23. First of all, most of the students focused on the integration of RRI after making the exhibits, which is parallel to practical approach of teachers. The students' common practical approaches in choosing a format for integrating RRI are integrating RRI through questions with questionnaire or knowledge test, preparing Likert type questions for assessing visitors' opinions on RRI, integrating RRI through (card) matching games, keeping statistics of visitors' answers or just giving conceptual explanation of each RRI dimension without relating it with NST or trying to prepare questions integrating RRI with respect to NST. After deciding the format, the common approaches taken for writing RRI questions are revising the module materials for integrating RRI, making an Internet search about RRI and examining the extra materials offered by the teacher. On the other side some students integrated all dimensions of RRI while some others integrated some dimensions of RRI. Finally, after forming questions students gave feedback to each other about integration of RRI, took suggestions from the project team and then revised questions through the feedback of the project team. The statements taken from varying data sources can be given as example of students' common practical approaches in integration of RRI:

> "After we completed the exhibit making, we are asked how the RRI is integrated. Then, we decided to integrate it through a game and a questionnaire" (SH1S1-Post).

> "We prepared questions for teaching it (RRI). They were about both nanotechnology and RRI. We developed questions by combining them" (SH1S3-Post).

> "After listening the project team's suggestions SH2S2 and another student suggested that there can be names of RRI dimensions on the balloons and visitors can match the balloons with the statements written on the corners or some spots" (SH2_The Project Team's School Visit).

> "SH3S5 and SH3S6 suggest SH3S1 to do multiple target destination that ping pong ball reaches so that each destination can represent a different RRI dimension" (SH3O3_Textual Sum.)

> "SH3S6 realized that he couldn't find much on the Internet when he made search as RRI. Then, he found it (information about RRI) in the official website of the project" (SH3T1-Post).

Apart from the common practical approaches, students in SH1 and SH3 taken an additional approach for RRI integration. Students in the SH1 focused on trying to keep it simple for understanding of visitors from varying ages. SH1S1 explains this approach as follows:

> "We tried to keep it simple because we wanted to introduce nanoscience and Responsible Research and Innovation (RRI) to every segment of the society and people of all ages from children to adults" (SH1S1-Post).

On the other side, the SH3 students read the article, which teacher shared, aloud all together for learning and discussing more about RRI in one of the nano school club period. The statement below exemplifies this approach:

> "Teacher said that she found when she searched on the Internet about RRI and she printed it to show it as an example. They started to reading it. Each part was read by a different student" (SH3O5_Textual Sum.).

The overall analysis of student's practical approaches in RRI integration reveals that the approaches taken by students are mostly in common and there are only two additional approaches in total from two different schools. The reason behind the substantial commonality in practical approaches taken in integration of RRI. might be the fact that it was a new concept for students and they mostly followed the guidance of their teachers, whom practical approaches are also mostly common in this stage, rather than taking initiative for showing original practical approaches with this purpose (Please see Section 7.5.2.2. for teachers' practical approaches in integration of RRI).

7.6.2.3. Practical Approaches in Making Exhibits Interactive. Making exhibits interactive was another aspect, which was asked from students to consider in the exhibit development. As a result of the analysis of the practical approaches shown by students in this manner, mostly common approaches are identified as seen in Table 7.23. These common practical approaches of students for making exhibits interactive are making discussions for possible ways of making exhibits interactive, providing interactivity with integration of RRI in an interactive way, preparing an exhibit format providing visitors an opportunity to experience to involve in exhibits by letting them to work on it and touch it, preparing an exhibit format providing visitors self-assessment of their knowledge like questionnaire or knowledge test and providing them a feedback mechanism for checking correctness of their answers, preparing a game, trying to prepare an exhibit format aiming to direct visitors to critical thinking, preparing an exhibit format providing visitors an opportunity to make a change on exhibit and see the results of their actions on the exhibit, planning to have a conversation with visitors and to let them asking their questions, and planning to share statistics of the visitors' answers in the first day of exhibition with the visitors coming in the second day of exhibition. The following statements taken from varying data sources can be given as examples:

> "Visitors should be able to experience the exhibits. For example, visitors were simply sending ball in our exhibits" (SH1S2-Post).
>
> "We provided interactivity with the questions in the knowledge test. When they gave a wrong answer they learned about the correct one" (SH1S4-Post)
>
> "The interactivity was not at the forefront in the 3-d model exhibit. We provided interactivity with matching of RRI dimensions by visitors" (SH2S1-Post)

> "Visitors were using the droppers and answering the questionnaire questions as "yes", "no" or "I don't know". They were putting popsicle sticks in a beaker (for stating their opinions)" (SH3S4-post).

> "I asked visitors to choose an RRI dimension. After they chose one of the RRI aspects, they were turning the wheel. These were the interactions" (SH3S6-Post).

> "A student gives SH1S4 suggestions as "You can use Q-A as I said before. This can be very informative. People learn better when they see their mistakes as an example"" (SH1O1_Textual Sum.) .

Differently from the students in other schools, the SH1 students shown three additional practical approaches about making of their exhibits interactive. Firstly, they shared their experiences about interactive exhibits or exhibitions, secondly, they discussed the advantages and disadvantages of the interactive exhibits and finally, they addressed the interactivity of the exhibits seen in the field trip to the science center. The following statement can be given as example:

> "A student mentions about her experience in British Science Museum; she says it was a huge exhibition and there were many interactive exhibits" (SH1O1_Textual Sum.).

> "SH1S4 tells he had never gone to an interactive exhibition before their visit in the ITU Science Center. The teacher asked what he was expecting an interactive exhibit to be by just inferring from its name. SH1S4 replies as "While the owner of exhibit informs the visitor, somehow, visitor can also involve in this process"" (SH1O1_Textual Sum.).

The analysis of students' practical approaches in making their exhibits interactive shows that the approaches taken by students are mostly in common. Nevertheless, the students in SH1 took few different approaches as well as the common ones. The parallelism in the different practical approaches of SH1 students and SH1T1 in the stage of making exhibits interactive might be the indicator of the fact that the difference among the students' practical approaches stems from following the guidance of teacher, especially in new experiences like in the case of RRI integration.

<u>7.6.2.4. Getting Support in Production of Exhibits.</u> The final sub-theme identified in the analysis of students' practical approaches in the stage of production of exhibits is about for what and from who the students got support in this phase. The common aspects that students got support for are technical issues, integration of RRI and motivation in the process. Students got support from other nano school club mates, students from other school clubs, other teachers in school, the project team and the teacher of the nano school club.

Besides the commonalities in practical approaches for getting support, there are also differences in the practical approaches of students in school base. For example, the SH1 students got support from the technical staff in the school, the SH2 students got support from the SPC, and Technology and Design teacher in the school, while the SH3 students got support from people out of school such as carpenter and family members in the production of exhibits.

The following statements taken from varying data sources can be given as examples for how students got support in the production of their exhibits:

> "We got help from the SPC for the motors and electric circuits of the exhibits. Besides, we got support from a middle school teacher. He introduced us the 3-d printer programming" (SH2S2-Post).
>
> "The group SH3G3 showed pictures of the materials of their exhibit. They said their materials were given to carpenter for assembly of exhibit mechanism" (SH3O3_Textual Sum.).
>
> "I had difficulty in preparing questions integrating RRI and NST. I got support from the teacher" (SH3S1-Post)
>
> "Some groups took support from other school clubs. For example, students (in the group SH1G1) got help about using adhesive in the water treatment model" (SH1S4-Post).

The overall analysis of students' practical approaches in the production stage generated four sub-themes, which are about practical approaches in making exhibits, integrating RRI, making exhibits interactive and getting support in this stage. The majority of the practical approaches taken by students with these intentions were common, but there were also several approaches, which are specific to students of certain schools in the study. The commonalities and differences in practical approaches of students depend on many factors such as students' pre-experiences, familiarity of the task, following the guidance of teacher, the organizational approaches and schools' facilities.

7.6.3. Some Practical Approaches of Students in The Overall Process of Exhibit Development

<u>7.6.3.1. Role of Students.</u> The first sub-theme under managing the overall process of exhibit development is about roles of students described by students themselves as well as the researchers' inferences depending on observations. The common roles of students from the

three schools in this study are finding an exhibit idea, making the exhibit, demonstrating the exhibit to the project team and presenting the exhibit in exhibition as seen in Table 7.24. The common roles of students from the SH1 and SH3 are supplying materials and contributing other groups' exhibits. The following statements can be given as examples of students' common roles in the overall process of exhibit development:

> "I contributed in the production and development of the exhibit idea. When we needed materials, I bought and prepared them together with few (group) friends. I also contributed in making of the exhibit" (SH1S3-Post).

> "I mostly contributed in preparing questions for the nanoquiz. Besides, I helped in use of 3-d printer and doing the electric circuit, while developing the bacteria model" (SH2S2-Post).

There are also some roles, which are specified only in a certain school. For example, the roles described by only the SH1 students are leading and organizing others in group, and solving problems faced in exhibit development. The statements below can be given as example:

> "I had the leading role and worked a lot. I think my contribution was mostly in transformation of the exhibit idea into real model" (SH1S4-Post).

On the other side the roles described only by the school SH3 are working individually in exhibit development and having the same role with other group members in all stages of the exhibit development. The following statements are few examples:

> "Both of us had the same roles. I can't tell that there was a difference in our contribution at any task. We were in communication all the time and taking decisions together" (SH3S2-Post).

The differences in the roles of students might be stemming from the varying practical approaches of teachers and varying organizational approaches of students. For example, the SH2 students do not have a role in supplying materials because the teacher took the responsibility of buying materials needed and they also used school sources for material supply. In addition, none of the students in SH2 led or organized other students in the nano school club in exhibit development because they didn't form groups and followed the guidance of the teacher from beginning to the end of the process.

Table 7.24. The practical approaches of students in the overall process of exhibit development.

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN THE OVERALL PROCESS	ROLE OF STUDENTS	Interviews	Observations	Weekly Logs	Field Notes	Common	Finding an exhibit idea (SH1, SH2, SH3) Supplying materials (SH1, SH3) Making the exhibit (SH1, SH2, SH3) Contributing others' exhibit (SH1, SH3) Demonstrating the exhibit to the project team (SH1, SH2, SH3) Presenting the exhibit in exhibition (SH1, SH2, SH3)
						SH1	Leading and organizing others in group Solving problems
						SH2	-
						SH3	Working individually in exhibit development Having the same role with other group members in all stages of the exhibit development
	ORGANIZATIONAL APPROACHES	Interviews	Observations	Weekly Logs	Field Notes	Common	GROUP FORMATION Dynamic form of group formation (SH1, SH3) Coming together with other students having similar exhibit idea (SH1, SH3) Leaving the group for forming a new group and developing another exhibit (SH1, SH3) Leaving the group because of not having a consensus on exhibit idea (SH1, SH3) Giving up from own exhibit idea and joining another group (SH1, SH3) TASK SHARING Regarding the contribution of each group member (SH1, SH2, SH3) Doing task sharing all together in group (SH1, SH3) Regarding the knowledge and skills in task sharing (SH1, SH2, SH3) Forming sub-groups for working on different parts of the exhibits (SH1, SH2) Team work (SH1, SH2, SH3) TIME MANAGEMENT Paying attention to fulfilment of tasks on time (SH1, SH2) Preparing a work plan for exhibit development and following it (SH1, SH3) Working on exhibits at lunch breaks (SH1, SH2) Working on exhibits after school hours (in school) (SH1, SH2) Working on exhibits at weekend (SH1, SH3) WORKING PLACE Working at the chemistry laboratory of the school for working on exhibits (SH1, SH2)

Table 7.24. The practical approaches of students in the overall process of exhibit development. (cont.)

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
PRACTICAL APPROACHES IN THE OVERALL PROCESS	ORGANIZATIONAL APPROACHES	Interviews	Observations	Weekly Logs	Field Notes	SH1	GROUP FORMATION: Leaving the group for supporting another group TASK SHARING: Leading of one of the group members in task sharing TIME MANAGEMENT: Working on exhibits at the period of some school lessons Working on exhibits at exam weeks Working on exhibits at the period of extra-curricular activities such as organizations like conferences
						SH2	GROUP FORMATION: Not forming groups, but working on each exhibit all together TASK SHARING: Guidance of the teacher in task sharing WORKING PLACE: Working with 3-d printer at the Technology and Design Laboratory of the school
						SH3	GROUP FORMATION: Deciding to work individually because of not having a common time for working on exhibit Deciding to form a group rather than working individually for finding a better exhibit idea WORKING PLACE: Working at home for exhibit development

<u>7.6.3.2. Organizational Approaches.</u> The second sub-theme under the managing the overall process of exhibit development is about the organizational approaches of students taken in the exhibit development process. Students' organizational approaches were classified under four categories, which are group formation, task sharing, time management and working place. Students have common organizational approaches as well as few different ones. Firstly, for the group formation, students of the SH1 and SH3 took initiative in forming groups and there was an active and dynamic form of group formation, where students were open to change their groups throughout the process unlike the SH2 students, who did not form groups by following their teacher's guidance. The dynamism in group formation in the two schools derives from few circumstances such as coming together with other students having similar exhibit idea, leaving the group for forming a new group and developing another exhibit, leaving the group because of not having a consensus on exhibit idea, and giving up from own exhibit idea and joining another group. The following approach of SH1S2 and SH1S3 can be given as example:

> "— We decided to merge groups because we had thought a similar exhibit idea together before (SH1S2)
> — We were told that the distance between cancer cells are larger compared to distance between healthy cells and they were covering the medicine with polymers so it is attached to cancer cells. We think, we can develop an exhibit modelling this (phenomenon) (SH1S2)
> — We can show the localization of medicine (to target area) or how NPs can be used in the treatment of the disease (SH1S3)" (SH1O1_Textual Sum).

Another motive for changing group, which only identified in the SH1, is leaving the group for supporting another group like in the case of SH1S4's:

> "I gave up developing my exhibit idea and helped another group in making their exhibit. They had an exhibit idea, but they didn't know how to do it. They asked help from me in making it. Then, we formed a group and worked together" (SH1S4-Post).

On the other hand, the other reasons for changing idea in group formation in the SH3 are deciding to work individually because of not having a common time with group friend for working on exhibit like in the case of SH3S1 and SH3S6, and deciding to form a group rather than working individually for finding a better exhibit idea like in the case of SH3S3 and SH3S4.

Secondly, in task sharing, the students of SH1 and SH3 had full control over it, while the SH2 students was guided by the teacher. The common practical approaches taken by students from at least two different schools in task sharing are regarding the contribution of each group member and team work, doing task sharing all together in group, regarding the knowledge and skills of each group member and forming sub-groups for working on different parts of the exhibits. The following statement can be given as example for practical approaches of students in task sharing:

> “A student suggests to divide students into groups focusing on different part of exhibits or different exhibits because it seems not possible to set a time that they can all work together other than the nano school club hours” (SH2O2_Textual Sum.).

Thirdly, students took common and varying approaches in time management during the exhibit development process. For example, SH2 students worked on their exhibits at lunch breaks and after school hours in school, and SH3 students worked at the weekend, while the SH1 students worked at all of these time periods and worked additionally at the period of some school lessons, at exam weeks and at the period of some extra-curricular activities such as organizations like conferences. In addition, SH1 and SH3 students prepared a work plan including time schedule, while the SH2 students followed the teacher’s guidance for time management. On the other hand, students of the SH1 and SH2 were self-motivated for fulfilment of tasks on time, while the SH3 students needed to be motivated for paying attention for doing tasks on time.

Final category of the organizational approaches of students is the working place, which shows similarity in the case of teachers’ organizational approaches such that the SH1 and SH2 students worked in the chemistry laboratory in the school, while the students of the SH3 worked at their homes for making their exhibits. On the other hand, SH2 students worked with the 3-d printer in the production stage at the Technology and Design Laboratory of the school.

The overall analysis of students organizational approaches reveals that their approaches in group formation, task sharing, time management and deciding working place show similarities and differences depending on varying factors such as following teacher guidance, their self-motivation, and the facilities and opportunities provided by their schools.

7.6.4. Practical Approaches of Students in The Exhibition

7.6.4.1. Practical Approaches in Preparing for the Exhibition. The first sub-theme of the *Exhibition-Related Practical Approaches* is about how students make preparation for the presentation of their exhibits in the exhibition. The students' practical approaches taken with this purpose are mostly common and there are only two additional approaches in total from two schools in the study as seen in Table 7.25. The common practical approaches of students are deciding the presentation plan as a group, making rehearsal for presentation, checking the correctness of presented information about NST, regarding verbal interactivity, thinking on possible questions that visitors may ask and giving support each other for the presentation. The following statements taken from interviews can be given as examples of students' such practical approaches:

> "There was a preparation at this stage. We would inform the visitors and so, prepared for the questions that might come from them" (SH1S3-Post).

> "We worked for the presentation. One of our group friend was more willing to make presentation, while we were more excited and concerned compared to him. However, thanks to him we felt more relieved after each practice" (SH1S5-Post).

> "We checked the correctness of information we present through an Internet search by benefitting from the open access" (SH1S3-Post).

Apart from the other students, the SH1 students addressed their experience in the field trip to the science center for thinking about the presentation of their exhibits. The following statement can be given as example:

> "A student gives suggestions to SH1S4: "I have an idea and this was actually done in the ITU Science Center. They were asking us our guesses before they work the exhibit. You can use this idea"" (SH1O1_Textual Sum.).

> "For instance, in the ITU Science Center there was an exhibit which one of our friend tried. He turned. Then, we asked why does it like this? And they explained it" (SH1S5 in SH1O1_Textaul Sum.).

On the other side, some students of the SH3 preferred not to make a presentation plan but instead decide their presentation spontaneously within the exhibition. The student SH3S2 explains their approaches as the following:

Table 7.25. The practical approaches of students in the exhibition stage.

Theme	Sub-theme	Type of Data Source				Participants	Practical Approaches
EXHIBITION-RELATED PRACTICAL APPROACHES	PRACTICAL APPROACHES IN PREPARING FOR THE EXHIBITION	Interviews	Observations	Weekly Logs	Field Notes	Common	Deciding the presentation plan as a group (SH1, SH2, SH3) Making rehearsal for presentation (SH1, SH2, SH3) Checking the correctness of presented information about NST (SH1, SH2, SH3) Regarding verbal interactivity (SH1, SH2, SH3) Thinking on possible questions that visitors may ask (SH1, SH3) Giving support each other for the presentation (SH1, SH2, SH3)
						SH1	Inspiring from their experience in the field trip to the science center for the presentation of their exhibits
						SH2	-
						SH3	Not making a plan for presentation but instead making it spontaneously (SH3)
	PRACTICAL APPROACHES IN THE EXHIBITION	Interviews	Observations	Weekly Logs	Field Notes	Common	Examining the other exhibits in the exhibition (SH1, SH2, SH3) Doing self-reflection and self-evaluation on own exhibit after seeing other exhibits (SH1, SH3)
						SH1	Working on the deficiencies of the exhibit (SH1)
						SH2	-
						SH3	-

> "I can tell that we had not determined our presentation (plan). We should have done it. We made task sharing (for presentation) later on (in the exhibition), but after some time, these tasks have started to interrupt" (SH3S2-Post).

The explanation of the student shows that not making a presentation plan decreased the efficiency of their presentation. The practical approach of their teacher SH3T1 in the exhibition also supports this argument:

> "For example, sometimes students delayed the interaction. In such cases, I interfered in their presentation. They also learned from this" (SH3T1-Post).

7.6.4.2. Practical Approaches in the Exhibition. The last sub-theme under exhibition-related practical approaches is about students' practical approaches in the exhibition other than their presentation. The common approach described by students from each schools in the study is leaving their exhibits by commending them to school club mates and visiting other exhibits developed by students from different schools in the project. On the other side, students from the SH1 and SH3 also explained that they did self-reflection and self-evaluation on their own exhibit after seeing other exhibits. The following statements can be given as example:

> "There were many exhibit ideas. Everybody had an original exhibit. We talked about exhibits like "This exhibit is similar to ours, some students made that and the others developed that…". Then, we talked about whether it would be better to do our exhibits in that way and etc." (SH3S4-Post).

Differently from other students, some groups in the SH1 had some technical problems needed to be solved as it is discussed in the Section 7.8.1 and so, they continued to work on the deficiencies of their exhibits in the beginnings of the first day of the exhibition until they solved the problem.

The overall analysis of the students' exhibition-related practical approaches revealed mostly common practical approaches besides few exceptions. The statements taken from varying data sources show that making a good preparation for the presentation of the exhibit can be a factor leading to an efficient experience for the exhibit owner and visitors. On the other side, the analysis indicates that examining other exhibits in the exhibition may encourage students to do self-reflection about their exhibits and their performances in the exhibit development process.

The overall analysis of students practical approaches in developing an exhibit shows that giving feedback for each other from the beginning stage which is finding an exhibit idea to the completion of the exhibits is a fruitful process for students and contributes in the efficiency of their experience of exhibit development in different ways. First of all, they improve each other's exhibits with their feedbacks. For example, a group in the SH1 used part of the SH1S4's following suggestions in their exhibit design:

> "You can represent vascular system with transparent hose. You can simulate blood stream by using a syringe. Then, there can be vascular occlusion where the hose narrows down" (SH1O1_Textual Sum).

Secondly, giving feedback for other's exhibits sometimes brings ideas in students' minds that they can use in their own exhibits. For instance, the group SH1G2 used one of their member's following feedback for SH1S4 in their exhibits with the join of SH1S4 in their group:

> "Does it have to be in the form of game? You can make a system that sends balls in row. The bigger balls pass through tiny holes. Instead of making two-way design you can make like this. Visitors may interact with such design" (A student from SH1G1 in SH1O1_Textual Sum.).

Finally, listening each other's ideas for giving feedback for them is inspiring for all students. The following statement can be given as example:

> "An idea came into my mind for our exhibit. I inspired from T.A.'s wheel exhibit. We can make the target cell in a form of turning wheel and control the Bakugan ball (a toy ball used for representing NP) with a magnet under that wheel" (SH3S2 in SH3O3_Textual Sum.).

7.7. Challenges and Benefits of Guiding Students Along the Exhibit Development and Exhibition Processes

The review of the literature has pointed out some challenges as well as benefits of guiding students through science fairs, teaching about Socio-Scientific Issues (SSI) and Responsible Research and Innovation (RRI). On the other hand, some benefits of interactive exhibits were also addressed in the literature review. This section of the study combines these several aspects by reporting the challenges and benefits of guiding students along the development of RRI integrated interactive exhibits on nanotechnology applications, which are explored and analyzed with respect to the RQ3 of the study. Several data sources were used for the analysis including interviews with teachers, nano school club observations, weekly logs, field notes and textual summaries of the CoL meetings in the exhibit development process. The challenges and benefits for teachers are reported in different sections following.

7.7.1. Challenges of Guiding Students Along Developing Science Exhibits on Nanotechnology Applications

Challenges teachers faced while guiding students in developing interactive science exhibits on nanotechnology applications, in which RRI is integrated, is one of the focuses of this study. As a result of the analysis of varying data sources, the challenges teachers faced in the process were classified under three themes and five sub-themes depending on tasks in certain stages which are presented, explained and exemplified in Table 7.26.

The first theme is *Challenges in the Stage of Finding an Exhibit Idea*, which is confronted in the pre-production stage of exhibit development and addresses challenges faced while guiding students in gathering an exhibit idea. There is one challenge identified under this category and it is about guiding students in elaboration of their knowledge coming from what is learned in the module and from the field trip to the university laboratories. The teacher SH1T1 describes this challenge as the follows:

> "I think student should have improved what they learned from the module and the field trip to the university laboratory. We should have guided students in this direction. I think it was our deficiency" (SH1T1-Post)

The second theme is *Challenges in the Stage of Production of Exhibits*, which consists of two sub-themes: (i) Challenges in Integration of RRI, and (ii) Lack of Technical Knowledge and Skills. The first sub-theme covers the challenges teachers faced while guiding students in integration of RRI in their exhibits. The common challenges are not having experience in teaching about topics like RRI, cannot understanding and internalizing the RRI dimensions very well, not being sure about how to use RRI dimensions for integrating them in exhibits, having difficulty in motivating students for integration of RRI, having difficulty in talking about RRI with students, having difficulty in relating all RRI dimensions with the NST theme of the exhibits and feeling insufficient in guiding students

Table 7.26. Themes and sub-themes identified under challenges of guiding students in developing science exhibits on nanotechnology applications.

Themes and Sub-themes	Explanation	Example
1. Challenges in the Stage of Finding an Exhibit Idea	Challenges teachers faced while guiding students in gathering an exhibit idea.	"I think student should have improved what they learned from the module and the field trip to the university laboratory. We should have guided students in this direction. I think it was our deficiency" (SH1T1-Post)
2. Challenges in the Stage of Production of Exhibits	Challenges teachers faced while guiding students within the production of exhibits.	
2a. Challenges in Integration of RRI	Challenges teachers faced while guiding students in integration of RRI in their exhibits.	"I couldn't explain some RRI dimensions such as "governance" sufficiently" (SH1T1 in CoL_Meeting#2).
2b. Lack of Technical Knowledge and Skills	Challenges teachers faced because of lack of technical knowledge and skills.	"Teacher tells they can get support from engineering club of the school" (SH1O3_Textual Sum.).
3. Challenges in the Overall Process of Exhibit Development	Challenges teachers faced in the overall process of exhibit development.	
3a. Limited Time	Challenges teachers faced because of limited time or the challenges leading to limitation of time.	"We had a problem about timing" (SH3T1-Post). "We are planning to take support from the technology teacher in the school in teaching students about creating digital works. But we don't have time" (SH1T1 in CoL_Meeting#2)
3b. Process Management	Challenges teachers faced in managing the process of exhibit development.	"I had concerns like "Am I interfering too much?", "Where should I involve in their progress?"" (SH3T1-Post).
3c. Other Responsibilities	Challenges teachers faced because of other responsibilities in the school.	"Some students even don't attend in school to study for exams starting 10 days before exams" (SH3T1 in CoL_Meeting#2). "Some students prefer studying for exams at home at exam weeks" (SH1T1 in CoL_Meeting#2).

in integration of RRI. The following statements taken from varying data sources can be given as example for the difficulties confronted by teachers in RRI integrating:

> "To tell the truth, we had questions in our minds about how to use RRI dimensions till the last minutes" (SH1T1-Post).

Table 7.27. The challenges of guiding students along developing a RRI integrated interactive science exhibit on NST.

Theme	Sub-theme	Type of Data Source					Participants	Challenges
CHALLENGES IN THE STAGE OF FINDING AN EXHIBIT IDEA	-	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	-
							SH1T1	Feeling insufficient in guiding students in elaboration of their knowledge coming from what is learned in the module and from the field trip to the university laboratories
							SH2T1	-
							SH3T1	-
CHALLENGES IN THE STAGE OF PRODUCTION OF EXHIBITS	CHALLENGES IN INTEGRATION OF RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Not having experience in teaching about topics like RRI (SH1T1, SH2T1, SH3T1) Cannot understanding and internalizing the RRI dimensions very well (SH1T1, SH2T1, SH3T1) Not being sure about how to use RRI dimensions for integrating them in exhibits (SH1T1, SH3T1) Having difficulty in motivating students for integration of RRI (SH1T1, SH2T1) Having difficulty in talking about RRI with students (SH1T1, SH2T1) Having difficulty in relating all RRI dimensions with the NST theme of the exhibits (SH1T1, SH2T1, SH3T1) Feeling insufficient in guiding students in integration of RRI (SH1T1, SH2T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
	LACK OF TECHNICAL KNOWLEDGE AND SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Needing support in technical issues (SH1T1, SH2T1) - Material planning - Electronics - Mechanics - 3-d printing
							SH1T1	-
							SH2T1	-
							SH3T1	-

Table 7.27. The challenges of guiding students along developing a RRI integrated interactive science exhibit on NST. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Challenges
CHALLENGES IN THE OVERALL PROCESS OF EXHIBIT DEVELOPMENT	LIMITED TIME	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Having concern about limited time for exhibit development (SH1T1, SH2T1, SH3T1) Not having an official school club period (SH1T1, SH3T1) Not having enough time to work on exhibits all together (SH1T1, SH2T1, SH3T1) Trying to create extra time for students to work on exhibits (SH1T1, SH2T1) Having concerns about students' insufficient progress in exhibit development (SH1T1, SH3T1)
							SH1T1	-
							SH2T1	Taking responsibility of buying materials because of limited time
							SH3T1	Having difficulty in time management
	PROCESS MANAGEMENT	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	-
							SH1T1	-
							SH2T1	-
							SH3T1	Not having an experience in guiding a group of students along exhibit development for a science fair involving different schools Having difficulty in guiding students in the exhibit development through the working sheets of the module Having concerns in deciding how much interfere in students' progress Finding it challenging to keeping away from traditional in-class strategies, where teachers tell students what to do, in guiding students along exhibit development Trying to take varying approaches for motivating different students Having difficulty in following students' progress in exhibit development because they work on exhibits out of school
	OTHER RESPONSIBILITIES	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	The responsibilities in exam weeks makes it challenging to work on exhibit development (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-

> "Students told me that they are aware of that they are expected to integrate RRI in their exhibits but they had concerns about how they can integrate all dimensions. I insisted in integration of at least few of them. It was a kind of a conflict between us" (SH1T1-Post).

> "I had difficulty most in the RRI integration because I couldn't understand it exactly. How could we do it? How could we integrate in the exhibits we had? I had never taught about such topics and integration of such topics systematically (SH3T1-Post).

> "I couldn't explain some RRI dimensions such as "governance" sufficiently" (SH1T1 in CoL_Meeting#2).

To overcome these challenges, teachers developed some strategies and taken some practical approaches from making an Internet search about RRI to consulting the project team and taking their suggestions in this stage, which are discussed in detail in the Section 7.5.2.2. Practical Approaches in Integration of RRI.

Another challenge the teachers faced in the production stage in exhibit development is lack of technical knowledge and skills. They needed support in guiding students in technical facets of their exhibits such as material planning, developing electronic and mechanic parts of their exhibits, and using 3-d printer. The teachers got support from technical staff or colleagues in the school for providing students efficient support in the process.

The third theme is *Challenges in the Overall Process of Exhibit Development*, which covers three factors challenging teachers in their guidance in the science exhibit development: (i) Limited Time, (ii) Process Management, and (iii) Other responsibilities. The first sub-theme is about challenges teachers faced because of limited time or the challenges leading to limitation of time. The common challenges in this manner are having concern about limited time for exhibit development, not having an official school club period, not having enough time to work on exhibits all together, trying to create extra time for students to work on exhibits, and having concerns about students' insufficient progress in exhibit development. Apart from the common ones, another challenge for the teacher SH2T1 was taking responsibility of buying materials because of limited time. On the other side, the teacher SH3T1 had difficulty in time management. The following statements can be given as example for time-related challenges teachers faced:

> "I want each group to complete their models in next week. We were supposed to finish making the exhibits so far but we acted slowly" (SH1T1 in SH1O3_Textual Sum.).

> "We are planning to take support from the technology teacher in the school in teaching students about creating digital works. But we don't have time" (SH1T1 in CoL_Meeting#2)

> "We had a problem about timing. It would be better if we had (official) school club period" (SH3T1-Post).

> "They work after school time depending on students' free time. Not all students come together and work on exhibits but rather they come in chemistry laboratory in group of 2-3 in their free time (SH2T1 in SH2O4_Textual Sum.).

Teachers used various strategies for dealing with limited time such as asking students to work on their exhibits at lunch breaks and after school hours or taking students from some school courses, which are exemplified and discussed in the Section 7.5.3.3. Organizational Approaches.

The second sub-theme under the challenges in the overall process addresses challenges in the process management. The challenges addressed by the teacher SH3T1 in this category are not having an experience in guiding a group of students along exhibit development for a science fair involving different schools, having difficulty in guiding students in the exhibit development through the working sheets of the module, having concerns in deciding how much interfere in students' progress; finding it challenging to keeping away from traditional in-class strategies, where teachers tell students what to do, in guiding students along exhibit development; trying to take varying approaches for motivating different students and having difficulty in following students' progress in exhibit development because they work on exhibits out of school. The following statements are examples of some challenges related with the process management:

> "I had concerns like "Am I interfering too much?", "Where should I involve in their progress?"" (SH3T1-Post).

> "It was a challenging experience for me. After students completed making their exhibits, it was hard to discuss with them about the deficiencies of their exhibits. They didn't want to talk about it and they found what they have done enough (SH3T1-Post).

> In the class, we are the one telling students "Make it like this", "Apply it like this" as a teacher. So, I had to keep away from such approaches (in guiding the exhibit development process) (SH3T1-Post).

> "The teacher tells the student SH3S6 "I think you changed your exhibit system. I think we had planned this exhibit differently. The upper part was turning in the plan before. The upper part would be made of a lighter material". She has difficulty in following students' progress in exhibit development" (SH3_The Project Team's School Visit).

The last sub-theme is Other Responsibilities. The common factor pointed out by the teachers, which makes it challenging to work on exhibit development is the responsibilities in the exam weeks of the school. It makes it harder to guide students firstly because sparing time for some official responsibilities and secondly because it is difficult to bring students together for working on their exhibits. This challenge is described by teachers as follows:

> "Some students even don't attend in school to study for exams starting 10 days before exams" (SH3T1 in CoL_Meeting#2).
>
> "Some students prefer studying for exams at home at exam weeks" (SH1T1 in CoL_Meeting#2).

The overall analysis of challenges the teachers confronted in guiding students in the development of RRI integrated interactive exhibits on nanotechnology applications revealed some common and different challenges. For instance, differently, from other two teachers, the teacher SH3T1, who has very limited experience in guiding students along exhibit development, faced with some challenges about process management. Besides, although all teachers addressed their time-related concerns, the teacher SH3T1, who doesn't have an official school club period, confronted with more challenges about time. On the other hand, the teachers SH1T1 and SH2T1, who have several experience in exhibit development with students, didn't took any common approaches in integration of RRI in exhibits. Interestingly, the teacher SH3T1, who has limited experience in this manner, showed more varying practical approaches in her guidance through RRI integration compared to the other teachers. This might stem from the fact that because the RRI integration was a new experience for all of them, having pre-experiences or not didn't create much difference in this specific task.

7.7.2. Benefits of Guiding Students Along the Exhibit Development and the Exhibition

Benefits for teachers, who guided students in developing RRI integrated interactive science exhibits on nanotechnology applications and in the exhibition, is another focus of this study. In consequence of the analysis of varying data sources, the benefits for teachers in the process were classified under five themes and sixteen sub-themes which are presented, explained and exemplified in Table 7.28. Most of the benefits addressed by the teachers and identified by the researcher through observations are common among teachers, however, there are also some benefits specific to a certain teacher.

The first theme is the *Reflection and Evaluation*, which includes three sub-themes: (i) Doing Self-reflection and Self-evaluation, (ii) Evaluation of Other Aspects, and (iii) Getting an Evaluation. The first sub-theme is about teachers' making of self-reflection and self-evaluation about their guiding performances, their knowledge, and their students' performances along the exhibit development as well as in the exhibition. The common benefits identified are doing reflection and evaluation about their guidance of students along the exhibit development, doing reflection and evaluation on their students' exhibits, and self-assessment of knowledge. Apart from the common ones, the teacher SH3T1 also mentioned about evaluating her students' presentation performances for their improvement. The following statement can be given as example of teachers' self-reflection and self-evaluation:

> "After I visited other exhibits in the exhibition, I reflected on the exhibitions. I thought like "We could do this part like this" or "This aspect of the exhibit is not very good. It could be done in another way"" (SH3T1-Post).

The second sub-theme covers evaluation of other aspects based on situation assessment of the process and exhibition, and on performances of other participants. The common benefits pointed out are making evaluations about increasing the effectiveness of the exhibit development process and student-created exhibitions, and evaluating other students' exhibits. Differently from other two, the teacher SH2 mentioned about evaluating visitors' knowledge and opinions. The following statements can be given as example of evaluation of other aspects:

> "I realized that the angle of the exhibit stand is important, our angle to visitors and where we stand or even where the (extension) cables are" (SH3T1-Post).

> "I wish I had wider time periods that me and students can be (work) all together" (SH2T1-Post).

The final sub-theme under the category of reflection and evaluation is about getting evaluation for their students' exhibits. Teachers address the opportunity of getting feedback from the visitors and the experts including two science education experts, a scientist and science center manager.

Table 7.28. Themes and sub-themes identified under benefits of guiding students in the exhibit development and the exhibition.

Theme and Sub-theme	Explanation	Example
1. Reflection and Evaluation	Making reflection and evaluation as well as getting evaluation in the exhibit development and exhibition processes.	
1a. Doing Self-reflection and Self-evaluation	Making self-reflection and self-evaluation in the exhibit development and exhibition processes.	"After we saw the other exhibits in the exhibition, we made comments like "We have misunderstood this" or "We could do this part like this"" (SH1T1-Post).
1b. Evaluation of Other Aspects	Evaluating some aspects related to the exhibit development process and the exhibition.	"There were some narrow places in the exhibition area. It is better not to have places like that in the (upcoming) international exhibition" (SH2T1-Post).
1c. Getting an Evaluation	Getting evaluation for the exhibits by visitors and experts.	"The exhibition provides you to take comments from visitors about what you have done" (SH1T1-Post).
2. Developing Skills	Developing various skills through guiding the exhibit development process and the exhibition.	
2a. Developing Exhibit Making Skills	Developing skills related with developing exhibits including technical skills as well as making an exhibit.	"Teachers and students are developing skills in making interactive exhibits" (SH3O4_FielNotes).
2b. Developing Teamwork Skills	Developing skills in collaborating with others through guiding the exhibit development process.	"The exhibition development process contributes in developing skills in making collaboration with colleagues" (SH2O1_FieldNotes).
2c. Developing Process Management Skills	Developing skills related with process management.	"I realized that I can make better time planning" (SH3T1-Post).
2d. Developing Skills in Teaching about RRI	Developing skills in teaching about topics like Responsible Research and Innovation in science education.	"The teacher develops skills in discussing about socio-scientific issues with students" (SH1O2_FiledNotes).
3. Gathering Knowledge	Knowledge acquisition or elaboration while guiding students in exhibit development and in the exhibition.	
3a. Gathering Exhibit Making-Related Knowledge	Increase in knowledge related with developing exhibits including technical and material knowledge as well as steps of exhibit making.	"I learned about some materials. I learned about their properties, technical specifications, where and how they are used" (SH2T1-Post).

Table 7.28. Themes and sub-themes identified under benefits of guiding students in the exhibit development and the exhibition. (cont.)

Theme and Sub-theme	Explanation	Example
3b. Gathering Exhibition-Related Knowledge	Gathering more idea about exhibitions.	"I think I have learned more about it (interactive exhibition) during this project" (SH3T1-Post).
3c. Gathering Knowledge about RRI	Learning and understanding more about Responsible Research and Innovation.	"Teachers and students learn more about thinking RRI with respect to NST with the support of the project team" (SH1_The Project Team's School Visit).
3d. Gathering Knowledge about NST	Learning more about Nanoscience and Nanotechnology.	"Now, I have broadened my knowledge about the usage area of NST as well as their impacts" (SH3T1-Post).
4. Increase in Awareness and Motivation	Increase in awareness and motivation of teachers in various aspects after guiding students along the exhibit development and the exhibition.	
4a. Increase in Self-awareness and Self-motivation	Increase in self-awareness and self-motivation in various aspects.	"I got encouraged. I saw that we can do it (exhibit development) once we start it if the module is suitable for it" (SH3T1-Post).
4b. Increase in Awareness about Students	Increase in awareness about students' capabilities, skills and interests.	"I realized which tasks my students can do better with enjoy" (SH3T1-Post).
4c. Increase in Awareness about RRI	Increase in awareness about Responsible Research and Innovation and its importance.	"RRI dimensions should be regarded when planning a research and doing research" (SH1T1-Post).
5. Observation and Inspiration	Making observations in the exhibition and making some inferences.	
5a. Observing Other Exhibits and Getting Inspired by Them	Examining exhibits developed by other students in the project and making inferences about them.	"After I visited other exhibits in the exhibition, I reflected on the exhibitions. I thought like "We could do this part like this" or "This aspect of the exhibit is not very good. It could be done in another way"" (SH3T1-Post)
5b. Observing Other Participants in the Exhibition and Getting Inspired by Them	Observing and communicating with other participants in the exhibition and learning from them.	"Apart from that, it was also nice to be with other colleagues, to see their (students') products, to listen their experiences and to compare them with ours" (SH1T1-Post).

The second theme is *Developing Skills*, which covers acquiring new skills besides developing the existing ones while guiding students in exhibit development. The first sub-theme is about developing exhibit making related skills such as making exhibits interactive, using different materials and acquiring new technical skills. The second sub-theme is about developing teamwork skills through collaborating with colleagues, students from different school clubs, technical staff and the project team including science education experts, scientist and science center manager. The third sub-theme addresses developing process management skills like guiding skills, time management skills and crisis management skills along the exhibit development process. The last sub-theme, on the other hand, covers developing skills in teaching about RRI such as discussing with students on RRI related issues around a science topic like NST. The following statements can be given as example for teachers developing skills in the process:

> "The exhibition development process contributes in developing skills in making collaboration with colleagues" (SH2O1_FieldNotes).
>
> "I realized that I can make better time planning" (SH3T1-Post).

The third theme is *Gathering Knowledge*, which is about acquisition or elaboration of knowledge within the exhibition as well as the exhibit development process, and consists of four sub-theme: (i) Gathering Exhibit Making Related Knowledge, (ii) Gathering Exhibition-Related Knowledge, (iii) Gathering Knowledge about RRI, and (iv) Gathering Knowledge about NST. The first sub-theme points out increase in teachers' material knowledge and technical knowledge in exhibit making as well as knowledge in modelling a scientific phenomenon. It also involves teachers' developing understanding of the evolutionary and dynamic nature of exhibit development process. The second sub-theme remarks gathering more idea about student-created exhibitions, interactive exhibitions, exhibition area design and effective presentation strategies. The improvement in teachers' knowledge on exhibitions is also reported in depth in the Section 7.3, which base on their descriptions of exhibition, interactive exhibition and science exhibition before and after the exhibit development and the exhibition processes. The third sub-theme addresses learning more about RRI with respect to scientific topics. Finally, the last sub-theme covers increase in knowledge about NST by learning more about NST theme of students' exhibits, different nanoparticles, different nano-products and their usage areas. The following statements can be given as example for benefits under this theme:

Table 7.29. The benefits of guiding students along the exhibit development and the exhibition.

Theme	Sub-theme	Type of Data Source					Participants	Benefits
REFLECTION AND EVALUATION	DOING SELF-REFLECTION AND SELF-EVALUATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Doing reflection and evaluation about their guidance of students along the exhibit development (SHT1, SH3T1) Doing reflection and evaluation on their students' exhibits (SH1T1,SH3T1) Self-assessment of knowledge (SH1T1, SH2T1)
							SH1T1	-
							SH2T1	-
							SH3T1	Evaluating their students' presentation performances for their improvement
	EVALUATION OF OTHER ASPECTS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Making evaluations about increasing the effectiveness of the exhibit development process (All) Making evaluations about increasing the efficiency of student-created exhibitions (SH1T1, SH2T1, SH3T1) Evaluating other students' exhibits (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	Evaluating visitors' knowledge and opinions
							SH3T1	-
	GETTING AN EVALUATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Getting feedback from visitors about their exhibits (SH1T1, SH2T1) Getting evaluation from experts including two science education experts, a scientist and science center manager (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
DEVELOPING SKILLS	DEVELOPING EXHIBIT MAKING SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing skills in making exhibits with students (SH1T1, SH3T1) Developing skills in making interactive exhibits (SH1T1, SH2T1, SH3T1) Developing skills in working with different materials (SH1T1, SH2T1) Developing technical skills (SH1T1, SH2T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
	DEVELOPING TEAMWORK SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Collaborating with colleagues (SH1T1, SH2T1) Collaborating with students from other school clubs (SH1T1, SH2T1) Collaborating with experts including science education experts, scientist and science center staff (All)
							SH1T1	Collaborating with other staff in school
							SH2T1	-
							SH3T1	-
	DEVELOPING PROCESS MANAGEMENT SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Gaining more experience in guiding students along exhibit development process (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	Developing time management skills Developing crisis management skills

Table 7.29. The benefits of guiding students along the exhibit development and the exhibition. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Benefits
DEVELOPING SKILLS	DEVELOPING SKILLS IN TEACHING ABOUT RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing skills in discussing RRI-related issues with students (SH1T1, SH2T1, SH3T1) Developing skills in relating a science topic with RRI (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
GATHERING KNOWLEDGE	GATHERING EXHIBIT MAKING-RELATED KNOWLEDGE	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Having more idea about ways of making an exhibit interactive (SH1T1, SH2T1, SH3T1) Increase in material knowledge (SH1T1, SH2T1) Increase in technical knowledge (SH1T1, SH2T1) Realizing the evolutionary and dynamic nature of exhibit development process (SH1T1, SH2T1, SH3T1)
							SH1T1	Having more idea about modelling a scientific phenomenon
							SH2T1	-
							SH3T1	Having more idea about ways of making an exhibit interesting
	GATHERING EXHIBITION-RELATED KNOWLEDGE	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Having more idea about student-created exhibitions (SH1T1, SH2T1, SH3T1) Having more idea about exhibition area design (SH1T1, SH2T1, SH3T1) Learning more about interactive exhibitions (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	Gaining new perspective as being exhibitor rather than being visitor Having more idea about effective presentation strategies
	GATHERING KNOWLEDGE ABOUT RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Increase in knowledge about RRI (SH1T1, SH2T1, SH3T1) Learning thinking about RRI with respect to NST (SH1T1, SH2T1, SH3T1) Learning about alternative ways for reflecting RRI in exhibits (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
	GATHERING KNOWLEDGE ABOUT NST	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Increase in knowledge about NST (SH1T1, SH2T1, SH3T1) Learning more about NST theme of their students' exhibits (SH1T1, SH2T1, SH3T1)
							SH1T1	Learning about different nanoparticles Learning about usage areas of different nanoparticles Learning about different nano-products
							SH2T1	-
							SH3T1	-

Table 7.29. The benefits of guiding students along the exhibit development and the exhibition. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Benefits
INCREASE IN AWARENESS AND MOTIVATION	INCREASE IN SELF-AWARENESS AND SELF-MOTIVATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	-
							SH1T1	-
							SH2T1	-
							SH3T1	Increase in self-confidence and self-motivation towards guiding students in exhibit development Raising awareness about differences in guiding students in-class and in exhibit development Increase in motivation towards letting students to be more active in-class Realizing that different kinds of education is possible in different environments Increase in motivation towards transferring guidance experience gained in the exhibition development process in guiding students for the term projects
	INCREASE IN AWARENESS ABOUT STUDENTS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Realizing students' capabilities in developing an exhibit (SH1T1, SH2T1, SH3T1) Realizing students' skills and interests more (SH1T1, SH2T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
	INCREASE IN AWARENESS ABOUT RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Raising awareness about the importance of RRI in daily life (SH1T1, SH2T1, SH3T1)
							SH1T1	Raising awareness about the importance of regarding RRI in a scientific research
							SH2T1	-
							SH3T1	Gaining more critical point of view in evaluating a new product Gaining more critical point of view about usage areas of NST and their effects Increase in motivation towards following current developments in NST
OBSERVATION AND INSPIRATION	OBSERVING OTHER EXHIBITS AND GETTING INSPIRED BY THEM	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Opportunity to examine exhibits developed by students from other schools (SH1T1, SH2T1, SH3T1) Opportunity to learn from other exhibits (SH1T1, SH3T1)
							SH1T1	-
							SH2T1	-
							SH3T1	-
	OBSERVING OTHER PARTICIPANTS IN THE EXHIBITION AND GETTING INSPIRED BY THEM	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	-
							SH1T1	Opportunity to meet with colleagues from other schools and learn about their experiences Opportunity for participants to learn from each other as well as learning from exhibits
							SH2T1	-
							SH3T1	-

> "I learned about some materials. I learned about their properties, technical specifications, where and how they are used" (SH2T1-Post).

> "Now, I have broadened my knowledge about the usage area of NST as well as their impacts" (SH3T1-Post).

The fourth theme is *Increase in Awareness and Motivation*, which embraces rise in teachers' awareness and motivation in various aspects after guiding students along the exhibit development and the exhibition. It comprises of three sub-themes as seen in Table 7.29. The first sub-theme, which is Increase in Self-awareness and Self-motivation, includes increase in self-confidence and self-motivation towards guiding students in exhibit development, raising awareness about differences in guiding students in-class and in exhibit development, increase in motivation towards letting students to be more active in-class, realizing that different kinds of education is possible in different environments, and rise in motivation towards transferring guidance experience gained in the exhibit development process in guiding students for the term projects. Furthermore, the second sub-theme is Increase in Awareness about Students, which is about realizing students' capabilities in developing an exhibit and their skills and interests more. Lastly, the third sub-theme is Increase in Awareness about RRI, which addresses raise in teachers' awareness about the importance of RRI in daily life as well as in scientific researches, gaining more critical point of view in evaluating a new product, having more critical perspective in usage areas of NST and their effects and increase in motivation towards following current developments in NST. The statement below can be given as example of increase in awareness and motivation:

> "I got encouraged. I saw that we can do it (exhibit development) once we start it if the module is suitable for it" (SH3T1-Post).

Finally, the last theme under the benefits of guiding students along the exhibit development and the exhibition is *Observation and Inspiration*, which includes two sub-themes: (i) Observing Other Exhibits and Getting Inspired by Them, and (ii) Observing Other Participants in the Exhibition and Getting Inspired by Them. The first sub-theme, as the name implies, bases on benefits coming with examining exhibits developed by other students in the project and making inferences about them. On the other side, the second sub-theme covers observing and communicating with other participants in the exhibition and learning from them. The explanation of the SH1T1 can be given as example:

> "Apart from that, it was also nice to be with other colleagues, to see their (students') products, to listen their experiences and to compare them with ours" (SH1T1-Post).

The overall analysis of benefits the teachers obtained from their guiding experience revealed many common benefits. However, the teacher SH3T1, who has only one experience in exhibit development with students, put extra emphasis on gaining process management skills and increase in her confidence and motivation towards involving in similar extra-curricular activities like guiding students for science fairs.

The overall analysis of challenges and benefits of guiding students along the exhibit development and the exhibition revealed some challenges from guiding students in integration of RRI in their exhibits to other official responsibilities of teachers, and points out many benefits from making reflection and evaluation about process-related aspects to increase in awareness and motivation of teachers in such tasks. Besides, it gave the reader some insight about the strategies teachers developed for overcoming the challenges they faced in their guidance.

7.8. Challenges and Benefits of Developing RRI Integrated Interactive Exhibit on Nanotechnology Applications and the Exhibition Processes

Similar to teachers, students confronted with some challenges while developing an RRI integrated interactive science exhibits on nanotechnology applications. They also addressed many benefits of engaging in such experience. This section of the study is aimed to report these challenges and benefits identified through analysis of varying data sources with respect to the RQ6. The data sources, used in this direction, are interviews, school observations, weekly logs, field notes and CoL meetings, which comprise of students' opinions, the researcher's observations and reflections, and also the teachers' statements. The challenges and benefits for students are reported in different sections following.

7.8.1. Challenges of Developing a RRI Integrated Interactive Science Exhibit on NST and the Exhibition

The first focus of the RQ6 is the challenges students faced in developing an RRI integrated interactive exhibit on NST. As a consequence of analysis of multiple data sources, the challenges students confronted were classified under six themes and ten sub-themes, which are presented, explained and exemplified in the Table 7.30. The corresponding challenges for each theme and sub-theme are presented in school-base in the Table 7.31, which also includes the challenges for students addressed by the teachers that are remarked in parenthesis.

The first theme is *Concerns Just Before the Exhibit Development Process*, which addresses the concerns of students in the beginning of the process. Some students had no experience in developing a science exhibit. In some cases, this inexperience brought together low self-confidence and low motivation for developing an exhibit like for the students of the school SH3. Besides, the ranking of exhibits was another factor creating stress for some students such as the SH1 students. To overcome the reluctance coming with these concerns, teachers showed some motivating and encouraging practical approaches as it is discussed in Section 7.5.3.1. Practical Approaches for Motivating Students.

The second theme is *Challenges in the Stage of Finding an Exhibit Idea*, which is about challenges students confronted in gathering an exhibit idea. Students from each school mentioned about spending too much time in finding an exhibit idea. The two challenges students faced in this phase are deciding to the final form of the exhibit idea and finding different exhibit ideas. The similarity of students' exhibit ideas was also addressed by the teacher SH1T1. She thinks students' exhibit ideas mostly are from what they learned about NST from the module and from the field trip to the university laboratories. Some students' explanations about what their exhibit ideas base on supports the SH1T1's argument:

> "When we visited the Boğaziçi University laboratories, they told us about these studies. Then, we talked with my group friend whether we can model it or not" (SH1S3-Post).
>
> "We had learned about the thermal property and size dependent color property of gold nanoparticles in one of our lessons in the school club. We decided to do something about it…" (SH1S5-Post).
>
> "We inspired from the animations we watched while we learning about it. It was showing how nanoparticles destroy bacteria" (SH2S1-Post).
>
> "We had a lesson about gold nanoparticles. It was interesting. So, I wanted to something about it" (SH3S1-Post).
>
> "We had inspired by the nano-socks washing experiment in the module" (SH3S4-Post).

Table 7.30. Themes and sub-themes identified under the challenges of developing a RRI integrated interactive science exhibits on nanotechnology applications and the exhibition.

Theme and Sub-theme	Explanation	Example
1. Concerns Just Before the Exhibit Development Process	Concerns of students in the beginning of the exhibit development process.	"When our teacher asked us to develop an exhibit, we had concerns about what and how we will going to do in the beginning" (SH3S3-Post).
2. Challenges in the Stage of Finding an Exhibit Idea	Challenges students faced in gathering an exhibit idea.	"It took about three weeks to thinking on an exhibit idea. Others had found an idea, but we couldn't" (SH1S5-Post).
3. Challenges in the Stage of Planning Exhibits	Challenges students faced in planning of their exhibits.	
3a. Challenges in Material Planning and Supply	Challenges students faced in planning and supplying materials.	"We had four or five exhibit ideas, but we had no idea which materials we should buy" (SH1S1-Post)
3b. Challenges in Planning Exhibit Design	Challenges students faced in planning their exhibit design.	"SPC is dominant in producing ideas. Mainly, he directs students about the design of their exhibits" (SH2O2_Textual Sum.).
4. Challenges in the Stage of Production of Exhibits	Challenges students faced in the production of their exhibits.	
4a. Lack of Technical Knowledge and Skills	Challenges students faced because of lack in their technical knowledge and skills.	"The exhibit was partly broken and we had to make it again" (SH1S4-Post).
4b. Challenges in Integration of RRI	Challenges students faced in integrating RRI in their exhibits.	"We had never done such thing before. We had difficulty about how to integrate RRI" (SH3S2-Post).
4c. Challenges in Making Exhibits Interactive	Challenges students faced in making their exhibits interactive.	"For us, developing an interactive exhibit was long and challenging process" (SH1S4-Post).
5. Challenges in the Overall Process of Exhibit Development	Challenges students faced in the overall process of exhibit development.	
5a. Limited Time	Challenges students faced because of limited time or the challenges leading to limitation of time.	"I changed the exhibit idea because we had time problem" (SH3S1-Post)

Table 7. 30 Themes and sub-themes identified under the challenges of developing a RRI integrated interactive science exhibits on nanotechnology applications and the exhibition (cont.)

Theme and Sub-theme	Explanation	Example
5b. Challenges of Teamwork	Challenges students faced in working as a group.	"It was challenging to work with others" (SH1S4-Post).
5c. Other Responsibilities	Challenges students faced because of other responsibilities in the school.	"When we realized that we need to change the whole design of the exhibit due to a technical problem, we got concerned because the exam week was very close and there were the school lessons and homework" (SH1S3-Post).
6. Challenges in the Exhibition		
6a. Challenges in Making Presentation	Challenges students faced in presentation of their exhibits.	"I can tell that we had not determined our presentation (plan). We should have done it. We made task sharing (for presentation) later on (in the exhibition), but after some time, these tasks have started to interrupt" (SH3S2-Post).
6b. Challenges about Physical Facilities in the Exhibition Area	Challenges students faced about physical facilities in the exhibition area.	"In the first day of the exhibition, we were in a room because our exhibits didn't fit the area reserved for us in the exhibition area. Therefore, we didn't get much visitor in the first day" (SH1S3-Post).

Another challenge faced in finding an exhibit idea is about the effect of having some specific ideas about "must-haves" of the exhibits on the students' exhibit idea gathering. The analysis shows that having alternative ideas about the necessities of exhibit is a limiting factor in finding an exhibit idea. The following case taken from a school observation can be given as example:

> "They examine a page about Graphene. SH2S1 said "This is Carbon but we mostly focused on Silver". Another student replied as "But we didn't talk only about silver. We came to the point of silver from nanotechnology" (SH2O1_Textual Sum.).

Although a student made a good point in unnecessity of limiting themselves with silver nanoparticles, the both exhibits SH2E1 and SH2E2 focus around silver nanoparticles. Apart from other two schools' students, who have strong command of English, the students of the school SH3 had difficulty in finding sources in mother language on the Internet as seen in Table 7.31.

The third theme is *Challenges in the Stage of Planning Exhibits*, which consists of two sub-themes: (i) Challenges in Material Planning and Supply, and (ii) Challenges in Planning Exhibit Design. The first sub-theme is about challenges students faced in planning and supplying materials. The first challenge in this manner is lack of material knowledge, which brings some other challenges together such as having difficulty in determining the materials needed, wrong/inefficient material choice, having difficulty in choosing durable materials, and having difficulty in building aesthetically pleasing exhibits. The second material-related challenge is material supply. Some students had difficulty in finding the materials in stores or finding a store. Some of them ended up by giving up their exhibit ideas because of not knowing how to supply materials needed for it like in the case of SH2S2 and SH1S1:

> "Actually, I had worked on an experiment. It would be a model showing the differences of spaces between the healthy cells and cancer cells. In the experiment, nanoparticles are able to move against the gravity under magnetic field. But, we couldn't do it. We couldn't find the materials needed" (SH2S2-Post).
>
> "We had a project idea (exhibit idea), which I really wanted to develop. We had a very limited idea about how to supply materials or how to produce materials we need by ourselves. It would be a very challenging process. We also had limited time. So, we didn't make this idea" (SH1S1-Post).

The second sub-theme is about challenges students confronted in planning of their exhibit designs. These are limiting the exhibit design with respect to material and technical knowledge as well as the limited time, having difficulty in deciding to the final form of the exhibit design plans, and needing support in planning of exhibit designs. Similar to its negative effect in the stage of finding exhibit idea, having alternative ideas about the necessities of exhibit is also a limiting factor in planning exhibit designs. The SH1T1's request from students to develop an exhibit design, which doesn't require any directions of the exhibit-owner while visitors examine it or the SH3T1's direction of developing models to make exhibits interactive can be given as examples of ideas restricting students in making their exhibit designs. The student SH1S4 explains how they changed their exhibit design plans few times because of such limitation:

> "Some were interpreting the sustainability of the exhibit as exhibits, which visitors can do it by themselves. Therefore, we gave up many exhibit design plans. We had to change the exhibit designs, which need us (exhibit-owner)" (SH1S4-Post).

The fourth theme is *Challenges in the Stage of Production of Exhibits*, which comprises of three sub-themes as given in Table 7.31. The first sub-theme is about lack of technical knowledge and skills, which brings along some challenges such as having difficulty in using a material efficiently, having difficulty in transferring exhibit ideas into exhibits and producing sustainable exhibit design plans, need of support in technical aspects, and facing with technical problems. In some cases, students had to rebuild their exhibit because of technical problems:

> "We had no idea about how to do the spinning mechanism of the exhibit and you know we faced a problem about adhesive. Besides, tubes were too long. We got support people from our school. I really appreciate their effort" (SH1S1-Post).

The second sub-theme is Challenges in Integration of RRI, which covers challenges students faced in RRI integration. Firstly, students had no experience in learning or discussing about topics like RRI, which decreases the chance of familiarity with the subject. It makes it difficult to understand some dimensions of RRI such as "governance" and "engagement". The following statements of a student and a teacher can be given as example:

> "We tried really hard to understand the "governance". In the beginning, neither any school club mates nor the teachers understood it. We understood it at last, when it was very close to the exhibition" (SH1S4-Post).

> "The governance dimension among the all dimensions challenged the students. In the beginning, they didn't get the contribution of it in our daily lives, but then they realized the necessity of it" (SH1T1-Post).

Table 7.31. The challenges of developing RRI integrated interactive science exhibits on nanotechnology applications.

Theme	Sub-theme	Type of Data Source	Participants	Challenges
CONCERNS JUST BEFORE THE EXHIBIT DEVELOPMENT PROCESS	-	Interviews, Observations, Weekly Logs, Field Notes, CoL Meetings	Common	Not having an experience in developing a science exhibit (SH1, SH3)
			SH1	Having concerns in ranking of exhibits in the exhibition (SH1)
			SH2	-
			SH3	Not having self-confidence in developing an exhibit (SH3) (SH3T1) Having low motivation for the exhibit development process (SH3) (SH3T1)
CHALLENGES IN THE STAGE OF FINDING AN EXHIBIT IDEA	-	Interviews, Observations, Weekly Logs, Field Notes, CoL Meetings	Common	Spending too much time in finding an exhibit idea (SH1, SH2, SH3) Deciding to the final form of the exhibit idea (SH1, SH2, SH3) Having difficulty in finding different exhibit ideas: (SH1, SH3) - Finding an exhibit idea different from what is learned about NST (SH1, SH2, SH3) (SH1T1) Having alternative ideas about the necessities of exhibit is a limiting factor in finding an exhibit idea (SH1, SH2, SH3)
			SH1	-
			SH2	-
			SH3	Finding sources in mother language on the Internet (SH3)
CHALLENGES IN THE STAGE OF PLANNING EXHIBITS	MATERIAL PLANNING AND SUPPLY	Interviews, Observations, Weekly Logs, Field Notes, CoL Meetings	Common	Lack of material knowledge: (SH1T1, SH3T1) - Having difficulty in determining the materials needed (SH1, SH2, SH3) (SH1T1, SH3T1) - Wrong/inefficient material choice (SH1, SH3) (SH1T1, SH3T1) - Having difficulty in choosing durable materials (SH1, SH3) (SH1T1, SH3T1) Challenges in material supply: (SH1, SH2, SH3) - Giving up an exhibit idea because of not knowing how to supply materials needed for it (SH1, SH2, SH3)
			SH1	-
			SH2	-
			SH3	Having difficulty in building aesthetically pleasing exhibits
	CHALLENGES IN PLANNING EXHIBIT DESIGN	Interviews, Observations, Weekly Logs, Field Notes, CoL Meetings	Common	Limiting the exhibit design with respect to material and technical knowledge (SH1, SH3) (SH1T1, SH3T1) Limiting the exhibit design with respect to limited time (SH1, SH2, SH3) (SH2T1) Having difficulty in deciding to the final form of the exhibit design plans (SH1, SH3) Needing support in planning of exhibit designs (SH1, SH2, SH3) Having alternative ideas about the necessities of exhibit is a limiting factor in planning exhibit designs (SH1, SH3)
			SH1	-
			SH2	-
			SH3	Having difficulty in drawing the exhibit design plan

Table 7.31. The challenges of developing RRI integrated interactive science exhibits on nanotechnology applications. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Challenges
CHALLENGES IN THE STAGE OF PRODUCTION OF EXHIBITS	LACK OF TECHNICAL KNOWLEDGE AND SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Lack of technical knowledge and skills (SH1T1, SH3T1) - Having difficulty in using a material efficiently (SH2, SH3) - Having difficulty in producing sustainable exhibit design plans (SH1, SH3) - Having difficulty in transferring exhibit ideas into exhibits (SH1, SH2, SH3) - Need of support in technical aspects (SH1, SH2, SH3) Facing with technical problems (SH1, SH3) - Rebuilding the exhibit because of technical problems (SH1, SH3)
							SH1	-
							SH2	-
							SH3	Giving up an exhibit idea because of not knowing how to build the exhibit mechanism in mind (SH3T1)
	CHALLENGES IN INTEGRATION OF RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Not having experience in learning about topics like RRI (SH1, SH2, SH3) Having difficulty in understanding some RRI dimensions (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Having difficulty in finding sources about RRI (SH1, SH2, SH3) Challenge of explaining RRI dimensions by using own words (SH1, SH2, SH3) Having low motivation for integration of RRI (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Delaying to focus on integration of RRI in exhibits (SH1, SH2, SH3) Having difficulty in finding a way for integration of RRI (SH1, SH3) (SH1T1, SH3T1) Having difficulty in integrating all of six RRI dimensions in exhibits (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Challenge of relating RRI dimensions with the NST theme of the exhibit (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) - Challenge of relating an objective concept with a subjective and abstract concepts (SH1, SH2, SH3) (SH3T1) Need of support in RRI integration (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
	CHALLENGES IN MAKING EXHIBITS INTERACTIVE	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Challenge of finding ways for making exhibits interactive (SH1, SH3)
							SH1	-
							SH2	-
							SH3	-

Table 7.31. The challenges of developing RRI integrated interactive science exhibits on nanotechnology applications. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Challenges
CHALLENGES IN THE OVERALL PROCESS OF EXHIBIT DEVELOPMENT	LIMITED TIME	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Having concern about limited time for exhibit development (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Losing time because of technical problems (SH1, SH2, SH3)
							SH1	Being not able to make desired changes on exhibits because of limited time Working on exhibits at some school lessons periods
							SH2	-
							SH3	-
	CHALLENGES OF TEAMWORK	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Having difficulty in finding a common time with group friends for working on exhibits (SH2, SH3) Challenge of having consensus in some aspects of exhibit development (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
	OTHER RESPONSIBILITIES	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Responsibilities in the exam weeks (SH1, SH2, SH3) Responsibilities of school lessons like homework and term projects (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
CHALLENGES IN THE EXHIBITION	CHALLENGES IN MAKING PRESENTATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Getting excited while presenting the exhibits (SH1, SH2, SH3) Challenge of making an effective presentation (SH1, SH3) (SH3T1) Simplifying the presentation for younger visitors (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
	CHALLENGES ABOUT PHYSICAL FACILITIES IN THE EXHIBITION AREA	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	
							SH1	Getting less visitor because of the position in the exhibition site
							SH2	Existence of narrow places in the exhibition area
							SH3	-

When it comes to searching about RRI for learning more about it, students had difficulty in finding sources about RRI, especially finding sources in their native language. In experience, low understanding and limited source led some other factors challenging students. These are challenge of explaining RRI dimensions by using own words, having low motivation for integration of RRI, delaying to focus on integration of RRI in exhibits, having difficulty in finding a way for integration of RRI, having difficulty in integrating all of six RRI dimensions, and challenge of relating RRI dimensions with the NST theme of the exhibit. Following statements taken from varying data sources can be given as example for challenging aspects of RRI integration:

> "I didn't know much about RRI. We had never done such thing before. We had difficulty about how to integrate RRI. We integrated all of RRI dimensions. If we would integrate few of them instead of all six, we could reflect them better." (SH3S2-Post).
>
> "It was challenging to reflect both RRI and the gold nanoparticles together on the model. It was easier to think them separately" (SH3S1-Post).
>
> "SH2S1 said "Ethics can change from person to person. So we can't form a True-False question (about ethics)". The teacher replied as "I accept its subjectivity. What about narrowing down its scope instead of thinking it generally?" Students asked how they can do it. The teacher gave an example of True-False question "Do Nano-products have impact on environmental pollution?"" (SH2O1_Textual Sum.).
>
> "A student from SH1G5 asked "How can we integrate ethics? I know what ethics is but I need an explanation about how can we integrate it in our exhibits" (SH1O2_Textual Sum.).
>
> "Some students have misunderstanding about some dimensions. The teacher asked a group how they will integrate RRI dimensions into their exhibit. They answered as "Ethics: Our exhibit aims to inform visitors, so it is ethical, Engagement: The exhibit should be beneficial for visitors, Gender equality: Nano-products should be for both genders. Another group replied as "Engagement: Direct interaction of visitor with the exhibit. Governance: We help visitors to work on exhibit" (SH1O2_Textual Sum.).
>
> "Students have difficulty in integrating all RRI dimensions in their exhibits" (SH1O4_FieldNotes).

Furthermore, the integration of RRI was the most addressed aspect, when the project team visited schools to give feedback for students' exhibits. The following statements can be given as example:

> "Students from the group SH1G1 were explaining the RRI integration in their exhibits like "For ethics: There is no harm on environment during the development of this exhibit. For gender equality: Our exhibit is not gender-specific. Both gender can benefit from this product and learn from this exhibit. The project coordinator asked students "How will you present your ideas about RRI to the visitors in the exhibition? Will you explain them like that (verbally)? What is your plan? Could you make it in a more interactive way like through games?" Then, she

suggested to relate the RRI dimensions with a research in the field of the NST theme of their exhibit" (SH1_The Project Team's School Visit).

"The project team suggests students to increase the number of RRI related questions in the nanoquiz exhibit. The integration of RRI is missing in the other exhibit" (SH2_The Project Team's School Visit).

"The project coordinator said SH3G3 "We don't see the integration of RRI at all in this exhibit". The teacher told "They tried to integrate "open access" with the brochure". Then, the project team made some suggestions about the ways they can integrate RRI like preparing question cards and including three boxes for visitors' answers such as "Yes", "No", "I have no idea" (SH3_The Project Team's School Visit).

Because of varying challenges base on integration of RRI, students needed support and guidance like they took from the project team as well as from their teachers and school club mates. Students also took some practical approaches and developed some strategies to overcome challenges of RRI integration from making search from the official website of the project to giving feedback for each other about RRI integration, which are discussed in the Section 7.6.2.2. Practical Approaches in Integration of RRI.

The last sub-theme under the challenges faced in the production stage is Challenges in Making Exhibits Interactive. Although, this challenge was not pointed out heavily like in the case of RRI integration, few students from the schools SH1 and SH3 mentioned about it. They considered it challenging to find ways for making exhibits interactive. The following statement can be given as example:

"I had never been in an interactive exhibition nor developed an interactive exhibit before. For us, developing an interactive exhibit was long and challenging process. When you develop an ordinary exhibit, it needs to appeal to eye and ear. But, when you create an interactive exhibit, it needs to appeal all senses of people by letting them to touch, to hear and to involve in it themselves" (SH1S4-Post).

The fifth theme is *Challenges in the Overall Process of Exhibit Development*, which includes three sub-themes: (i) Limited Time, (ii) Challenges of Teamwork, and (iii) Other Responsibilities. The first sub-theme is about challenges students faced because of limited time or the challenges leading to limitation of time. Firstly, all students addressed their concern about limited time in the exhibit development. Besides, some students lost some time in the process because of technical problems, while some were not able to make desired changes on exhibits because of limited time. On the other side, some students worked on exhibits at some school lessons periods to create extra time. The statements below can be given as example for time-related challenges students confronted in the exhibit development:

"We got worried about whether we can finish exhibit development in time" (SH3S4-Post).

"I changed the exhibit idea because we had time problem" (SH3S1-Post)

"They also work after school times in different days. School club hours are not sufficient to complete their exhibit on time" (SH2O4_Textual Sum.).

The second sub-theme is about the challenges faced in making group work. The first challenge is having difficulty in finding a common time with group friends for working on exhibits. In some cases, like the SH3S1 and SH3S6, this situation ends up with giving up doing a group work but instead deciding to work individually in exhibit development. The following statements exemplifies challenges of teamwork for students:

"Working with others was challenging. Making a plan together and following it were difficult" (SH1S4-Post).

"When we decided to come together at a weekend, my group friend couldn't join our meeting. But the teacher had asked us to make a progress in exhibit development. So, I did something, but my group friend was unaware of what was I did. Then, he said "I am doing something my own. Let's do it like that (working individually)" and I said "All right" (SH3S6-Post).

Not having an official school club period possibly made way for such ending. Another challenge in teamwork is trying to have consensus with other group members in some aspects of exhibit development like aforementioned case in SH3, in which a student was suggesting to pick Graphene as an exhibit theme, while the other insisted on choosing Silver nanoparticles because it was the focus of the module. The last sub-theme is about challenges stem from the other school-related responsibilities of students like the exam weeks, homework or attending seminars.

"The time interval of the exhibit development was bad. Besides of limited time, the half of the time interval comprised of the exam week. So, it was challenging to spare time for it (exhibit development). All of group members wanted to study for exams, which demotivate us for developing exhibits. But, eventually we did it" (SH1S1-Post).

"Sometimes students have other activities such as attending a seminar or they missed the club hours because of snow break and report card day. Therefore, we lost 2-3 weeks" (SH2T1 in CoL_Meeting#2).

The last theme under the challenges students faced in the process is *Challenges in the Exhibition*, which consists of two sub-themes: (i) Challenges in Making Presentation, and (ii) Challenges about Physical Facilities in the Exhibition Area. The challenges about presentation are overcoming excitement while presenting the exhibits, making an effective presentation and simplifying the presentation for younger visitors. The following statement can be given as example:

> "I can tell that we had not determined our presentation (plan). We should have done it. We made task sharing (for presentation) later on (in the exhibition), but after some time, these tasks have started to interrupt" (SH3S2-Post).

The other factor creating challenges for students is the physical facilities in the exhibition. The SH1S3 explains how the physical conditions they confronted in the exhibition area did effect the number of visitors they got:

> "In the first day of the exhibition, we were in a room because our exhibits didn't fit the area reserved for us in the exhibition area. Therefore, we didn't get much visitor in the first day" (SH1S3-Post).

7.8.2. Benefits of Developing a RRI Integrated Interactive Science Exhibit on NST and the Exhibition

The experience students went through in developing an RRI integrated interactive science exhibit on NST led them to learn from numerous challenges they faced and from the practical approaches they took to cope with the struggles on their ways. This section of the study is aimed to present the benefits students obtained from this experience. As a result of analysis of multiple data sources, the benefits students gained were classified under five themes and seventeen sub-themes, which are presented, explained and exemplified in Table 7.32. The benefits under each theme and sub-theme are given in school-base in the Table 7.33, which also includes the student-acquired benefits addressed by the teachers that are remarked in parenthesis. The benefits students derived from the process are mostly parallel with the teachers' benefits with few exceptions and reflect of students' experiences and perspectives.

The first theme is the *Reflection and Evaluation*, which consists of three sub-themes: (i) Doing Self-reflection and Self-evaluation, (ii) Evaluation of Other Aspects, and (iii) Getting an Evaluation. The first sub-theme is about students' self-reflection and self-evaluation about their performances along the exhibit development as well as in the exhibition, their exhibits and their related experiences in the past. The common benefits identified under this category are reflecting on and evaluating their performance along the exhibit development, evaluation of their own exhibits regarding ways of improving the design and RRI integration, doing reflection and evaluation about the projects or exhibits developed in the past regarding their interactivity and RRI, and evaluating the exhibition experiences in the past regarding their interactivity. The statements below can be given as examples for the first sub-theme:

> "My personal opinion is we could build a little more integral design. It (parts of exhibits) is isolated in this form" (SH1S2-Post).
>
> "I think doing our exhibits interactive contributed not only us but also visitors a lot" (SH2S2-Post).
>
> "Now, I realize that the exhibit I developed before was interactive. The visitors were pouring water themselves (the exhibit was on water cycle)" (SH3S4-Post).
>
> "In the school projects we developed before, we were given more directives. I mean we were much more directed to prepare a certain type of projects. But, in the Project Irresistible, we were asked to develop an exhibit on NST and it was more open ended. It led to arise more creative ideas" (SH2S1-Post).
>
> "The project I developed before was including only the "open access" dimension of RRI, but the current one integrates all six of them" (SH3S5-Post).
>
> "It (the exhibition) was more interactive compared to my past experiences" (SH1S3-Post).
>
> "The Periodic Table I prepared before was touch-operated. Because it was designed for blind people, we blindfolded visitors and they touched on it" (SH2S2-Post).

The second sub-theme is about evaluation of other aspects such as evaluating exhibits developed by other students regarding their NST theme, designs, interactivity and RRI integration. Besides, students got chance to evaluate visitors' opinions about RRI as well as NST. The following statement can be given as example under this category:

> "There were many creative exhibit ideas. Some were better than ours, but it is not important. We have learned from them." (SH3S5-Post).

The third sub-theme is about opportunity get evaluation from others for the exhibits developed. In the process of exhibit development, students got feedback from their teachers and the Nano school club mates. As it is addressed in previous sections, before the exhibition, students got feedback from the project team including science education experts, a scientist and science center manager. These feedbacks contributed students to improve their exhibits before they meet with larger population. Finally, in the exhibition students got feedback for their exhibits from the visitors, which may help them in making constructive inferences for future projects. The statements below can be given as example of benefit of getting evaluation from others:

> "After we presented our exhibits to our friends through pictures, we developed it with their ideas" (SH3S5-Post).

> "A student from SH1G1 told the project team "We are confused whether it is a chemical or mechanical filtration. Because nano-scale filtration is seen as chemical filtration in the literature but membrane filters are used in this process. We want to hear your point of view". One of the science education experts said "What I understand in nano filtration is filtration of particles in nano size thanks to its nanoscale pores besides filtration of organic entities like bacteria thanks to the property of certain NPs like Ag NPs integrated in nano-filters" (SH1_The Project Team's School Visit).

The second theme under the benefits students obtained is *Developing Skills*, which comprises of five sub-themes: (i) Developing Exhibit Making Skills, (ii)Developing Teamwork Skills, (iii) Developing Process Management Skills, (iv) Developing Presentation Skills, and (v) Developing Skills in Data Collection and Evaluation. The first sub-theme addresses developing of students' skills related with exhibit making such as making exhibits interactive, working with different materials, and technical skills. The following statements of students can be given as example:

> "I always wanted to use 3d- printer but I didn't know (how to use it). It seems too much complicated. But I learned it with the support of the (Technology and Design) teacher and I am planning to use it in my future projects" (SH2S2-Post).

> "Speaking for myself, I developed new ideas with the skills I learned, which I had never done before, like building electric circuit system" (SH1S5-Post).

The second sub-theme is about skills students developed through making teamwork. First of all, students developed skills in collaborating with others including group members, the Nano school club mates, students from other school clubs, and other teachers or staff in their school. Along with the collaborative skills, students have improved their skills in communication, reaching a comprise and taking responsibilities. Furthermore, in some cases, students formed groups with others from different classes or grade levels, which promoted their teamwork skills as well. The following statements can be given as example of benefits identified under this category:

> "While developing this exhibit, I developed my skills and learned to be in interaction and communication with others, and making teamwork as a group" (SH1S4-Post).

Table 7.32. Themes and sub-themes identified under the benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications and the exhibition.

Theme and Sub-theme	Explanation	Example
1. Reflection and Evaluation	Making reflection and evaluation as well as getting evaluation in the exhibit development and exhibition processes.	
1a. Doing Self-reflection and Self-evaluation	Making self-reflection and self-evaluation upon the experience and performance in the exhibit development and exhibition processes as well as related past experiences.	"We had used acetate papers, but we could use plastic tube instead" (SH1S2-Post).
1b. Evaluation of Other Aspects	Evaluating some aspects including the exhibit development process, the exhibition, other exhibits and visitors' opinions.	"There were many creative exhibit ideas. Some were better than ours, but it is not important. We have learned from them." (SH3S5-Post).
1c. Getting an Evaluation	Getting evaluated for the exhibits by visitors and experts.	"The project coordinator suggests SH1G1 to put emphasis on the transfer of nanoparticles in nature" (SH1_The Project Team's School Visit).
2. Developing Skills	Developing various skills through guiding the exhibit development process and the exhibition.	
2a. Developing Exhibit Making Skills	Developing skills related with developing exhibits including technical skills as well as making an exhibit.	"I always wanted to use 3d- printer but I didn't know (how to use it). It seems too much complicated. But I learned it…" (SH2S2-Post).
2b. Developing Teamwork Skills	Developing skills in collaborating with others through guiding the exhibit development process.	"…I learned to make teamwork as a group…" (SH1S4-Post).
2c. Developing Process Management Skills	Developing skills related with process management.	"Students had difficulty in finding the right materials. But they overcame it. They searched on the Internet, consulted their acquaintances, families, and other teachers" (SH1T1-Post).
2d. Developing Presentation Skills	Developing skills in making an effective presentation.	"It contributed a lot in terms of presentation" (SH3S3-Post).

Table 7.32. Themes and sub-themes identified under the benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications and the exhibition. (cont.)

Theme and Sub-theme	Explanation	Example
2e. Developing Skills in Data Collection and Evaluation	Developing skills in collecting and evaluating data.	"I prepared questionnaire including RRI questions. Then, I kept record of visitors' answers in a table" (SH3S1-Post).
3. Gathering Knowledge	Knowledge acquisition or elaboration while guiding students in exhibit development and in the exhibition.	
3a. Gathering Exhibit Making-Related Knowledge	Increase in knowledge related with developing exhibits including technical and material knowledge as well as steps of exhibit making.	"I gained knowledge about industrial materials a lot" (SH1S1-Post).
3b. Gathering Exhibition-Related Knowledge	Gathering more idea about exhibitions.	"Before our exhibition, I had no idea about interactive exhibition. But after we developed one, we learned about it and we gathered more in-detail knowledge about it" (SH1S5-Post).
3c. Gathering Knowledge about RRI	Learning and understanding more about Responsible Research and Innovation.	"…students learn more about thinking RRI with respect to NST with the support of the project team" (SH1_The Project Team's School Visit).
3d. Gathering Knowledge about NST	Learning more about Nanoscience and Nanotechnology.	"In the beginning, we had less knowledge about NST and our knowledge has improved" (SH1S5-Post).
4. Increase in Awareness and Motivation	Increase in awareness and motivation of teachers in various aspects after guiding students along the exhibit development and the exhibition.	
4a. Increase in Self-awareness and Self-motivation	Increase in self-awareness and self-motivation in various aspects.	"Exhibition day was beautiful. It was an unforgettable experience for me. Visitors were very interested in our exhibit. They were really curious and they knew the exhibition. I was so impressed" (SH3S4-Post).
4b. Increase in Awareness about RRI	Increase in awareness about Responsible Research and Innovation and its importance.	"Studies done without regarding RRI may not contribute much in science" (SH2S1-Post).

Table 7.32. Themes and sub-themes identified under the benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications and the exhibition. (cont.)

Theme and Sub-theme	Explanation	Example
4c. Raising Awareness and Motivation of Others	Raising awareness and motivations of others including acquaintances, visitors and other students in school.	"There was a student (not from the Nano school club), who wore make up. One of the students asked her questions like "Did you check its label? Does it include ingredients? Did you search them? Are they healthy?" (SH3T1-Post).
5. Observation and Inspiration	Making observations in the exhibition and making some inferences.	
5a. Observing Other Exhibits and Getting Inspired by Them	Examining exhibits developed by other students in the project and making inferences about them.	"The exhibits developed by other schools gave me some ideas. I mean ideas about what can I do if I do something like that in the future" (SH3S6-Post).
5b. Observing Other Participants in the Exhibition and Getting Inspired by Them	Observing and communicating with other participants in the exhibition and learning from them.	"The exhibition provided us with meeting with new people" (SH3S1-Post).

"We worked on different parts of the project, but we didn't totally separate. We were helping each other" (SH2S1-Post).

"It was my first experience and it contributed a lot to me. My social circle even expanded. We developed projects by coming together from two different classes" (SH3S3-Post).

The third sub-theme addresses developing process management skills like organizational skills including time management skills. In addition, dealing with the challenges faced in the process has improved students' problem solving skills such as adapting the exhibits through the problems faced and the feedbacks, and thinking alternative ways for materials, technique or sources for support.

"We had faced with some problems in the prototype we built. Therefore, we developed the current final form of the exhibit design" (SH3S1-Post).

The fourth sub-theme referring another developing skills of students is about improvement in their effective presentation skills. Students believe they made a progress in developing quality of their presentation through practicing, feedback of their teacher, and help of their school club mates. The following statements can be given as example:

"We worked for the presentation. One of our group friend was more willing to make presentation, while we were more excited and concerned compared to him. However, thanks to him we felt more relieved after each practice" (SH1S5-Post).

"It contributed a lot in terms of presentation" (SH3S3-Post).

The last sub-theme is about developing skills in collecting, evaluating and reporting the data. As it is described before, most students developed questionnaire, mini quizzes or knowledge test as a part of their exhibits for learning about visitors' opinions on NST with respect to RRI. Most groups, collecting data from the visitors, evaluated the data they collected in the first day of the exhibition, and then shared it with the visitors in the second day of the exhibition. The statements below can be given as example:

"I prepared questionnaire including RRI questions. Then, I kept record of visitors' answers in a table" (SH3S1-Post).

"Visitors touched the exhibit and turned the tube upside down. Besides, they filled a questionnaire and placed it in a box. In the second day of the exhibition, we reported visitors the results of questionnaire answered a day before" (SH1S1-Post).

Table 7.33. The benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications.

Theme	Sub-theme	Type of Data Source					Participants	Benefits
REFLECTION AND EVALUATION	DOING SELF-REFLECTION AND SELF-EVALUATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Doing reflection and evaluation about their performance along the exhibit development (SH1, SH2, SH3) Doing reflection and evaluation on their own exhibits (SH1, SH2, SH3) (SH1T1, SH3T1) - Ways of improving the design - Ways of improving the RRI integration Doing reflection and evaluation on the projects or exhibits developed in the past regarding interactivity and RRI (SH2, SH3) Evaluating and reflecting on the exhibitions experiences in the past regarding interactivity (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
	EVALUATION OF OTHER ASPECTS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Evaluating other students' exhibits (SH1, SH2, SH3) (SH1T1, SH3T1) Evaluating visitors' opinions on RRI (SH1, SH2, SH3) (SH2T1)
							SH1	-
							SH2	-
							SH3	-
	GETTING AN EVALUATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Getting feedback from visitors about their exhibits (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Getting evaluation from experts including two science education experts, a scientist and science center manager (SH1, SH2, SH3) Getting feedback from their teachers and the school club mates (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
DEVELOPING SKILLS	DEVELOPING EXHIBIT MAKING SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing skills in making exhibits (SH1, SH2, SH3) (SH1T1, SH3T1) Developing skills in making exhibits interactive (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Developing skills in working with different materials (SH1, SH2, SH3) (SH1T1, SH2T1) Developing technical skills (SH1, SH2, SH3) (SH1T1, SH2T1)
							SH1	-
							SH2	-
							SH3	-
	DEVELOPING TEAMWORK SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Collaborating with group members (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Collaborating with other group members (SH1, SH3) (SH1T1, SH3T1) Collaborating with other teachers or staff in school (SH1, SH2) (SH2T1) Collaborating with students from other school clubs in school (SH1, SH2) (SH1T1, SH2T1) Developing communication skills (SH1, SH2, SH3) Developing skills in reaching a compromise (SH1, SH2, SH3)

Table 7.33. The benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Benefits
DEVELOPING SKILLS	DEVELOPING TEAMWORK SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing the sense of responsibility (SH1T1, SH3T1)
							SH1	Collaborating with students from different grade levels (SH1T1)
							SH2	-
							SH3	-
	DEVELOPING PROCESS MANAGEMENT SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing organizational skills (SH1, SH2, SH3) Developing problem solving skills: (SH1, SH2, SH3) (SH3T1) - Adapting the exhibits through the problems faced - Thinking alternative ways (materials, technique, sources for support) - Adapting the exhibits through the feedbacks Overcoming the challenges in the process (SH1T1, SH3T1)
							SH1	-
							SH2	-
							SH3	Developing time management skills (SH3T1)
	DEVELOPING PRESENTATION SKILLS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing effective presentation skills (SH1, SH2, SH3) (SH3T1)
							SH1	-
							SH2	-
							SH3	-
	DEVELOPING SKILLS IN DATA COLLECTION AND EVALUATION	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Developing skills in data collection (SH1, SH2, SH3) Developing skills in data evaluation (SH1, SH2, SH3) Developing skills in reporting (SH1, SH3)
							SH1	-
							SH2	-
							SH3	-
GATHERING KNOWLEDGE	GATHERING EXHIBIT MAKING-RELATED KNOWLEDGE	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Having more idea about ways of making an exhibit interactive (SH1, SH2, SH3) (SH1T1 Increase in material knowledge (SH1, SH2, SH3) (SH1T1, SH2T1) Increase in technical knowledge (SH1, SH2, SH3) Realizing the evolutionary and dynamic nature of exhibit development process (SH1, SH3) Having more idea about modelling a scientific phenomenon (SH1, SH2, SH3) (SH1T1 Having more idea about ways of making an exhibit interesting (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-

Table 7.33. The benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Benefits
GATHERING KNOWLEDGE	GATHERING EXHIBITION-RELATED KNOWLEDGE	**Interviews**	**Observations**	Weekly Logs	Field Notes	CoL Meetings	Common	Having more idea about student-created exhibitions (SH1, SH2, SH3) Having more idea about interactive exhibitions (SH1, SH2, SH3) Having more ide about science exhibitions (SH1, SH2, SH3) Understanding the importance of interactive exhibitions more (SH1, SH3)
							SH1	-
							SH2	-
							SH3	-
	GATHERING KNOWLEDGE ABOUT RRI	**Interviews**	**Observations**	Weekly Logs	**Field Notes**	CoL Meetings	Common	Increase in knowledge about RRI (SH1, SH2, SH3) (SH1T1, SH3T1) Learning thinking about RRI wrt NST (SH1, SH2, SH3) Learning about alternative ways for integration of RRI in exhibits (SH1, SH2, SH3) (SH1T1, SH3T1)
							SH1	-
							SH2	-
							SH3	-
	GATHERING KNOWLEDGE ABOUT NST	**Interviews**	**Observations**	**Weekly Logs**	**Field Notes**	CoL Meetings	Common	Increase in knowledge about NST (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) - Learning more about NST theme of their exhibits - Learning more about NST from other students' exhibits - Reinforcement of the module topics - Reinforcement of what is learned from the field trip to university laboratory
							SH1	-
							SH2	-
							SH3	-
INCREASE IN AWARENESS AND MOTIVATION	INCERASE IN SELF-AWARENESS AND SELF-MOTIVATION	**Interviews**	Observations	Weekly Logs	Field Notes	**CoL Meetings**	Common	Increase in self-confidence and self-motivation towards science exhibit development (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Having feeling of success (SH1, SH3) (SH3T1) Feeling important themselves (SH1, SH2, SH3) (SH3T1) - Having visitors who are curious about their exhibits - Getting feedback from the project team - Showing others their skills Increase in motivation towards transferring experience in doing other projects (SH1, SH2, SH3) Students realized that they can improve themselves (SH1T1, SH3T1)
							SH1	-
							SH2	-
							SH3	Students realized their own skills (SH3T1) Increase of performance in school lessons (SH3T1)

Table 7.33. The benefits of developing a RRI integrated interactive science exhibits on nanotechnology applications. (cont.)

Theme	Sub-theme	Type of Data Source					Participants	Benefits
INCREASE IN AWARENESS AND MOTIVATION	INCREASE IN AWARENESS ABOUT RRI	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Raising self-awareness about the importance of RRI in daily life (SH1, SH2, SH3) (SH1T1, SH3T1) Raising self-awareness about the importance of regarding RRI in a scientific research (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	Making evaluations in daily life regarding RRI (SH3T1)
	RAISING AWARENESS AND MOTIVATION OF OTHERS	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Opportunity to share what they did with visitors (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Raising awareness of visitors about RRI (SH1, SH2, SH3) (SH1T1, SH3T1) Raising curiosity of visitors about NST (SH1, SH2, SH3) Raising curiosity and interest of other students in the school (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1)
							SH1	-
							SH2	-
							SH3	Raising awareness of class-mates about RRI (SH3T1)
OBSERVATION AND INSPIRATION	OBSERVING OTHER EXHIBITS AND GETTING INSPIRED BY THEM	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	Opportunity to examine exhibits developed by students from other schools (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) Opportunity to learn from other exhibits (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1) - NST - Ways of RRI integration - Ways of interaction - Exhibit Designs - Different perspectives Inspiration for future projects (SH1, SH2, SH3)
							SH1	-
							SH2	-
							SH3	-
	OBSERVING OTHER PARTICIPANTS IN THE EXHIBITION AND GETTING INSPIRED BY THEM	Interviews	Observations	Weekly Logs	Field Notes	CoL Meetings	Common	-
							SH1	Opportunity to meet with students from other schools in the project, who went through a similar experience (SH1, SH2, SH3) (SH1T1, SH2T1, SH3T1)
							SH2	-
							SH3	-

The third theme is *Gathering Knowledge*, which covers learning of something new or elaboration of the existing knowledge in the processes of exhibit development and the exhibition. It involves four sub-themes, which are the same with the ones addressed in the benefits teachers obtained: (i) Gathering Exhibit Making-Related Knowledge, (ii) Gathering Exhibition-Related Knowledge, (iii) Gathering Knowledge About RRI, and (iv) Gathering Knowledge About NST. The first sub-theme covers increase in knowledge of students related with exhibit making. The corresponding benefits are having more idea about ways of making an exhibit interactive and interesting, increase in material and technical knowledge, understanding the evolutionary and dynamic nature of exhibit development process more, and having more idea about modelling a scientific phenomenon. The statement below can be given as example for students' gathering of exhibit-making related knowledge:

> "First of all we learned where we can find the materials. We saw that what kind of possible problems we may face while developing (an exhibit). We realized how it is important to make search (in the process)" (SH1S5-Post).

The second sub-theme is about gathering more knowledge about exhibitions. This improvement in students' knowledge is reported in depth in the Section 7.4., which base on their descriptions of exhibition, interactive exhibition and science exhibition before and after the exhibit development and the exhibition processes. On the other side, most of the students mentioned about gaining broader knowledge on exhibitions. The following statement can be given as example:

> "Before our exhibition, I had no idea about interactive exhibition. But after we developed one, we learned about it and we gathered more in-detail knowledge about it" (SH1S5-Post).

The third sub-theme under gathering knowledge is about enrichment of knowledge of RRI. After experiencing to integrate RRI in their science exhibits, students became more knowledgeable in terms of thinking about RRI with respect to a cutting-edge science topic, which is NST in this case, as well as comprehending the RRI dimensions more. This improvement was also pointed out by the students. The statements below can be given as example:

> "After we had learned that we need to integrate RRI in our exhibits, we made search about it on the Internet. We had idea about it before, but we learned a little more about it" (SH2S2-Post).

> "Actually, I learned what RRI is. We had never considered it before. I learned about the six dimensions of RRI such as "science education" regarding how science education should be done and how to develop it or "gender equality". These are things from daily life actually, but I learned that these six aspects are brought together as RRI" (SH1S5-Post).

The last sub-theme is Gaining Knowledge About NST, which addresses learning more about NST theme of their exhibits and reinforcement of the module topics and what is learned from the field trip to university laboratory through search done in the exhibit development process and the other students' exhibits in the exhibition. The statements below can be given as example for the third sub-theme, which covers increase in knowledge about NST:

> "It was nice because brushed up my knowledge coming from the module and I learned more over it" (SH1S2-Post).

> "While developing our exhibits, I learned how the (silver) nanoparticles kill the bacteria" (SH2S1-Post).

> "In the beginning, we had less knowledge about NST and our knowledge has improved" (SH1S5-Post).

> "We actually had information about the cancer. We had no idea about the interaction of cancer cells with gold nanoparticles. Later, we studied, we thought. We searched it on the Internet. Later we read the properties on the Internet. It was mentioning about the features of the cancer cells. We learned directly from there" (SH3S2-Post).

> "When we made search about usage area of nanoparticles and nanoscience on the Internet, we learned many useful and interesting information" (SH2S2-Post).

The forth theme identified under benefits for students is *Increase in Awareness and Motivation*, which comprises of three sub-themes as seen in Table 7.33. The first sub-theme, which is Increase in Self-awareness and Self-motivation, matches with the teacher-acquired benefits in the same category. Firstly, after attending in a science exhibition with their own exhibits promoted students' feeling of success. Besides, the analysis indicates that students have felt important in the process because of having visitors who are curious about their exhibits, getting feedback from the project team, and having opportunity to show others their skills. These facets of their experiences increased students' self-confidence and self-motivation towards science exhibit development and made them to realize that they can improve themselves. Furthermore, some students addressed their motivation towards transferring their current experiences in doing other projects. Apart from these, the teacher SH3T1 remarked two more aspects of gains of students from the process, which are realizing their own skills, and increasing performance in school lessons. The following statements can be given as example of students' increased awareness and motivations:

> "Exhibition day was beautiful. It was an unforgettable experience for me. Visitors were very interested in our exhibit. They were really curious and they knew the exhibition. I was so impressed" (SH3S4-Post).

> "In my previous experience, I had presented (my exhibit) in the corridor of my elementary school. This time, we went to the science center. We had visited there before display of our exhibits in there. It was very different. We made our own presentations at a place, where we once visited the exhibits in there. In the elementary school, our visitors were mostly family members and they were asking us questions just for we can explain (our exhibits). This time there were visitors asking questions seriously to learn about our exhibits" (SH1S1-Post).

> "I made an exhibit by myself. I mean I was capable of doing it by myself" (SH3S6-Post).

> "I developed another exhibit after the Project Irresistible. There is an additive called as "monosodium glutamate". I made an experiment about it and presented it in another school. My previous experience contributed a lot, especially in terms of (making) presentation. I was alone in the latter one, but I was less excited" (SH3S3-Post).

The second sub-theme is Increase in Awareness About RRI. Differently from the sub-theme Gathering Knowledge About RRI, which covers increase in "theoretical" knowledge of RRI, the current sub-theme addresses students' awareness about the importance of regarding the RRI in their daily lives as well as in research studies and their gain of "RRI perspective". The following statements can be given as example:

> "…I got a new experience about these (RRI dimensions). I understood that I need to regard them while developing a product" (SH3S5-Post).

> "Studies done without regarding RRI may go too far and end up with producing harmful substances or it may not be successful because it is not open to access of other scientists and the public. Studies done without regarding RRI may not contribute much in science. Other one (regarding RRI) might be more safe and more successful" (SH2S1-Post).

The last sub-theme is about raising awareness and motivation of others in different aspects such as RRI and NST. The data analysis revealed that some students consider the exhibition as an opportunity to share what they did with visitors not only for showing others their work, but also for others' learning. Therefore, most students were willing to took the responsibility for raising awareness of visitors about RRI and raising their curiosity about NST. The statements below can be given as example:

> "…Besides, we use gold nanoparticles in daily life a lot such as in DNA tests or pregnancy tests. We wanted to show it people and wanted people to say like "Oh! See? It is also used in these areas"" (SH1S5-Post).

> "We wanted to enrich the visitors and be able to create questions about nanotechnology in their minds after they visit our exhibit such as "Where does nanotechnology is used?", "Are there any risks besides the benefits?". We wanted to make visitors think about such aspects" (SH3S3-Post).

> "Some visitors wondered the mechanism of the exhibit and the electric circuit system of it. On the other side, some asked to learn more about the medicine (used in cancer treatment). I mean they wanted to learn about it more comprehensively than what we aimed" (SH1S3-Post).

In addition, students sometimes contributed in raising curiosity and interest of other students in the school in RRI as well as for the nano school club activities including the exhibit development process. The teacher SH3T1 describes how some students in the SH3 were trying to raising awareness of class-mates through "RRI perspective":

> "There was a student (not from the Nano school club), who wore make up. One of the students asked her questions like "Did you check its label? Does it include ingredients? Did you search them? Are they healthy?" (SH3T1-Post).

The last theme identified for the benefits obtained from the exhibit development and the exhibition processes is *Observation and Inspiration*, which consists of two sub-theme that are same with "the teacher-acquired" benefits under the same category: (i) Observing Other Exhibits and Getting Inspired by Them, and (ii) Observing Other Participants in the Exhibition and Getting Inspired by Them. The first sub-theme includes benefits like opportunity to examine exhibits developed by students from other schools, and to learn from them about NST, ways of RRI integration and interaction, exhibit designs, and different perspectives, which can be an inspiration for future projects. The second sub-theme involves the participants of the exhibition and addresses the opportunity for students to meet with students from different schools in the project, who went through a similar experience. The following statements can be given as example for benefits under the last theme:

> "In the exhibition, there were many people coming from different school and they socialized with each other. It really makes difference. For instance, when you all are from the same school, you have already know each other or at least familiar to each other, but in here, you interact with people you don't know. I think it contributes us a lot" (SH3S3-Post).

> "We met many new people while visiting the other exhibits" (SH1S2-Post).

> "The exhibits developed by other schools gave me some ideas. I mean ideas about what can I do if I do something like that in the future" (SH3S6-Post).

> "The exhibition provided us to meet with different people" (SH3S1-Post)

The overall analysis of challenges and benefits of developing a Responsible Research and Innovation integrated interactive science exhibit on Nanoscience and Nanotechnology, and in the exhibition revealed many challenges students faced in these processes classified under six themes and ten sub-themes, which include challenges from integrating of RRI to limited time. It also remarked many benefits students obtained in these processes, which are categorized under five themes and seven-teen sub-themes involving benefits from developing new skills to increase in motivation towards developing and exhibiting a science exhibit. Although many themes and sub-themes of challenges and benefits for teachers and students were common, there were some exceptions and additional ones mainly stem from the fact that the differences in their roles in the exhibit development and the exhibition resulted in having different experiences and perspectives throughout these processes.

8. DISCUSSION

The present study was designed to explore knowledge of group of high school teachers and students, who involved in the Project IRRESISTIBLE, about exhibitions, interactive exhibitions and science exhibitions before and after *the development and exhibiting of interactive science exhibit on NST integrating RRI)*, their practical approaches in the process, challenges they faced along the process, and benefits they obtained from their experiences in the process. With this purpose, the data from 3 science teachers and 13 high school students were collected through the pre and post interviews, video recordings of the school club periods and meetings done with teachers within the ongoing process, weekly logs filled by the participants, field notes of the researcher and the exhibits developed by the students.

8.1. Discussion with Respect to Change in Exhibition, Interactive Exhibition and Science Exhibition Descriptions of the Participants

The purposes of the RQ1 and RQ4 of this study is exploring respectively the teachers' and students' descriptions of exhibition, interactive exhibition and science exhibition before and after the exhibit development and exhibition processes.

The analysis of participants' exhibition descriptions reveals a remarkable improvement in their conceptions of exhibition, especially in terms of roles of exhibition. The participants addressed many aspects of the exhibition definition given in the literature review such as comprehensive grouping of exhibits, public display and promotion of varying types of exhibits, presentation of information for public use and catching up with recent developments (Dean, 1999; Dean, 2002; Dudley, 1990; Khoon and Ramaiah, 2008). The students also referred the potential of exhibits in changing public opinions, which is pointed out by Dean, (2002). Aside from these facets of the exhibitions, the participants also brought up evaluative role of exhibitions in terms of both exhibitors and visitors, i.e., it is opportunity for exhibitors to get feedback, while for visitors to make self-evaluation.

Similarly, there is an important transformation in participants' understanding of interactive exhibition, especially regarding the type of interaction, benefits of interactive exhibitions and elimination of alternative conceptions about it. The participants' post-descriptions of interactive exhibitions refer both "mental interaction" and "physical interaction" accordingly with McLean's (1993) interactive exhibition definition, which encompasses "conducting activities, gathering evidence, selecting opinions, forming conclusion, testing skills, providing input. The participants also mentioned of "reciprocity of action" which implies the reaction of exhibit in some way regarding visitor's input, establishes extensive interaction (Allen and Gutwill, 2004, p.199; Bitgood, 1991; McLean, 1993). Differently from the McLean's (1993) definition, the participants included also the verbal interaction between the visitor and the exhibitor through dialogue or questions&answer within the presentation of exhibits as an aspect of interactive exhibitions. This perspective might originate from their current experience, in which the students were in conversation with the visitors during their visits. Besides, the participants' addressed some advantages of interactive exhibitions such as enhanced relevancy, longer attention of visitors, facilitated meaning-making, ownership of learning process and unique experience for each visitor (Allen and Gutwill, 2004; Bequette *et al*., 2011; Bitgood 1991; Heath and Lhen, 2009; Hein, 2002; Labar *et al.,* 2006; McLean, 2011).

Finally, there is a slight difference in teachers' descriptions of science exhibitions which might be based upon the existence of their previous multi-experiences about science exhibitions and a minor shift in their descriptions towards describing their current experience of science fair as discussed before. On the other side, although most students had a background about science exhibition based on their self-experiences, there is a remarkable difference in their post-description of science exhibition with respect to its role and methods used in science exhibitions. The participants in their science exhibition descriptions mentioned about the opportunity it provides visitor with gaining insight about nature of science through their experience in exploring of scientific instruments, experiments, equipment or laboratory reagents, and recent scientific developments (Science Exhibition, 1946). In addition, the participants remarked the appropriateness of each element of science exhibitions to 'the proper realm of science' (Macdonald, 1998, p.2; Siegel, 2006).

The overall analysis of the participants' descriptions of exhibition, interactive exhibition and science exhibition indicates that the first-hand experience of being a part of an interactive science exhibition, which includes interactive exhibits developed by the student-participants, led them to gain more insight about these types of exhibitions and the improvement of their understandings on them.

8.2. Discussion with Respect to the Practical Approaches of the Participants in the Development of Exhibits and in the Exhibition

The aims of the RQ2 and RQ5 is to explore respectively the teachers' and students' practical approaches in the exhibit development and exhibition processes, which was defined as "practical applications, which base on their existing experiences, ideas and theoretical knowledge, in managing, handling or guiding a situation".

The practical approaches of the participants were classified under four categories regarding the stages in the processes of exhibit development and exhibition: (i) Practical Approaches in Pre-Production Stage, (ii) Practical Approaches in Production Stage, (iii) Practical Approaches in Managing the Overall Process, and (iv) Practical Approaches in Exhibition Stage.

8.2.1. Discussion Regarding Teachers' Practical Approaches in the Process

Firstly, the overall analysis of teachers' practical approaches in the pre-production stage, which were categorized under three themes, namely *Practical Approaches in Preparing for Exhibit Development Process*, *Practical Approaches in Finding an Exhibit Idea* and *Practical Approaches in Planning of Exhibits*, reveals that teachers took mostly common practical approaches as well as different ones. One of the reasons behind the commonalities in approaches might be the fact that teachers were guided along the exhibit development process starting with a workshop and continuing with in-process CoL meetings. On the other side, the differences in practical approaches in the pre-production stage might stem from the changing experiences of teachers in guiding students through exhibit development. For instance, SH1T1 and SH2T1, who have several experiences in exhibit development with students, seem to collaborate more with colleagues or technical staff to consult them in the exhibit planning phase compared to the teacher SH3T1, who had an only experience. Another reason of teachers' varying practical approaches in the pre-production stage might be changing facilities and opportunities of the school they work. For instance, SH2T1, who works in a private school, has Technology and Design Laboratory or Science Project Coordinator in their school; while the teachers SH1T1 and SH3T1, who works in public school, don't have such opportunities.

Secondly, the analysis of teachers' practical approaches in the production phase, which consists of *Practical Approaches in Making of Exhibits, Practical Approaches in Integration of RRI, Practical Approaches in Making Exhibits Interactive*, and *Getting Support in Production of Exhibits*, indicates that teachers showed mostly common approaches as well as different ones. For instance, in the integration of RRI in exhibits many common approaches of teachers besides the peculiar ones were identified. Nevertheless, there is no common practical approach shown only by SH1T1 and SH2T1, who have multiple experience in exhibit development with students. Interestingly, SH3T1, who had only one experience in guiding students along exhibit development, took the higher number of different practical approaches in RRI integration compared to two others. This situation might stem from the fact that guiding students about RRI was a brand new experience for all of the teachers and therefore, their previous experiences in exhibit development with students didn't make a difference at all. On the other side, the number of practical approaches taken by the teachers for making exhibits interactive is quite lower than the number of practical approaches shown in RRI integration. The reason behind it might be the fact that making exhibits interactive was an easier task for the participants compared to integrating RRI in their exhibits. Besides, the practical approaches of teachers showed difference based on their dependency to follow the module worksheets relating with the exhibit development process. Therefore, the teacher SH1T1, who followed the module worksheets step by step, guided more fruitful discussions about interactive exhibitions through addressing interactive exhibits in the science center, their experiences about interactive exhibits, and the advantages and disadvantages of the interactive exhibits. Furthermore, the teachers' practical approaches in getting support in the production of students' exhibits vary as well. For example, while the teachers SH1T1 and SH2T1 got support from colleagues or staff in their school, the teacher SH3T1 didn't get in-school support. The reason might be the fact that it was her first year in this public school and therefore she may not know her colleagues or the other staff like technicians working in the school very well. Besides, unlike the private schools like SH2T1 works in, the public schools don't have staff, who are experts in science projects, robotics or 3-d printers. The analysis shows that this is an important factor affecting teachers’ practical approaches while getting support.

Thirdly, the overall analysis of teachers’ practical approaches in managing the overall process, which were classified under three themes, namely *Practical Approaches for Motivating Students, Organizational Approaches*, and *Role of the Teacher*, remarks teachers’ common and varying approaches in these manners. The top three aspects teachers put effort in motivating students are their involvement in exhibit development process, their concerns about the ranking of exhibits in the exhibition and the RRI integration in their exhibits. On the other hand, the analysis of teachers’ organizational approaches shows that the teacher SH2T1 took more initiative in group formation, task sharing and time management, while other two let students to take their own decisions. Although, allowing students to use their own initiative were more time taking and leading more unstable group dynamics, it creates an opportunity to take more responsibility and develop organizational skills in these manners. In addition, the analysis also reveals that teachers’ organizational approaches vary depending on the facilities of the school like in the case of SH3T1, who doesn’t have an official weekly school club period. It led her to organize students out of the school for exhibit development. Furthermore, while describing their role in the process, teacher mentioned their guiding, coordinating, motivating and supervising roles. Teachers addressed the guiding role as guiding students by trying to make students to come up with their own ideas by directing them through questions and avoiding to state their own opinions directly. They described the coordinating role by referring their organizational approaches in time management, group formation, task sharing, setting of working place and dealing with formal procedures. Besides, they also addressed their aforementioned motivating and encouraging role. Finally, teacher explained the supervising role by referring following and checking students' progress to try to prevent any inconvenience, answering students' questions and supporting students in their struggles in the process.

Finally, the analysis of teachers’ practical approaches in the exhibition stage, which are collected under the theme *Practical Approaches in the Exhibition,* are being available at their school’s section in the exhibition area for visitors as well as for their students, and evaluating their own students' exhibits after seeing other students' exhibits. On the other hand, the teacher SH3T1, whose half of the students had no experience in developing and exhibiting an exhibit, addressed her involvement in students' presentation of their exhibits in the first day of the exhibition by explaining them the reason for their improvement, and then, letting students to have full control in their presentations in the second day of exhibition.

8.2.2. Discussion Regarding Students' Practical Approaches in the Process

Firstly, the overall analysis of students' practical approaches in the pre-production stage reveals that students mostly shown common approaches as well as few different ones, which were classified under two themes, namely *Practical Approaches in Finding an Exhibit Idea* and *Practical Approaches in Planning of Exhibits.* A reason behind the differences in students' practical approaches in this manner might be the differences in guidance of teachers in this stage. The second reason behind the differences in practical approaches in pre-production stage might be the differences in the facilities and opportunities provided by the school. For example, the students of the SH2, which is a private school planned to use 3-d printer in building of bacteria models because they have such opportunity and a teacher that can support them in this process. On the other hand, the school SH3's students, who have not such in-school opportunities, for instance, consulted people from out of school like carpenter or acquaintances for exhibit design and materials. Another factor creating differences in approaches taken by students might be the students' backgrounds and pre-experiences in developing exhibits and projects for science fairs or a similar organization. For instance, the SH2S1, who had developed science projects before for multiple science project contests and have a background in electronics were able to guide his teacher and other students in benefitting from electronic components that were planned to use in their exhibits, while they were planning materials.

Secondly, the students' practical approaches in the production phase were classified under four themes same with the teachers', which are *Practical Approaches in Making of Exhibits, Practical Approaches in Integration of RRI, Practical Approaches in Making Exhibits Interactive*, and *Getting Support in Production of Exhibits*. The analysis indicates that students showed mostly common approaches as well as different ones. For example, the analysis of student's practical approaches in RRI integration reveals many common and few different approaches of students. The reason behind the substantial commonality in practical approaches taken in integration of RRI. might be the fact that it was a new concept for students and they mostly followed the guidance of their teachers, whom practical approaches are also mostly common in this stage, rather than taking initiative for showing original practical approaches with this purpose. In addition, the analysis of students' practical approaches in making their exhibits interactive shows that the approaches taken by students are mostly in common. Nevertheless, the students in SH1 took few different approaches as well as the common ones. The parallelism in the different practical approaches of SH1 students and SH1T1 in making exhibits interactive might be the indicator of the fact that the difference among the students' practical approaches stems from following the guidance of teacher, especially in new experiences like in the case of RRI integration. Furthermore, the analysis of students' practical approaches related with getting support in production of their exhibits reveals some common aspects that students got support for such as technical issues, integration of RRI and motivation in the process. Most students got in-school support like support of students from other school clubs, other teachers and technical staff in the school as well as the Nanoscience school club mates, while some others got help from people out of school like family members or a carpenter. The people students ask help from also varies depending on their availability. For example, the private school SH2 students got support from the Science Project Coordinator and Technology and Design teacher in the school, while the other public school students had no such opportunity.

Thirdly, the analysis of students' practical approaches in managing the overall process, which were categorized under two themes, namely *Organizational Approaches*, and *Role of the Student*, points out some common and varying approaches of them in these manners. The students' organizational approaches reveal that their approaches in group formation, task sharing, time management and deciding working place show similarities and differences depending on varying factors such as following teacher guidance, their self-motivation, and the facilities and opportunities provided by their schools. For instance, the SH1 and SH3 students, who were more independent in taking initiative in organizational aspects, had more active group dynamics, while the SH2 students, who were mainly guided by their teachers in regard of their opinions, didn't form groups by following SH2T1's suggestion. Furthermore, while describing their role in the process, students commonly addressed finding an exhibit idea, making the exhibit, solving problems faced, demonstrating the exhibit to the project team and presenting the exhibit in exhibition. On the other side, the

SH1 and SH3 students, who worked in groups and were responsible for every aspect of their exhibit development experience, also addressed some of their additional roles in the process such as supplying materials, contributing other groups' exhibits and leading and organizing others in group.

Finally, the practical approaches of students in the exhibition stage were categorized under the theme of *Exhibition-Related Practical Approaches*, which includes students' preparation for the presentation and their practical approaches in the exhibition. The overall analysis of the students' exhibition-related practical approaches revealed mostly common practical approaches besides few exceptions. The statements taken from varying data sources show that making a good preparation for the presentation of the exhibit can be a factor leading to an efficient experience for the exhibit owner and visitors. While SH1 and SH2 students prepared for the presentation, SH3students preferred not to make a presentation plan but instead decide their presentation spontaneously within the exhibition. The explanation of the student shows that not making a presentation plan decreased the efficiency of their presentation. The involvement of the teacher SH3T1 also supports this argument. On the other side, the analysis indicates that examining other exhibits in the exhibition may encourage students to do self-reflection about their exhibits and their performances in the exhibit development process.

The overall analysis of students' practical approaches in the exhibit development and exhibition processes indicates that commonalities and differences in their practical approaches depend on many factors such as students' pre-experiences, self-motivations, familiarity of the task, following the guidance of teacher, and the facilities and opportunities provided by their schools.

8.3. Discussion with Respect to the Challenges and Benefits of the Development of Exhibits and the Exhibition for the Participants

The purpose of the RQ3 and RQ6 of the study is to explore the challenges respectively the teachers and students faced in the exhibit development and the exhibition processes, and also the benefits they obtained from their experience in these processes.

8.3.1. Discussion with Respect to the Challenges the Participants Confronted in the Process

The challenges teachers faced in guiding students in the exhibit development and the exhibition processes were classified under three themes including *Challenges in the Stage of Finding an Exhibit Idea, Challenges in the Production of Exhibits* and *Challenges in the Overall Process of Exhibit Development*.

Firstly, the challenges of guiding students in the phase of exhibit idea gathering is about feeling insufficient in guiding students through elaboration of their knowledge coming from what is learned in the module and from the field trip to the university laboratories. From this aspect, it differs from the challenge of this initial step addressed in the literature, which refers directly to difficulty of finding an idea for the exhibit (Tortop; 2013b).

Secondly, challenges the teachers confronted in the production of exhibits consists of challenges in RRI integration and lack of technical knowledge and skills. The main reason of having difficulty in guiding students in RRI integration is not having experience in teaching about topics like RRI, which was also identified in the study of Blonder and colleagues (2007). The inexperience of science teachers in this manner mainly stems from the absence of SSI in curriculum standards, which is referred in the literature about challenges of SSI education as an external constraint (Mansour, 2007; Sadler *et al.*, 2006). Another RRI-related challenge for teachers is understanding and internalizing the RRI dimensions, which brings other challenges together such as having difficulty in talking about RRI with students, and in relating all RRI dimensions with the NST theme of the exhibits. This situation shows resemblance with findings of Ratinen's and colleagues' (2015) study, in which the pre-service teachers had difficulty in integrating the governance, gender equality and engagement dimensions of RRI in their science lesson plans. Similarly, in Kolstø's study (2001), regarding SSI education, teachers had problems in finding appropriate topics that improve students' skills in interpreting statements about SSI. Finally, it was challenging for teachers to motivate students for integration of RRI. Students' inadequate background about such topics makes it harder to motivate them. Similarly, some studies on SSI education point out how lack in students' background based on STS constitutes a challenge for teachers (Kolstø, 2001; Levinson, 2006; Mansour, 2007). As a result of numerous challenges they face, teachers, including the ones in this study, find their guidance in RRI teaching insufficient (Venturi *et al.*, 2015). On the other side, additional to the challenges addressed in the literature, the second challenge teachers faced in guiding the production of exhibits is lack in their technical knowledge and skills. This situation directed teachers to ask for getting support if they have such an opportunity as it is discussed in previous sections. Teachers' tendency to seek for professional help in case of facing varying challenges also addressed in the studies of Grote (1995) and Tortop (2013b).

Finally, challenges teachers faced in the overall process of exhibit development covers limited time, challenges in process management and their other school-related responsibilities. Lack of time and space is the most common problem stressing and discouraging teachers in involving in extra-curricular activities like science fairs (Demirel *et al.,* 2013; Tortop, 2013a). Teachers in this study also mentioned about their time-related concerns. Besides, the data analysis revealed that the absence or shortage of official school club periods is another significant factors challenging teachers in finding extra time for such activities. In addition, the other responsibilities of teachers in the school is a limiting factor both in terms of time and their motivation. Finally, the analysis indicates that teacher, who has limited experience in guiding students through exhibit development, confronts with challenges in process management like having concerns like their guidance to be too directive or too superficial.

On the other hand, the challenges students faced in the exhibit development and the exhibition processes were categorized under six themes including *Concerns Just Before the Exhibit Development Process Challenges in the Stage of Finding an Exhibit Idea, Challenges in the Stage of Planning Exhibits, Challenges in the Stage of Production of Exhibits, Challenges in the Overall Process of Exhibit Development*, and *Challenges in the Exhibition.*

Firstly, one of the students' concerns just before the process base on having no experience in developing a science exhibit. In some cases, this inexperience brought together low self-confidence and low motivation for developing an exhibit like in the case of some of the SH3 students. Another aspect creating stress for some students is the ranking of exhibits in the exhibition, which was also addressed in other studies (Reis *et al.*, 2014; White *et al.,* 1963).

Secondly, the first crucial challenge students faced in the stage of finding an exhibit idea is finding an original idea, which does not directly relate with what is learned from the module or the university laboratories and is different from other groups' idea. This facet of gathering an exhibit idea was also addressed by some of the teachers. Similarity of the exhibit ideas on NST was also referred in the literature. Most of these projects on NST address environmental issues or health problems and are on similar topics such as "Cancer Treatment" and "Cleaning Up Oil Spills with Nanotechnology" (OCR, 2009; PCS, 2015; The Catholic Voice, 2015). The exhibits of students in this study supports this argument. From the 10 exhibits developed by the students in this study, 8 were about health, 4 were specifically about cancer treatment, and 2 were addressing environmental impacts of NST. On the other side, having alternative ideas about the necessities of exhibit is a limiting factor in finding an exhibit idea like in the case of some SH2 students, who thought the exhibits should be about silver nanoparticles because the module addresses it most.

Thirdly, in the planning of their exhibits, students had faced with some challenges because of lack in their material knowledge and knowledge about stores they can supply the materials. Besides, in most cases, students' exhibit designs were limited with respect to their material and technical knowledge as well as the limited time. The challenge of finding sources like required tools and apparatus to develop or experiment their projects was also addressed in some other studies (Tortop, 2013a; Reis *et al.*, 2014; White *et al.,* 1963). Furthermore, similar to its negative effect in the stage of finding exhibit idea, having alternative ideas about the necessities of exhibit is also a limiting factor in planning exhibit designs. The SH1T1's request from students to develop an exhibit design, which doesn't require any directions of the exhibit-owner while visitors examine it or the SH3T1's direction of developing models to make exhibits interactive can be given as example.

Fourthly, the lack of technical knowledge and skills was the first challenge students faced in the production phase. Tortop's (2013a) study also points out lack of students' knowledge in doing a project as a factor that creates difficulty for students in the production phase. The second challenge in the production stage is integration of RRI. Firstly, similar to the teachers, the students had no experience in learning or discussing about topics like RRI. RRI approach is a new for students and most of them have never related scientific content with a society in their school lessons before, which makes discussing on RRI is challenging for most students, even for the high-performing students (Blonder *et al.,* 2016). This factor decreases the chance of students' familiarity with the subject, which accordingly makes it difficult to understand some dimensions of RRI such as "governance" and "engagement". The difficulty of students in developing understanding on the "governance, engagement and ethics" dimensions of RRI was also remarked in the studies of Akaygun and colleauges (2015), and Adadan and Akaygun (2016). In addition, when it comes to searching about RRI for learning more about it, students had difficulty in finding sources about RRI, especially finding sources in their native language. Therefore, it was also challenging for the students to relate the RRI dimensions with the NST theme of the exhibit. Some students declared that although they know the meanings of each RRI dimension, they had difficulty in thinking each of them with respect to NST theme of their exhibits. Besides the value-based nature of RRI approach, which was also addressed in Blonder's and colleagues' (2016) study, makes it difficult to discuss on it such that there are many aspects to think on and there is no one right answer. Therefore, it was also challenging for students to regard objectivity in preparing questions or writing statements about RRI while integrating it in their exhibits.

Fifthly, similar to case in the teachers, the two of the challenges in the overall process of exhibit development for the students were limited time and their other school-related responsibilities like exam weeks, homework or attending seminars. On the other side, some students found it challenging to do teamwork firstly because having difficulty in finding a common time with group friends for working on exhibits. In some cases, like the SH3S1 and SH3S6, this situation ends up with giving up doing a group work but instead deciding to work individually in exhibit development. Not having an official school club period possibly made way for such ending. The other challenging facet of teamwork is determining a common work plan and following it accordingly. The challenging factor of setting a collaboration with others is also addressed by Şahin and Çelikkanlı (2014).

Finally, two challenging factors of the exhibition stage for some of the students were making presentation and physical facilities of the exhibition area. The challenges about presentation are overcoming excitement while presenting the exhibits, making an effective presentation and simplifying the presentation for younger visitors. On the other hand, the other factor creating challenges for students is physical facilities in the exhibition. For instance, the number of visitor some groups got in the exhibition was affected by the physical conditions in the exhibition area.

8.3.2. Discussion with Respect to the Benefits the Participants Obtained from the Process

The benefits the participants obtained from their experiences in the process were classified into five themes including *Reflection and Evaluation, Gathering Knowledge, Developing Skills, Increase in Awareness and Motivation*, and *Observation and Inspiration*. Although the benefits the teachers and students acquired collected under common themes, they show differences as well mainly because different roles of them in the process.

Firstly, the experience the participants went through encouraged the participants to do self-reflection and self- evaluation. While the teachers reflected and evaluated about their guiding performances, their knowledge, and their students' performances along the exhibit development as well as in the exhibition, most students' made self-reflection and self-evaluation about their performances in the process, their current exhibits and exhibits developed in the past regarding their interactivity and RRI, and also evaluated their exhibition experiences in the past regarding the interactivity. The study of Rogers (1956) also address the opportunity for teachers to evaluate their students' projects, whereas the study of Tirre and colleagues (2015) points out the chance for students to make self-assessment on their own research studies. On the other hand, the participants also evaluated some other aspects of the process based on situation assessment of the process and exhibition, and on performances of other participants regarding the NST theme, designs, interactivity and RRI integration of their exhibits. Besides, students got chance to evaluate visitors' opinions about RRI as well as NST. Another evaluative aspect of this process for the participants is getting a professional evaluation for their scientific endeavors (Fredericks and Asimov, 2001; Jones, 1953; Livingood, 1955; McBurney, 1978; Moore, 1958). In this study, the participants got an evaluation from the project team, which consists of the experts including two science education experts, a scientist and science center manager not only in the exhibition, but also within the ongoing process of exhibit development. The students also got feedback from their teachers and the Nanoscience school club mates within the exhibit development, and also from the visitors in the exhibition. The inferences the participants get from their reflections and evaluations have potential to increase the effectiveness of their experience in the exhibit development process and student-created exhibitions they involve in the future.

Secondly, the acquisition of new knowledge or the elaboration of the existing knowledge is another fruitful aspect of the exhibit development and the exhibition processes. After the participants involved in developing and exhibiting an interactive science exhibit on NST integrating RRI, they stated that their knowledge has improved in many aspects. First of all, they gathered more knowledge about exhibit-making including material and technical knowledge, making an exhibit interactive, modelling a scientific phenomenon as well as developing understanding about the evolutionary and dynamic nature of exhibit development process, which involves going back and forth among the different stages of the process. In addition, the participants' exhibition-related knowledge including knowledge in interactive exhibitions, science exhibitions, student-created exhibitions besides to exhibition area design. On the other side, working on RRI integration has contributed the participants' knowledge about RRI. Furthermore, involving in science fairs by developing a science project is an efficient way for students to learn about a subject because it provides learning about a new science topic as well as remembering old ones (Padovani *et al.*, 2013; Şahin and Çelikkanlı, 2014). However, guiding the exhibit development process also enhances teachers' scientific knowledge. For instance, in the Yeh's and colleagues' (2015) study, both teachers and students learned about fundamental NST concepts after developing exhibits with NST theme. Besides, in the Çolakoğlu's (2018) study, the increase in content area knowledge is among the expected outcomes of guiding students for TUBITAK 4006 Science Fairs. In this study, the participants' learned more about NST topic of students' exhibits, different nanoparticles, different nano-products and their usage areas.

Thirdly, developing varying skills is another advantage of involving in exhibit development and exhibition process for both teachers and students. Both the teachers and students mentioned about developing exhibit-making related skills consisting of many aspects from developing technical skills to creative skills. Besides, as Padovani and colleagues (2013) also point out, the students got some idea about how to make an exhibit more “user-friendly” for visitors at different age (p.5). Another contribution of this process is developing skills in teamwork (D’Acquisto and Scatena, 2006). The participants, in this study, developed teamwork skills through collaborating with other teachers, students from different school clubs, technical staff and the project team including experts in varying fields. The students developed skills in group work also through collaborating with group members and the Nanoscience School Club mates. Besides, this process was a chance for students to collaborate with students from varying grades (Tirre *et al.,* 2015). The studies of Marsee and Wilson (2014), and Şahin and Çelikkanlı (2014) remark that such collaborations contribute their interpersonal skills such as communicating and negotiating as well as intrapersonal skills like taking responsibility, which are also addressed by the participants of this study. On the other hand, being a part of the exhibit development process enhanced the participants’ process management skills such as organizational skills including time management, problem-solving skills or, like in the case of the teachers, the guiding skills. The findings of Reis and Marques (2016) also address such gaining in regard of students. Apart from these skills, the teachers also developed their skills in teaching about RRI because challenges the teacher faced in discussing about the RRI with students led them to seek for strategies to overcome these difficulties.

The exhibition process also provided students to develop some skills as well as the exhibit development process. The first contribution of it for students is improvement of presentation skills through practicing, feedback of their teacher, and help of their school club mates. The students in the study of Şahin and Çelikkanlı (2004) also state that they learn to control their excitement thanks to their presentation in a science fair. Another contribution of the exhibition for students is development of skills in collecting, evaluating and reporting data, which is also addressed in the study of Marsee and Wilson (2014). As it is described before, most students developed questionnaire, mini quizzes or knowledge test as a part of their exhibits for learning about visitors’ opinions on NST with respect to RRI. Most groups, collecting data from the visitors, evaluated the data they collected in the first day of the exhibition, and then shared it with the visitors in the second day of the exhibition.

Fourthly, some studies point out that providing students with a platform, at which they can share their knowledge and creations, and lead others, gives them the feeling that their voices and ideas are valued and matter, and so improves their confidence (Livingood, 1955;

Marsee and Wilson, 2014; Şahin and Çelikkanlı, 2014). Besides, involving in specifically science fairs with their own science projects enhances students' confidence and interest in science (TUBITAK, 2013a; Wartinger, 1999). It encourages students to be more active in science lessons and develops students' academic success in science (Padovani *et al.*, 2013; Şahin, 2012; Yıldırım and Şensoy, 2016). Similarly, in this study, attending in a science exhibition with their own exhibits promoted students' feeling of success. Besides, students have felt important in the process because of having visitors who are really curious about their exhibits, getting feedback from the experts, and having opportunity to show others their skills. These facets of their experiences increased students' self-confidence and self-motivation towards science exhibit development and made them to realize that they can improve themselves. In addition, a teacher addressed increase in some students' performance in school lessons after the process. Apart from these, a teacher also mentioned about rise in students' self-awareness about their own skills and interest, which is also remarked in Şahin's and Çelikkanlı's (2014) study. On the other side, the guiding experience of the teachers has improved the self-awareness and self-motivation of them as well. The teachers' declared that their self-confidence and self-motivation towards guiding students in exhibit development have increased. Furthermore, Galen (1993), as a teacher author, considers the whole process as an opportunity to know about students more and set a closer relationship with them. In this study, a teacher pointed out that this process provided her to realize their students' capabilities more and know them better. Finally, some of the participants addressed their motivation towards transferring their current experiences in their other performances. For instance, a teacher explained that she has started to use the approach she developed in this process in her classes and in her guidance of students for term projects. Similarly, some students addressed their increasing motivation towards transferring what they learned or inferred from this process in doing future projects.

In addition to increase in self-awareness and self-motivation of the participants and the teachers' awareness about their students, the participants' awareness about RRI has developed after the stage of RRI integration in exhibits such that their understanding the importance of RRI both in their daily lives and in science advanced more and they gained to evaluate the related issues they confront through RRI perspective. The studies of Blonder and colleagues (2016), and Venturi and colleagues (2015), which examine the process of RRI education, also address similar tendency of the teachers and students after learning about RRI. On the other hand, the students in this study addressed raising awareness and motivation of others in different aspects such as RRI and NST. Some students consider the exhibition as an opportunity to share what they did with visitors not only for showing others their work, but also for others' learning. Therefore, most students were willing to took the responsibility for raising awareness of visitors about RRI and raising their curiosity about NST. This situation is parallel with findings of Tirre and colleagues (2015), who point out an increasing understanding of students about the importance of science communication after they developed exhibits on NST regarding SSI. Furthermore, a teacher, in this study, pointed out rising motivation of some of her students in sharing of RRI approach with others like class-mates in another context. In the Blonder's and colleagues' (2016) study, on the other hand, similar approach were identified for the teachers after teaching about RRI.

Finally, the exhibition process is an opportunity for students to examine the exhibits in there and get inspired (D'Acquisto and Scatena, 2006; DeClue *et al.*, 2000). It may also contribute in their observational skills (Şahin and Çelikkanlı, 2014). In this study, not only the students but also the teachers mentioned how examining other exhibits were fruitful experience for them to get inspired for the future projects in terms of the NST theme, the RRI integration, the exhibit design and the interactive elements. On the other side, the exhibition is an opportunity for the teachers to come together with their colleagues and college scientists, and involve in an interaction, which might be a reference for future collaborations (Rogers, 1956). Besides, meeting students from other schools and sharing ideas with others is an important aspect of science fairs (Abernathy and Vineyard, 2001). In this study, both the teachers and students addressed the opportunity to observe, communicate with and learn from teachers and students from other schools, who went through a similar experience.

As a result, this study has a potential for contributing the literature through exploration of high school students' and teachers' knowledge on exhibitions and their experiences in interactive science exhibit development and in a science fair because as Şahin (2012) pointed out most of the research studies on science fairs involve elementary school students. Besides, this study can contribute the literature also through inclusion of Nanoscience and Nanotechnology (NST) in its scope because as it was remarked in the beginning studies involving teachers and students, who develop exhibits on NST are very limited

(Kampschulte, 2015; Tirre *et al.,* 2015; Yeh *et al.*, 2011). Finally, this study can contribute the literature through examination of students' experiences in integration of Responsible Research and Innovation (RRI) in their exhibits. Consequently, this research introduces some innovative elements, such as RRI integration, interactive exhibit and cutting-edge science theme, to the literature on science fairs.

8.4. Limitations of the Study

The present study is structured around qualitative design with the approach of phenomenological research, which depends on experiences of the participants around a certain phenomenon. Therefore, the data collected for examination of the participants' experiences mainly bases on the articulations of the participants' feelings and thoughts on their experiences in the interviews done with the researcher. This aspect of the study might be setting a barrier for the amount of data coming directly from the participants because in some cases it might have been difficult for the participants to reflect their thoughts comprehensively within the time they spared for the interviews. On the other hand, interviews with semi-structured nature created opportunities for the researcher to make instant shifts in the interview guideline with respect to the emerging needs. Besides, collecting data through multiple ways including the video recordings of school observations, field notes, video recordings of the teacher meetings in the ongoing process, weekly logs filled by the participants in the process contributed in the compensation of this limitation.

Secondly, because the exhibit development is a long process extended over time, it was not possible for the researcher to make observations other than the times determined for the school club periods of the three schools in the study. In this sense, the meetings done with the teachers in the ongoing process of exhibit development were helpful to catch up with missing aspects.

Thirdly, the human-based nature of this study makes it impossible to produce generalizable findings. On the other hand, it gives an in-depth examination of a certain phenomenon experienced by a group of participants.

Finally, the analysis of a qualitative data requires the researchers' interpretation, which inevitably lies upon assumptions, previous experiences and biases. The researcher explained her role in the process in detail as well as her related experiences to give an insight the reader in case of their further interest in the researcher's background.

8.5. Implications of the Study

Although the findings of a qualitative study with a phenomenological approach cannot be generalized, with the inclusion of the participants from different types of schools having varying school cultures, the participants with different backgrounds, and in-detailed descriptions of their experiences covering many aspects of their experience may give the readers substantial amount of ideas, which they may relate with their previous experiences or adapt them for their future projects.

Firstly, the time is one of the factors that stresses teachers and students in the exhibit development process. Therefore, it might be more efficient to extend such activities over a period of time regarding the complexity of task, students' related backgrounds and teachers' readiness for guiding such process. Besides, having periodic and common meetings like in official school club periods may enhance the quality of the exhibit development process for both students and teachers.

Secondly, collaborating with experts from a university and a science center may encourage teachers to involve in such processes more especially when they have limited experiences in this regard because it might be a relief for them to know they can get support in challenging situations. In addition, collaboration among teachers having different expertise while guiding students in exhibit development might be a fruitful process for both themselves and students in terms of enrichment of perspectives and learning from each other.

Thirdly, preparing a worksheet, which structures the process of the exhibit development through guiding questions, and then moving accordingly with it may increase the efficiency of the process. The related worksheet of the module Nano and Health, which is given in Appendix-A can be a guide for teachers, who want to prepare a similar document.

Fourthly, the lack of material and technical knowledge and skills is one of the factors making the exhibit development challenging for students and teachers. Therefore, it might be useful to spend few sessions for improving such knowledge and skills before the exhibit development process.

Fifthly, making field trips to science centers or university laboratories before the exhibit development process might be inspiring for students while picking an exhibit idea. However, seeing too much example of exhibits or learning about specific studies conducted in universities might be limiting for students' creativity and originality of their exhibit idea.

Sixthly, the exhibit development can be used to improve students' scientific knowledge base on science curricula or to developed their knowledge on cutting-edge science topics like NST, which are not involved in curricula or involved very limitedly.

Seventhly, developing interactive exhibits for science exhibitions may increase the efficiency of the exhibits for visitors because as it is addressed by many studies and by the participants of this study the interactive exhibits promote and improve learning by keeping attention of visitors, facilitating meaning making and allowing them to take ownership of their learning process (Allen and Gutwill, 2004; Bitgood 1991; Heath and Lhen, 2009; Labar *et al.,* 2006; McLean, 2011).

Eighthly, developing science exhibits addressing RRI might be used to reinforce the ability to think and discuss on scientific issues in regard of RRI and to improve the skills in teaching about RRI. To improve the efficiency of RRI integration in exhibits, it might be useful to make discussions with students on varying scientific topics with respect to the RRI framework for increase familiarity and internalization of RRI dimensions.

Finally, the findings of this study can be used to increase the quality and effectiveness of science fairs through regard of the challenges and the aspects teachers and students need support. Besides, the results of this study is promising in terms of encouragement of teachers and students in involvement both in national science fairs such as TUBITAK 4006 Science Fairs in Turkey, and also in international science fairs like Intel International Science and Engineering Fair.

8.6. Recommendation for Future Researches

The literature review indicates that most of the research studies on science fairs involve elementary school students (Şahin, 2012). There are also lower number of studies examining teachers' experiences in guiding students through exhibit development. Besides, projects or educational programs encouraging students to develop exhibits on NST are limited (Kampschulte, 2015; Laherto, 2011; Tirre *et al.,* 2015; Yeh *et al.*, 2011). On the other side, the studies about students' and teachers' experiences in the development of science projects regarding RRI or SSI are very limited. Finally, the studies encouraging students and teachers for development of interactive science exhibits are very limited. Therefore, there is need for future researches addressing high school teachers' and students' experiences in the development of interactive science exhibits on cutting-edge science topics like NST integrating RRI or SSI. In this sense, this study may give the researchers significant amount of ideas, which they may relate with or adapt in methodology and settings of their studies.

First of all, for closer tracing of the process of exhibit development, the researcher may conduct one more interview through the half of the process besides to the interviews done in the beginning and end of the process.

Secondly, working with participants, who have periodic official school club hours, might be more systematic and efficient for the researcher, who wants to observe exhibit development process of the participants. Otherwise, the researcher may set fixed periods together with teachers.

Finally, this study addresses few suggestions of students and teachers that can improve the quality of the exhibit development process and the student-created exhibitions. However, another research study might be conducted for exploring the participants' in-detail and direct suggestions for enhancement of these processes.

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APPENDIX A: THE CHAPTER 9. DEVELOPING AN INTERACTIVE EXHIBIT WORKSHEET OF THE MODULE NANO AND HEALTH

Name:...................................
Date:....................................

Chapter 9 – Developing an Interactive Exhibit
Week-1 Activity Sheet

Discuss the questions below in your group and answer the questions.

Week 1:

1. Have you ever been to an interactive exhibition? Describe that exhibition.
   a. What was it about?

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   b. How was interaction provided?

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   c. What were its positive and negative aspects?

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2. Please do some research on the internet and brainstorm ideas for **how** you might design your exhibition product. Write your ideas below.

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Figure A.1. The chapter 9 worksheet page 1. (Akaygun *et al.,* 2016)

RRI 3. Please do some Internet research and brainstorm individually or as a group about the ideas for an exhibition product related to *Responsible Research and Innovation in Nanotechnology Applications*. Write your ideas below.

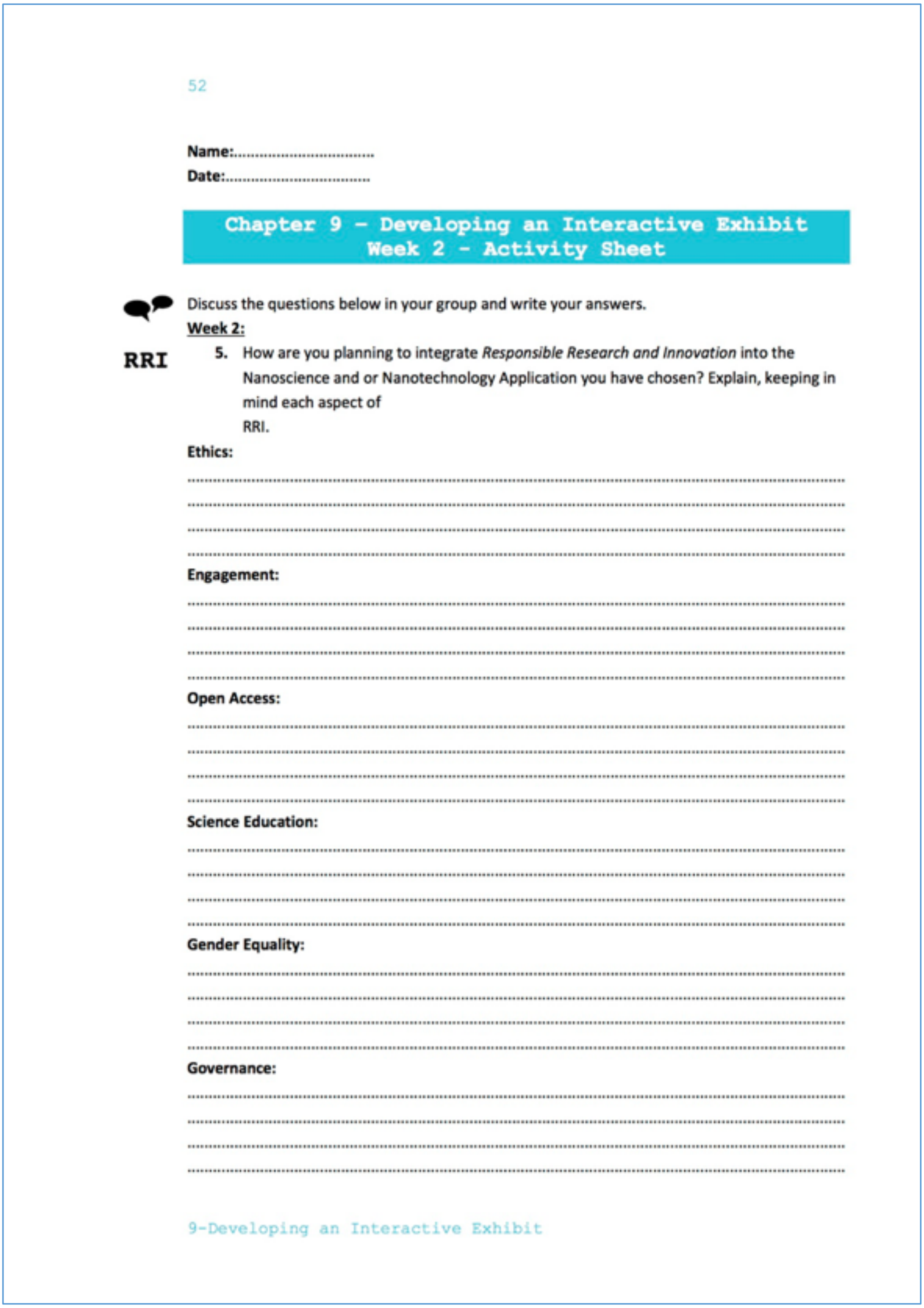
a. Which Nanoscience and Nanotechnology Application have you selected? Why?

b. How will you integrate Responsible Research and Innovation into the Nanoscience and Nanotechnology Applications? Explain.

You have 3 weeks to design and develop the exhibition product. Make a plan to develop your exhibition and write the steps of including dates.

Step	Date	To Do		Step	Date	To Do
1				12		
2				13		
3				14		
4				15		
5				16		
6				17		
7				18		
8				19		
9				20		
10				21		
11				22		

Figure A.2. The chapter 9 worksheet page 2. (Akaygun *et al.,* 2016)



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Name:..................................

Date:..................................

Chapter 9 – Developing an Interactive Exhibit
Week 2 - Activity Sheet

Discuss the questions below in your group and write your answers.

Week 2:

RRI

5. How are you planning to integrate *Responsible Research and Innovation* into the Nanoscience and or Nanotechnology Application you have chosen? Explain, keeping in mind each aspect of RRI.

Ethics:

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Engagement:

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Open Access:

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Science Education:

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Gender Equality:

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Governance:

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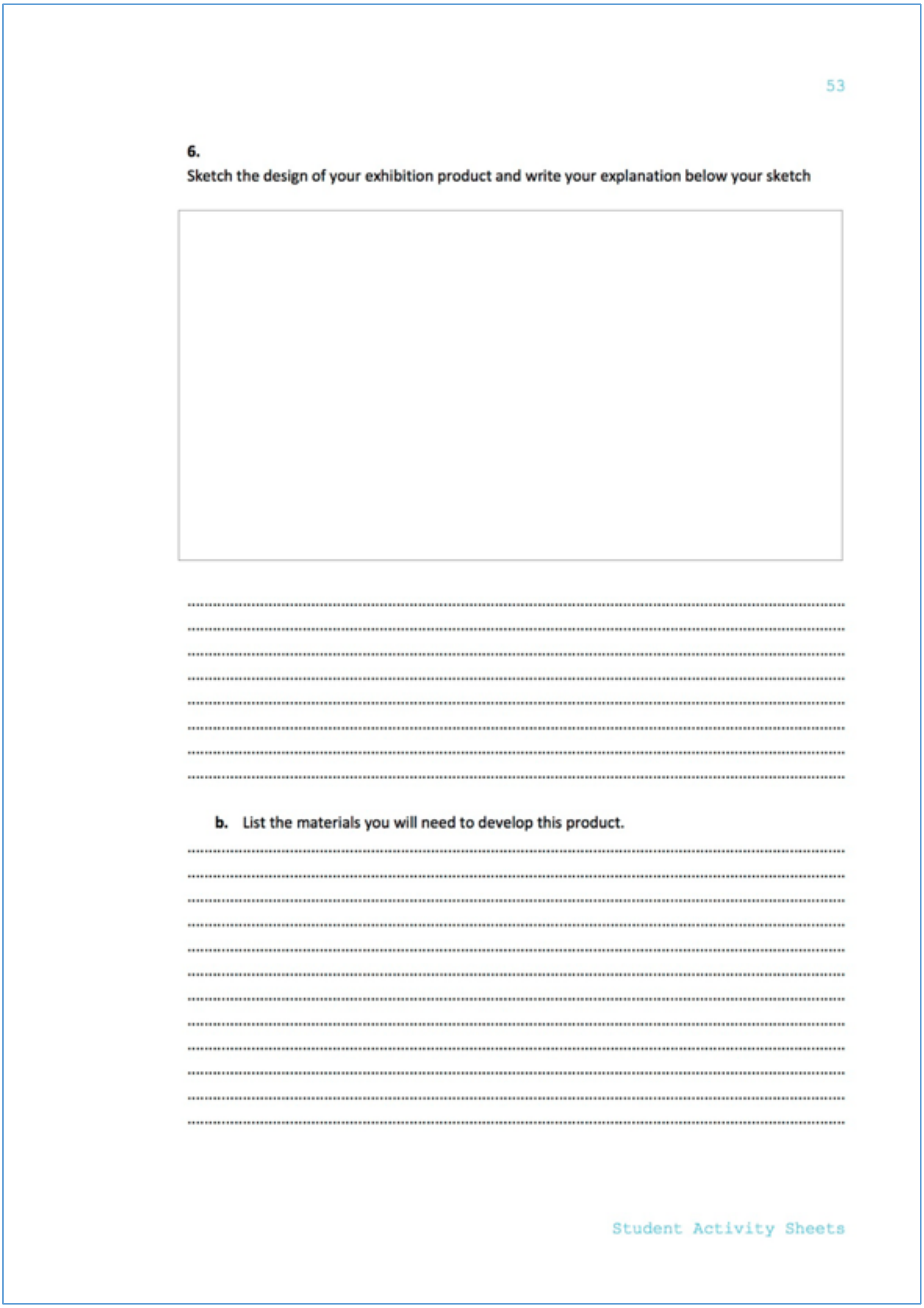
9-Developing an Interactive Exhibit

Figure A.3. The chapter 9 worksheet page 3. (Akaygun *et al.,* 2016)



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6.
Sketch the design of your exhibition product and write your explanation below your sketch

b. List the materials you will need to develop this product.

Student Activity Sheets

Figure A.4. The chapter 9 worksheet page 4. (Akaygun *et al.,* 2016)

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Name:.................................

Date:..................................

Chapter 9 – Developing an Interactive Exhibit
Week 3 - Activity Sheet

Discuss the questions below with your group and answer them.

Week 3:

7. Present your exhibition product to the class. Write the feedback you receive from the class in the space below.

9-Developing an Interactive Exhibit

Figure A.5. The chapter 9 worksheet page 5. (Akaygun *et al.,* 2016)

Name:..................................
Date:..................................

Chapter 9 – Developing an Interactive Exhibit
Week 4 – Activity Sheet

Discuss the questions below in your group and answer them.

Week 4

8. How you will revise your exhibition product in light of the feedback you received? Explain.

9. What you have learned from designing and developing your product?

10. What difficulties did you face in designing and developing your product?

Figure A.6. The chapter 9 worksheet page 6. (Akaygun *et al.,* 2016)

APPENDIX B: PRE-INTERVIEW PROTOCOL FOR TEACHERS

Would you introduce yourself briefly? What is your branch? How many years have you been teaching?

1.
   a. What is an exhibition? Do you know about the types of exhibitions?
   b. Do you have any knowledge about the interactive exhibit?
   c. Do you visit exhibitions in your daily life? Is there any exhibition that impressed you?
2.
   a. Have you ever visit a science exhibition?
   b. What do you think the unique characteristics of a scientific exhibition are?
3.
   a. Have you ever visited a student-created exhibition (project, science fair, etc.)?
   b. Do you have any experience on developing an exhibit or project with a group of students?
4.
   a. What kind of exhibits did you see before?
   b. What kind of exhibits do you think you and your students will develop?
   c. What kind of sources do your students benefit from in the exhibit development process?
5.
   a. What kind of role do you think you will have in the exhibit development process?
   b. Do you want to receive any kind of support before and during the exhibit development process?
6.
   a. What do you think your students should pay attention to in the exhibit development process?
   b. What do you think you should pay attention to while guiding along the exhibit development process?

7.

a. Do you think your students will face any difficulties in the exhibit development process?

   If yes, ask

   What kind of solution do you think to offer if you face such difficulty?

b. Do you think you will face any difficulties in guiding along the exhibit development process?

   If yes, ask

   What kind of solution do you think to offer if you face such difficulty?

APPENDIX C: POST-INTERVIEW PROTOCOL FOR TEACHERS

1.
   a. What is an exhibition? Do you know about the types of exhibitions?
   b. Do you have any knowledge about the interactive exhibit?
   c. What do you think the unique characteristics of a scientific exhibition are?
2.
   a. Have you ever visited a student-created exhibition (project, science fair, etc.)? Yes/No.
      If yes, ask 2.b.
   b. You have visited the student-created exhibition organized by the Project IRRESISTIBLE. What are the similarities and differences between this exhibition and the previous ones?
3.
   a. Do you have any experience on developing an exhibit or project with a group of students? Yes/No.
      If yes, ask 3.b.
   b. You experienced to develop an exhibit together with your students under the Project IRRESISTIBLE. If you think about this process from the beginning what have you experienced? Can you tell a bit?
      (Introductory speech for students on exhibitions, the phase of finding an idea, planning stage, developing stage and exhibiting stage)
   c. What are the similarities and differences between the current experience of exhibit development under the Project IREESISTIBLE with your previous experiences in this sense?
4.
   a. What kind of exhibits did you see in the exhibition organized by the Project IRRESISTIBLE?
   b. What kind of exhibit did you together with your students prefer to develop? Why?
      (Topic, type of exhibit)

c. When do you consider the themes of your students' exhibits, do you think they might be impressed by anything in the stage of finding an idea? Could they be impressed by something they learned in the module or in the field trips?

d. Did your students change their idea about the exhibit they were planning to do in the stages of planning and developing an exhibit? Why?

e. What kind of sources did your students benefit from in the exhibit development process?

5.

a. What was your role in the exhibit development process?

b. Did you need any kind of support before or during the exhibit development process? What kind of?

6.

a. What did you ask for students to pay attention to in the exhibit development process?

b. What did you pay attention to while guiding along the exhibit development process?

7.

a. Did your students face any difficulties in the exhibit development process?
If yes, ask
What kind of solution did they find when they face such difficulty?

b. Did you face any difficulties in guiding along the exhibit development process?
If yes, ask
What kind of solution did you find when you face such difficulty?

8.

a. Could your students make their exhibits interactive? How?

b. Could your students integrate Responsible Research and Innovation in their exhibit? How?

APPENDIX D: PRE-INTERVIEW PROTOCOL FOR STUDENTS

Would you introduce yourself briefly? Which school are you going to? What is your grade level?

1.
   a. What is an exhibition?
   b. Do you visit exhibitions in your daily life? Is there any exhibition that impressed you?
   c. Do you have any knowledge about the interactive exhibit?
   d. Do you know about the types of exhibitions?
2.
   a. Have you ever visit a science exhibition?
   b. What do you think the unique characteristics of a scientific exhibition are?
3.
   a. Have you ever visited a student-created exhibition (project, science fair, etc.)?
   b. Do you have any experience on developing an exhibit or project individually or with a group of friends?
4.
   a. What kind of exhibits did you see before?
   b. **If students have previous experience on developing an exhibit, ask**: What kind of exhibit(s) did you develop before?
   c. What kind of exhibit do you plan to develop with your group friends in this work?
   d. What kind of sources do you planning to benefit from in the exhibit development process?
5.
   a. **If students have previous experience on developing an exhibit, ask**:
      What kind of role did you have in your previous experience of developing a project, an exhibit etc.?
   b. What kind of role do you plan to have while developing an exhibit with your group friends in this work?

   c. Do you want to receive any kind of support before and during the exhibit development process?

6. What do you think you should pay attention to in the exhibit development process?
7. Do you think you will face any difficulties in the exhibit development process?

   If yes, ask

   What kind of solution do you think to offer if you face such difficulty?

APPENDIX E: POST-INTERVIEW PROTOCOL FOR STUDENTS

1.
   a. What is an exhibition?
   b. Do you know about the types of exhibitions?
   c. Do you have any knowledge about the interactive exhibit?
   d. What do you think the unique characteristics of a scientific exhibition are?
2.
   a. Have you ever visited a student-created exhibition (project, science fair, etc.)? Yes/No.
      If yes, ask 2.b.
   b. You have participated the student-created exhibition organized by the Project IRRESISTIBLE. What are the similarities and differences between this exhibition and the previous ones?
3.
   a. Did you develop an exhibit or project with a group of friends or individually before this project? Yes/No.
      If yes, ask 3.b.
   b. You experienced to develop an exhibit together with your group friends or individually in the Project IRRESISTIBLE. If you think about this process from the beginning what have you experienced? Can you tell a bit?
      (Teacher's introductory speech on exhibitions, the phase of finding an idea, planning stage, developing stage and exhibiting stage)
   c. What are the similarities and differences between the current experience of exhibit development under the Project IREESISTIBLE with your previous experiences in this sense?
4.
   a. What kind of exhibits did you see in the exhibition organized by the Project IRRESISTIBLE?
   b. What kind of exhibit did you prefer to develop? Why?
      (Topic, type of exhibit)
   c. How did you come up with this idea?

d. When do you consider the theme of your exhibit, do you think you might be impressed by anything in the stage of finding an idea? Could you be impressed by something you learned in the module or in the field trips?
e. Did you change your idea about the exhibit you were planning to do in the stages of planning and developing an exhibit? Did you develop the exhibit you were planning to in the beginning? Why?
f. What kind of sources did you benefit from in the exhibit development process?

5.

a. What was your role when you were developing the exhibit with your group friends or individually?
b. Did you need any kind of support before or during the exhibit development process? What kind of?

6.

a. What did you pay attention to in the exhibit development process?

7.

a. Did you face any difficulties in the exhibit development process?
   If yes, ask
   What kind of solution did you find when you face such difficulty?

8.

a. Do you think you could make your exhibit interactive? How?
b. Do you think you could integrate Responsible Research and Innovation in your exhibit? How?

APPENDIX F: THE TIMELINE OF THE FIELD NOTES TAKEN IN EACH SCHOOL

Table A.1. The timeline of the field notes taken in each school.

School	Number of Weeks of Observation	Number of Observation	Date the Observations Done
SH1	4	5	02/25/16 03/03/16 03/10/16 03/24/16
SH2	4	6	02/26/16 02/29/16 03/04/16 03/11/16 03/14/16 03/18/16 03/25/16
SH3	6	6	02/18/16 02/24/16 03/02/16 03/09/16 03/16/16 03/28/16

APPENDIX G: THE TIMELINE OF THE WORKSHOP ON EXHIBITION AND CoL MEETINGS HELD IN EXHIBIT DEVELOPMENT PROCESS

Table A.2. The timeline of the workshop and CoL meetings held in the exhibit development process.

Organization Type	Date
The Workshop on Exhibition	01/16/16
1st CoL Meeting	02/20/16
2nd CoL Meeting	03/12/16

APPENDIX H: AN EXAMPLE TRANSCRIPTION OF INTERVIEWS WITH PARTICIPANTS

	Öngörüşme_SH2S2	Notlar:
B.A.	Merhabalar, hoşgeldiniz.	
T.B.	Merhaba.	
B.A.	**Kısaca kendinizi tanıtabilir misiniz?**	
T.B.	11. Sınıftayım.	
B.A.	Hı hı, peki şu an sizinle daha önceki varsa deneyimlerinize yönelik ve ayrıca şu an biliyorsunuz bir sergi ürünü geliştireceksiniz buna dair varsa öngörülerinize yönelik bir görüşme yapmak istiyorum. Hazırsanız başlayabiliriz.	
T.B.	Tabii ki.	
B.A.	**Sizce sergi nedir?**	
T.B.	İnsanların kendi yaptığı şeyleri, kendi yaptığı yeni projeleri başkalarına göstermeye dayalı ve bunu tanıtmaya dayalı ve varsa da bu dolaşanların işte yeni şeyler öğrenmeye ve işte bu konu ile ilgili daha derin bir şeyleri keşfetmeye dayalı gibi bir proje gibi bir şey, proje.	
B.A.	Hı hı, tamam. **Peki günlük yaşamınızda sergi gezer misiniz?**	
T.B.	Evet. Bu hafta sonu tekne fuarını gezdim. Ondan önceki hafta da oyun fuarı vardı onu gezdim.	
B.A.	Hımm bayağı sıkı takipçisisiniz o zaman fuarların.	
T.B.	Evet.	
B.A.	Güzel. **Peki şimdiye kadar bunların arasından sizi etkileyen bir sergi ya da işte fuar vesaire oldu mu?**	
T.B.	Oyun fuarı etkilemişti. İlk turnuva şeyimi kazanmıştım. Onun dışında ben de 2-3 sergide şey yaptım. 7 ve 8. Sınıfta TÜBİTAK, ondan sonra da ilk senede FLL (First Lego Liege)'de gibi sergilerde kendi projemi sunma imkanı buldum.	
B.A.	Onlar da etkileyiciydi sizin için. Peki ee az önce bahsettiğiniz, ilk söylediğiniz sizi etkileyen sergi için ne demiştiniz?	
T.B.	Oyun fuarı.	
B.A.	Evet oyun fuarı. Orada sizi etkileyen şey neydi?	
T.B.	Eee sadece bakmak değil de bir etkileşim içindeydik. Yani ımm karşılıklı, nasıl desem? Onların gösterdiği şeyleri deneme imkanım olmuştu. Çünkü diğer fuarlarda öyle bir şey yoktu. Mesela tekne fuarına gittiğiniz zaman tekneyi deneyemezsiniz ☺.	
B.A.	Evet.	
T.B.	Anca görüyorsunuz. Ama onda deneme imkanım oldu. O yüzden de etkilemişti beni.	
B.A.	Aslında bak bu iyi bir fikir. Öyle bir ortamda yapılabilir tekne fuarlarında da denenebileceği yani gelen ziyaretçilerin deneyebileceği. **Peki ee daha önce etkileşimli sergi diye bir kavram duydunuz mu?**	
T.B.	Etkileşimli sergi. Mesela bir çıkarım yapabilirim.	
B.A.	Duymadınız ama bir çıkarım yapacak olursanız?	
T.B.	Etkileşim deyince karşılıklı olduğundan dolayı fuarı gezenlerin de bu arada hani sorular yöneltip karşılığında bir şey çıkartabildiği sergi midir bilmem.	
B.A.	Hı hı olabilir. **Peki sergi çeşitleri hakkında bilginiz var mı?**	
T.B.	Yok.	
B.A.	Hı hı. Mesela az önce söylediklerinizden belki örnek verecek olursanız, kendi deneyimlerinizden.	
T.B.	Sergi çeşitleri için mi?	
B.A.	Hı hı.	

Figure A.7. An example transcription of interviews with participant page 1.

T.B.	Pek çok konuda yani nasıl desem pek çok konuda sergi çeşidi yapılabilir. Yani pek çok çeşidi olabilir. Çünkü ee insanların bakmak istediği ve görmek istediği pek çok konu olabilir. Bilimsel açıdan, deniz tekne gibi işte bir çok hobiler üzerine yapılabilen pek çok sergi olabilir.	
B.A.	Hı hı peki çok güzel. Peki daha önce bilim sergisi gezdiniz mi? Mesela işte bilim merkezlerinde olabilir.	
T.B.	Yok bilim merkezlerinde gezmemiştim de bir kere annem ve babamla, annem öğretmen bu arada da, onların öğrencileri ile buraya insan anatomisi fuarı gelmişti, orayı gezmiştim.	
B.A.	Hımm, çok güzel. **Peki ee sizce bir bilim sergisinin kendine özgü özellikleri var mıdır?** Varsa nelerdir? Onu düşünecek olursanız mesela. Diğer gittiğiniz sergilerle karşılaştırabilirsiniz belki.	
T.B.	Tek farkı diğer sergilerde o kadar tanıtım yani sadece göstermek üzerineyken bilim sergisinde biraz daha nasıl desem ona gittiğinde orada duran görevli vardı, etrafımda durup bize anlatmıştı yani. Çünkü diğer sergilerde de belirli bir fikrimiz olabilir. Çünkü orada bir hobi üzerine yani bildiğimiz bir şey üzerine gidiyoruz fakat bilim sergisinde genelde öğretme amaçlı olduğundan dolayı	
B.A.	Hı hı öğretme amacı güder diyorsunuz.	
T.B.	Evet.	
B.A.	Çok güzel. **Peki daha önce bir öğrenci grubunun hazırladığı işte proje olabilir, okulda bilim şenlikleri olabilir vesaire bir sergiyi gezdiniz mi?**	
T.B.	Ben hazırladım ama belirli bir şeyi gezmedim.	
B.A.	Yani kendinizin katıldıkları vardı.	
T.B.	Evet.	
B.A.	Kaçıncı sınıflarda demiştiniz?	
T.B.	7-8 bir de 9-10.	
B.A.	Hımm bayağı bir deneyiminiz var.	
T.B.	9da FLL.	
B.A.	Hı hı. Peki bunları biraz detaylandırabilir misiniz?	
T.B.	Ne gibi?	
B.A.	Mesela bireysel miydi grup arkadaşlarıyla mı?	
T.B.	Grup arkadaşlarıylaydı. 7-8'de TÜBİTAK'ta. 7'de tam katılamadım. Sadece gösterme amaçlı. O yüzden fazla jüri de gelmedi insan da gelmedi. Sadece orada uzaktan pek etkileyici bir şey değildi.	
B.A.	Olsun.	
T.B.	Ama 8'de jürilere ve insanlara anlatma, oradaki gezen insanlara...	
B.A.	Ziyaretçilere...	
T.B.	Ziyaretçileri hani	
B.A.	Anlatma fırsatınız oldu.	
T.B.	Tam ziyaretçi miydi onu da bilemiyorum şu an. Çok eski olunca. Onlara anlatma tek kişi olduğum için öğretmenim de anlatmamı desteklemediği için tek başıma yapmak zordu ama 9 ve 10. Sınıfta jürilere grup olarak gittiğimizden dolayı üzerimden bayağı bir yük kalktı.	
B.A.	Hı hı, güzel. Orada belki biraz daha rahat hareket ederek anlattınız ürünlerinizi. Peki konuları neydi? Hatırlıyor musunuz?	
T.B.	7'de Geri Dönüşüm ile ilgiliydi, 8'de de kalori yakmakla ilgili bir şey yapmıştık. Yani gene sağlık konusundaydı. 9'da depremzedelerde ve inşaat çalışanlarına özel bir frekanslı bir kurtarma telsiz, telefona o telsizden eklenecek bir projemiz vardı. 10'da görme engelliler için periyodik tablo	

Figure A.8. An example transcription of interviews with participant page 2.

	yaptık.	
B.A.	Hı hı, çok güzel. **Peki daha önce ne tür sergi ürünleri ile karşılaştınız?**	
T.B.	Biraz açabilir misiniz?	
B.A.	Mesela örnek verelim. Diyelim ki işte body anotomy sergisine gittiğiniz zaman oradaki sergilenen ürün neydi?	
T.B.	Sergi ürünleri yaniii… nasıl cevap vereceğimi tam bilemedim.	
B.A.	Ya da işte atıyorum orada muhtemelen…	
T.B.	Sergi ürünleri tamam söyleyeyim bazılarının geliştirmiş olduğu projeler veya body anotomy'de de insan modelleri, adaleleri üzerinden sergi yapmışlardı. Tamamını gezemedim onun. Ama diğerlerinde ürün satmak amacıylaydı fakat oyun fuarına gittiğimde de orada benim de bulunduğum şeyler de kendi projemizi kendi yapacağımız ürünümüzü başkalarına sergilemek ve onların tanıtımını gerçekleştirmek için gitmiştim.	
B.A.	Hı hı çok güzel. Peki daha önce bir çok deneyiminiz olduğundan bahsettiniz ve neler geliştirdiğinizi de anlattınız. O yüzden şunu geçiyorum.	
T.B.	☺	
B.A.	Peki ımm **bu çalışmada şu an grup arkadaşlarınızla ne tür bir sergi ürünü yapmayı düşünüyorsunuz? Var mı aklınızda bir fikir?**	
T.B.	Şu an belirli 2-3 tane fikrimiz var ama hani tam net değil.	
B.A.	Neyler olsun? Belli olmayanları da öğrenebilirim?	
T.B.	Yani daha doğrusu hoca öğretmenimizin ilk başta bizi bir hani 2-3 fikrimiz var dedi ama önce sizden çıkması lazım dedi. Ona göre şey yapacağız ve biz de sadece işte öğrenciler arasında..	
B.A.	Tamam olsun. Ne yani. Kabataslak düşündüğünüz şey ne?	
T.B.	Şimdi pek şeyim yok, ona ben pek destek olmadım şuan. O yüzden pek bir şey diyemem.	
B.A.	Peki tamam. Şöyle sorayım o zaman. Diyelim ki sergi ürününe karar verdiniz ve bir ürün geliştireceksiniz. **Bu süreç boyunca ne tür kaynaklar kullanmayı düşünürsünüz?**	
T.B.	Imm günlük hayatta kullandığımız kaynaklar. Çünkü mesela ayrıyeten büyük masraflı ya da o kadar teknolojik şeyler kullanmak istemeyiz. Çünkü bu eee ürün sadece ütopik bir değer kazanır. Ama günlük hayatta kullandığımız basit bir şey olursa gerçekleştirilmesi daha kolay olduğu için daha da rahat gerçekleştirebiliriz.	
B.A.	Günlük hayatta kullanılan malzemeleri kullanmayı düşünüyorsunuz. Peki bilgi mesela diyelim ki o ürünü geliştirirken bir bilgiye ihtiyaç duyarsınız bu bilgiye nereden erişmeyi düşünüyorsunuz? Ne tür kaynaklar kullanmayı düşünüyorsunuz bunun için?	
T.B.	Önceden araştırılmış ise makaleler. Genelde evet makale ağırlıklı gidiyoruz.	
B.A.	Hı hı, makaleleri kullanırsınız.	
T.B.	…ımmm…	
B.A.	Peki şu an bu kadar geliyor aklınıza.	
T.B.	Evet.	
B.A.	Olur.	
T.B.	Çünkü makalelerde biraz daha bilimsel olduğu için. Mesela internet veya başka türlü kaynaklarda pek gerçek tam kesin, gerçeklik payı vermediğimizden dolayı sadece makaleleri göz önünde bulundururuz muhtemelen.	
B.A.	Hı hı, çok güzel. **Peki daha önce grup arkadaşlarınızla proje ya da sergi ürünü geliştirirken nasıl bir rol üstlenmiştiniz?**	
T.B.	Ürünü geliştirmede yardım, şey önceden deneyimim olduğu için sunumda	

Figure A.9. An example transcription of interviews with participant page 3.

	da epey bir katkım olmuştu ama ürünü geliştirme de, 10'daki periyodik tabo ve 9'daki o depremzedelere yatığımız telefon için çipte de, eee teknolojik kısımları üstlenmiştim. Bu programı yaratma gibi bir de işte sunumda. Çünkü üretiminin bir parçasında olduğum için o kısmı sundum.	
B.A.	Hı hı. **Peki şu an bu çalışmada nasıl bir rol üstlenmeyi düşünürsünüz?** Mesela işte daha çok şu şu kısmında yer almayı isterim gibi.	
T.B.	Genelde bunun sunum aşamasında olmak isterdim. Çünkü gelecek herhalde soruları biraz daha yetkin olduğumu düşünüyorum.	
B.A.	Hı hı cevaplandırma açısından.	
T.B.	Evet.	
B.A.	Hı hı, çok güzel. **Peki sergi ürünü oluşturma süreci öncesinde ya da bu süreç boyunca herhangi bir anlamda destek almak ister misiniz?**	
T.B.	Destek almak ister misiniz?. Imm..	
B.A.	Mesela herhangi bir konuda desteğe ihtiyacınız olacağını düşünüyor musunuz? Öyle de sorulabilir.	
T.B.	Desteğe ihtiyacımız olacağını düşünüyorum ama nasıl bir proje yapacağımıza bağlı. Sonuçta biraz daha bilgi gerektiren bir şeyse sonuçta nanoteknolojide şu an gördüğümüz gümüş nanoparçacıkalrın insan vücuduna ne tür zararları olduğu konusunda hala bir bilgimiz yok. O yüzden bu nanoteknolojilerin şu an gelişmekte olan bir bilim dalı olduğu için genelde bazı üniversitelerden ya da bazı araştırmalardan destek alacağımızı düşünüyorum.	
B.A.	Hı hı, çok güzel. **Peki sergi ürünü oluşturma sürecinde nelere dikkat etmeniz gerektiğini düşünüyorsunuz?**	
T.B.	Daha önce yapılmamış olması, özgün olması yani. Yararlı olması öncelikle. Ve dediğim gibi fazla ütopik değil de yapılabilecek bir şey olması.	
B.A.	Hı hı. **Peki bu süreçte herhangi bir zorlukla karşılaşacağınızı düşünüyor musunuz?**	
T.B.	Yeni bir ürün üretmede bence her şekilde bir zorlukla karşılaşacağımızı düşünüyorum. Çünkü yeni bir ürün üretmek gerçekten zor ve bunun her bir açıdan değerlendirilip öyle yapılması gerekiyor. Bu yüzden her açıdan değerlendirmek epey zorluklu, baş ağrıtıcı bir süreç.	
B.A.	Peki her açıdan değerlendirmek derken neyi kastediyorsunuz?	
T.B.	Bunun çevresel faktörleri, çevreye yararı veya zararı ya da insana zararları veya yararları, bunun nasıl karşılanacağı, nasıl direk yaşama geçirilebileceği ya da bunu daha iyisi olabileceği ya da daha önce olmuş şeyler gibi.	
B.A.	Hı hı, çok güzel. Peki diyelim ki bu kapsamlı düşünme kısmında zorluk yaşıyorsunuz. **Bu zorluğu aşmak için nasıl bir çözüm önerirsiniz? Nasıl bir çözüm bulmayı düşünüyorsunuz?**	
T.B.	Bu konu hakkında bilgi sahibi olan insanlara danışarak bunun başka açılardan zorluklarını onlardan öğrenebiliriz.	
B.A.	Hı hı daha bilgi sahibi kişilere danışmak şeklinde.	
T.B.	Evet.	
B.A.	**Peki daha önceki deneyimlerinizde bir zorlukla karşılaşmış mıydınız?**	
T.B.	Evet. Sunumda 8 ve 9'da bu ürünün yapımında bana çok fazla katkıda bulunan arkadaşlarım seminere gelmemişti. O yüzden 8'de tek başımaydım. 9'da da grup olmama rağmen genelde hani artı sorular bana geldiğinden dolayı biraz zorlanmıştım.	
B.A.	Peki şu an öyle bir zorluk yaşamamak için ne yapmayı düşünüyorsunuz?	
T.B.	Herkesin bu işte bir katkısı olacağını düşünüyorum. Çünkü buradaki	

Figure A.10. An example transcription of interviews with participant page 4.

	arkadaşlarımın hepsi cidden çalışkan ve bunu yapmak için gelmiş insanlar. Çünkü hocamız burada bize böyle bir şey, böyle nanoteknoloji alanında bir araştırma görevi olduğunda buna biz büyük bir istekle geldik buraya. Hepsini de tanıdığım için bir sorun olacağını düşünmüyorum.	
B.A.	Görev paylaşımı iyi olursa o zaman bir sorun olmayacaktır.	
T.B.	Evet.	
B.A.	Güzel. Peki benim sormak istediklerim bu kadar. Teşekkür ederim. Sizin eklemek istediğiniz bir şey var mı?	
T.B.	Yok teşekkürler.	
B.A.	Tamam.	

Figure A.11. An example transcription of interviews with participant page 5.

APPENDIX I: AN EXAMPLE OF FIELD NOTES

03032016 KAL SH1O2 Field Notes

- SH1T1.: Bir ürün yapmak zorunda değilsiniz. Birden fazla yapabilirsiniz.
- SH1T1.: Ürünleri yeniden bir gözden geçirelim. Sonra SAİ unsurlarını nasıl entegre ederizi konuşacağız.
- *Öğrenciler Etik unsurunu nasıl dahil edebileceklerini soruyorlar.

  SH1T1: Sizin ürününüz insanlık için yararlı mı zararlı mı?
- **Grup 1:**

  Alçıpan: Nano boya ve normal boya

  Su tabancası ile iki yüzeye de kir sıkma

  SH1S5: Cam olsun daha iyi gözlemleriz.

  *Toplumsal Paydaş Katılımı → ziyaretçi kendi gelip yapıyor.

  Diğer boyutları ya da nedeni (kir tutmayan yüzeyin arkasındaki neden) poster ile açıklamak

  SH1T1: Kendisinin ulaşması ve 6 maddeyi düşündürmesi

  SH1T1: Yönetişim → kuralları kimler koymuştur?
- SH1S4: Hiç aşağıya inmediğinde canlı hücrelere bir şey olmadığını göstermek. ?????
- **Grup 2:**

  NPler zararlı olabilir mi? Bunu göstermek.

  Kan: Su+Kırmızı gıda boyası

  NP: Demir tozu

  Vücudun ortasına mıknatıs.

  Etik→ Bilgilendirmeyi amaçlıyoruz

  Toplumsal paydaş katılımı→ Toplu

  Bu ürünün demir tozu devinimi üzerine tartışılıyor.

  Bir öğrenci İTÜ'deki ürünleri örnek vererek "Tamamen otomatik değildi. Elle manipülasyon vardı. Yarı otomatik."
- **Grup 4-5:**

  Devre: Üst bölüm kanserli hücre, alt bölüm sağlık hücre

  Devrenin tamamlanması hücrenin ölmesini temsil ediyor.

  Bir bilgi yarışması da hazırlamayı planlıyorlar. PPT kullanmayı düşünüyorlar.

  Etik→özgün bir fikir olması

  Toplumsal paydaş katılımı→ ziyaretçi

  Cinsiyet eşitliği→ Bir kız bir erkek sunum yapması

  Yönetişim→ Yöneten ve yönetilenlerin bir arada çalışması: öğretmen-öğrenci-okul idaresi

  Öğretmenleri bu işin ne kadar içerisinde var?

  Bir ürün geliştirdiniz. Bu ürünün kullanımına kimler karar verecek?

  Uygulanabilirliği aşamasında...

  *Bir öğrenci: Bu bir sergi ürünü. Bunu sergi esnasında nasıl gösterebilirsiniz ki?

  SH1T1: Okul idaresi bunu yapmanıza izin vererek destek oluyor.
- **Grup 6:**

Figure A.12. Example of field notes page 1.

Fikir 1:

Büyüklük ve ölçek

Fikir 2:

Hastalıklı ve sağlıklı hücre

İki ayrı cam küre

Ana tema: Fiber ipliklerle sağlıklı hücreyi koruma

Su geçişi için kürenin alt kısmı açık olacak

Erişime açıklık→Halka açık bir sergi

Fen eğitimi→

Etik→ Çevreye zarar vermeyen bir ürün. Zararları olsa bile insanlara yararlı bir şey yapmaya çalışırken çıkan zararlar ve bunları telafi etmeye çalışıyorlar.

- Fikir bulma aşamasında öğrenciler modül derslerinde öğrendiklerini ve Boğaziçi Üniversitesi laboratuvar gezisinde öğrendiklerini gözden geçiriyor.

Comment: Bilimsel bir konuyu SAİ bakış açısı ile değerlendirme becerisi kazanma

Comment: Öğretmenin öğrencilerle sosyobilimsel konular üzerine tartışma becerisinin gelişmesi

Figure A.13. Example of field notes page 2.