Deliverable Report

Deliverable D3.6	Recommendations on how the organisational form for Nano Risk Governance should train and educate civil society and insurers - Showcases and best practice examples
Due date of deliverable	2022/04/30
Approved by MC	2022/05/23 (by written procedure)
Actual submission date	2022/05/23 uploaded to EC portal
File name	D3.6 - Recommendations on training_final

Author(s) and beneficiary acronym:	Lead authors: Véronique Adam (TEMASOL) Beatrice Salieri (TEMASOL) Blanca Suarez-Merino (TEMASOL) Devendra Joshi (TEMASOL)
Work package/task:	WP3 / Task 3.3
Document status:	draft / final
Confidentiality:	confidential / restricted / public
Key words:	

DOCUMENT HISTORY

Version	Date	Reason of change
1.0	25.08.2021	Beatrice Salieri first draft
2.0	10.02.2022	Veronique Adam second draft
3.0	01.03.2022	Blanca Suarez-Merino third draft
4.0	11.03.2022	Veronique Adam fourth draft
5.0	27.04.2022	Susanne Resch WP3 leader review
6.0	28.04.2022	Veronique Adam final version

Lead beneficiary for this deliverable: TEMAS Solutions GmbH Switzerland

Owner(s) of this document TEMASOL	
Owner of the content	TEMASOL

Dissemination Level:			
PU	Defined in the DoA	Public	PU PP RE CO
PP		Restricted to other programme participants (including the Commission Services)	
RE		Restricted to a group specified by the consortium (including the Commission Services)	
CO		Confidential, only for partners of the consortium (including the Commission Services)	

1.	Gov4Nano Advisory Board	Yes
2.	NMBP-13 NANORIGO	Yes
3.	NMBP-13 RiskGONE	Yes

Table of Contents

1 Summary

TEMSOL collected literature and existing experience on training and education in the field of nanotechnology. The literature review aimed to support future training activities and to understand what the needs are for potential trainees. It also supports the understanding of best practices and effectiveness of different training and educational methodologies. It highlighted that the main barriers for an effective training and education in nanotechnology is the educational background of the audience. In addition, the literature review revealed the need of "educated and trained" teachers or course leaders in the topic of nanotechnology.

Then, TEMASOL organized and conducted an online workshop entitled "Nanotechnology and its implications to society: Training session on risks, benefits and governance" for scientists at early career stages (PhD students and post-docs). Five topics were covered during the workshop: 1) Perception of risks and benefits; 2) Safe-and-sustainable-by-design; 3) Risk assessment; 4) Risk governance, and 5) Regulation for nanomaterials.

2 Description of task

Task 3.3 aims to interact with people from civil society on the one hand and (re-)insurance industry on the other hand. Its aim is to facilitate out-of-the-box thinking related to current experimental, informatics and modelling practices and to enable civil society to form their own non-biased opinion. Key actions consist in:

- Developing and conducting training and education activities with civil society and (re-)insurance industry
- Evaluating the risk perception indicators and providing feedback to Tasks 3.1 and 3.2.

To this aim, lectures, training and education activities were built and suggested to these stakeholders.

3 Description of work & main achievements

3.1 Background of the task

The overarching objective of the Gov4Nano project is to develop a proof of concept of an efficient and effective risk governance process for nanotechnologies, encouraging a participative and pro-active form of governance. In this aim, the organisational form for nano risk governance will involve all relevant stakeholders, including civil society and insurance industry, understanding their needs and concerns about nanotechnology to overcome any barriers to stimulating their dialogue. Activities addressing training, education and out-of-the-box thinking will on the one hand enable the project partners to understand how training and education can help various audiences build their opinion on such an emerging and fast-evolving technology, and on the other hand help raise awareness and involvement from such stakeholders.

Within WP3, specific focus is given to two specific stakeholder groups: civil society and (re-)insurance industry, to understand how their risk perceptions are formed and how risk communication is communicated and received. Another (related) WP3 objective is to elaborate and conduct training and education activities to help stakeholders build their own opinion on nanotechnology. Task 3.3 and the present deliverable (D3.6) are dedicated to these training activities, which are described below.

3.2 Description of the work carried out and methodology

3.2.1 Literature review

TEMASOL collected literature and existing experience on training and education in the field of nanotechnology. The literature review aimed to support future training activities and to understand what the needs are for potential trainees.

3.2.2 Workshop for training in nanotechnology safe-and-sustainability-by-design, risk assessment and risk perception and associated survey on risk perception

An online workshop entitled "Nanotechnology and its implications to society: Training session on risks, benefits and governance" was prepared by TEMAS Solutions for scientists at early career stages (PhD students and post-docs). Invitations to the workshop were sent to members of the group Early career researchers in nanotechnology, of NMBP13 projects (Gov4Nano, NANORIGO, RiskGONE), NMBP15 projects (ASINA, SABYDOMA, SAbyNA, SbD4Nano) and to all working groups of the NanoSafety Cluster. Five topics were covered during the workshop: 1) Perception of risks and benefits; 2) Safe-and-sustainable-by-design; 3) Risk assessment; 4) Risk governance and 5) Regulation for nanomaterials. Literature reviews and the authors' own knowledge were used to create the content of the workshop, which was divided in three parts:

- Introductory lecture to the various topics of the workshop (30 min);
- Brainstorming session in groups of 3 to 4 participants (2h45, in Zoom breakout rooms using a Mural training support);
- Restitution of ideas and feedback from each group to all participants (45 min).

The workshop was associated to two questionnaires:

- The first questionnaire was sent to all registered participants to understand their perceptions of nanotechnology. It was divided in four sections: 1) General information and knowledge of nanotechnology; 2) Training in sustainability, safety and risk assessment; 3) Perception of nanotechnology and 4) Trust in nanotechnology governance. It contained 26 questions in total.
- The second questionnaire was sent to all attending participants (14 people) to get feedback on the workshop and comments on potential improvements. It includes 3 sections (1 – General feedback; 2 – Introductory lecture; 3 – Brainstorming session) and 17 questions in total.

3.2.3 Insurance

Script Development

The activities surrounding insurance companies started with the production of a script to approach them based on why Nano Risk Governance was an important topic to be taken into account by the (re)insurance sector. The main items of the script are highlighted below:

- A proactive risk management approach to address emerging risks is essential to avoid unnecessary material and financial losses, linked to workers, consumers, and environmental health, and to avoid legal charges of negligence
- Insurance companies are at the forefront to provide risk management consultancy for non-conventional (emerging) industry sectors, but not all companies are looking for insurance, or are aware that they might need insurance support
- Risk management of a technological application at a country level is translated as Risk Governance. EC is developing a model for emerging risks governance, starting with nanotechnology, but already considering advanced materials and new products

- While nanotechnology currently on the market is covered for the most part by regulations, there is a future where new nanotechnology applications (e.g. active nanoparticles) will be developed, creating new risks which need to be addressed from now (creating products and approaches for the business of the future)
- Insurance is a key stakeholder of governance of an emerging technology application, and they should be an active part of the governance process, which could then be translated into applicable (business) knowledge and development of tools for insurance needs
- Insurance aim is to reduce uncertainty to be able to quantify risks properly and have at the same time proper and effective risk management processes, so models, data and other tools that could support this scope are useful
- In addition to the advanced services, there is a need for insurance products that can be applied to SMEs, and that can be less tailored and more generic, to allow for a faster, and at the same time safer implementation of advanced materials in products.

The activity was structured in two phases. The first phase was based on a survey, delivered with a google form by email. The aim of this first short survey was to collect preliminary information on risk management and the process by which the risk is determined and managed. An optional interview, followed in some cases, either face to face or by phone. The interviews content was based on the answers to the surveys, including the process taken to get to the responses, as well as questions regarding what information was needed about the emerging risks before making these informed decisions.

Incentives:

- Introduce insurance needs in the growing risk governance community
- Promote development of specific training material tailored to insurance needs to address risk management of emerging risks also at local agency level
- Increase the pace of translation of tailored special insurance service into general marketable products for SMEs (increasing the market)
- Benefit from outcomes of our interviews with small and medium nanotechnology companies about their needs of insurance products
- Benefit from the results of governance EU projects in terms of knowledge, strategies, and methodology platforms for risk governance.

Presentation material

The following preparatory material was produced to approach the (re)insurance sector and discussed with the Swiss Insurance Association.

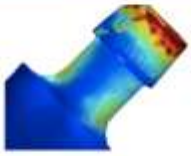
Managing the uncertainties regarding Emerging Risks in the insurance sector

Gov4Nano
meeting the needs of nanotechnology

Micheletti C, Joshi D, Suarez-Merino B

Nanotechnology as an example: uncertainty

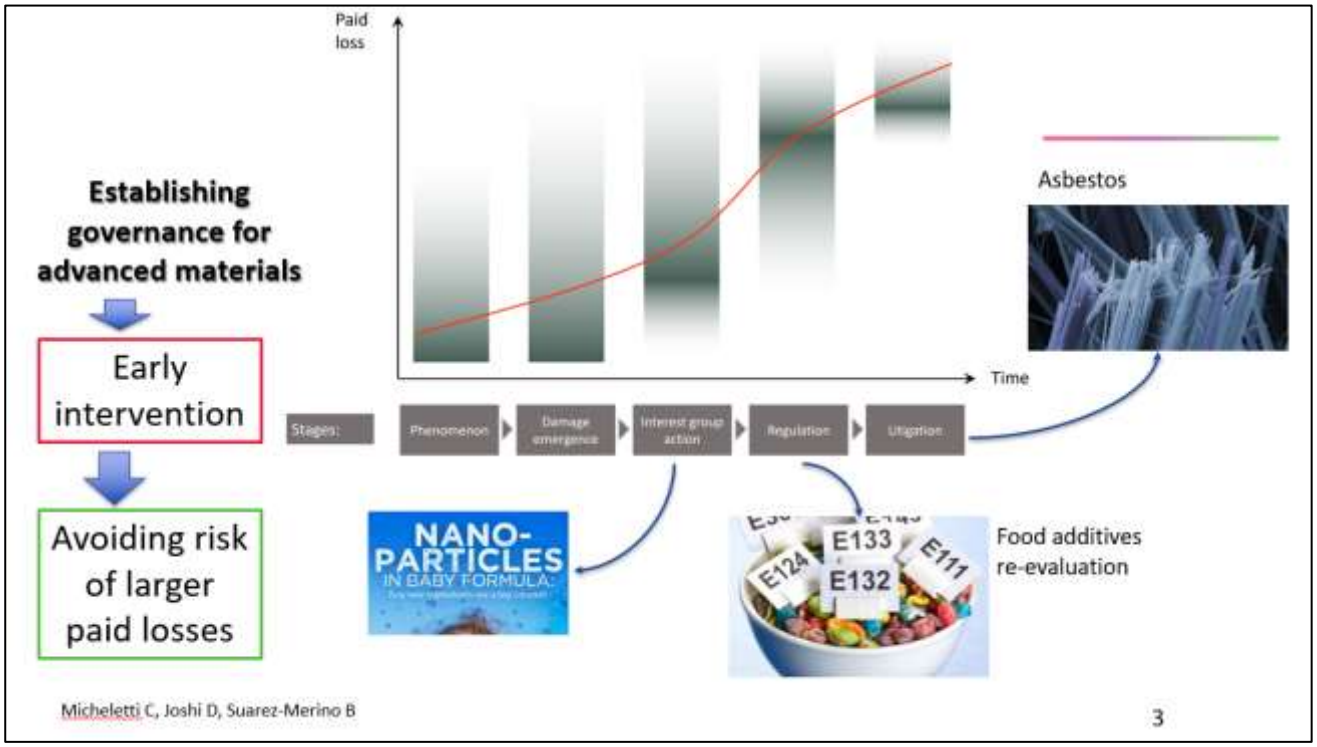
Tattoo Ink Migrates

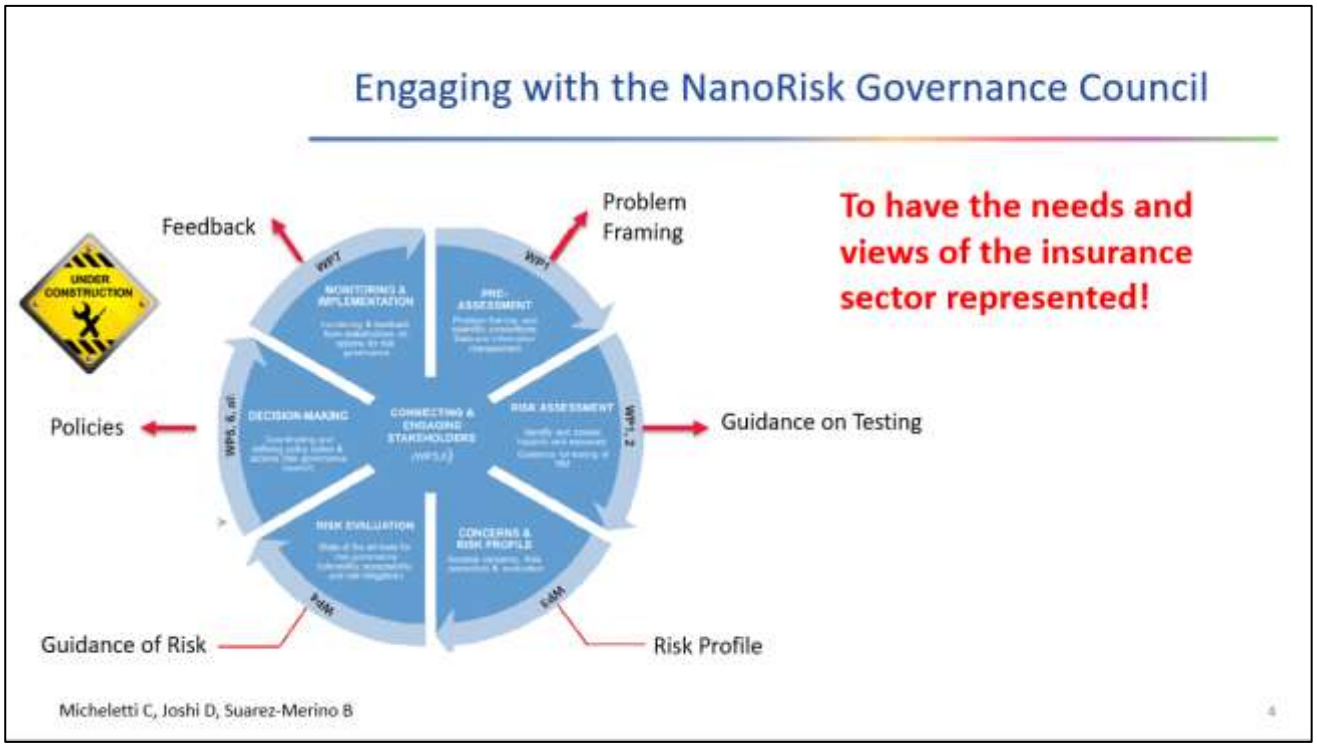


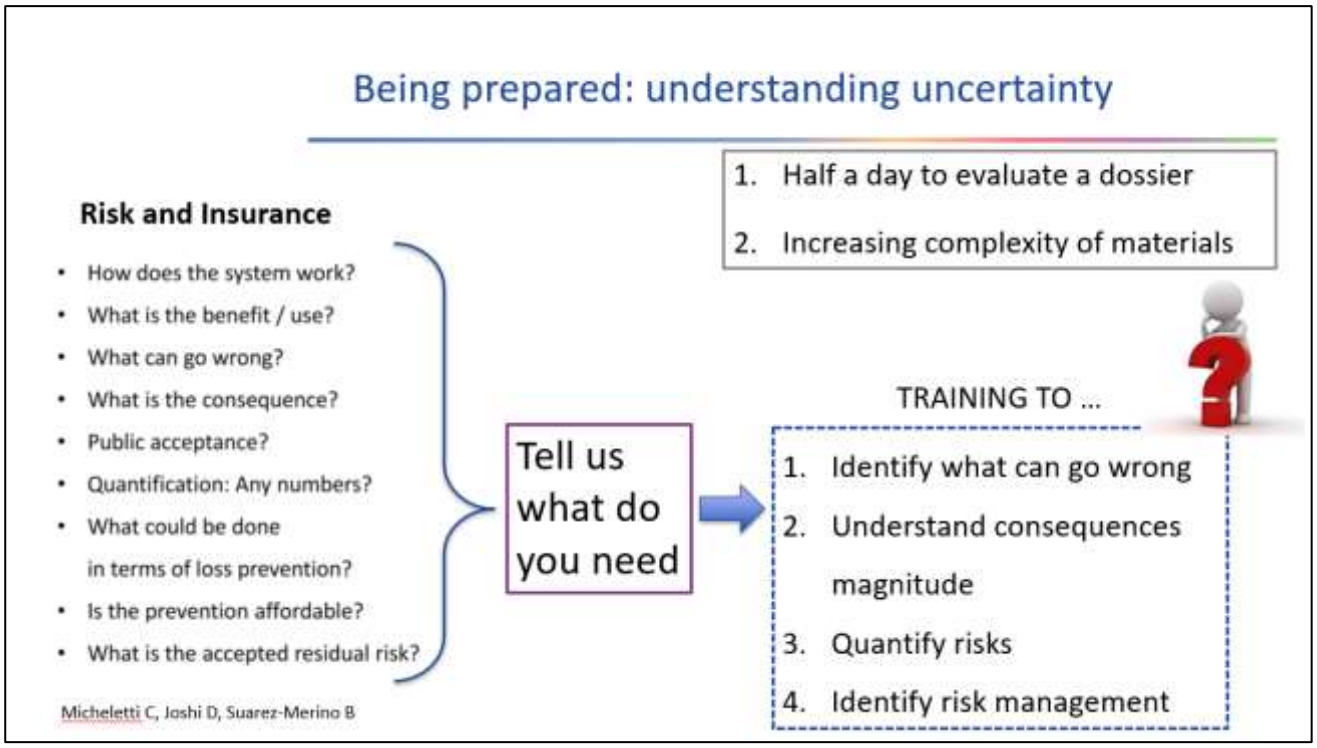
Release of metal particles by wear

Authorized by EU

Micheletti C, Joshi D, Suarez-Merino B


Paid loss
Time
Establishing governance for advanced materials
Early intervention
Avoiding risk of larger paid losses
Asbestos
Stages:
Phenomenon
Damage emergence
Interest group action
Regulation
Litigation
NANO-PARTICLES IN BABY FORMULA
E124
E133
E132
E111
Food additives re-evaluation
Micheletti C, Joshi D, Suarez-Merino B
3


Engaging with the NanoRisk Governance Council
To have the needs and views of the insurance sector represented!
Feedback
Problem Framing
Policies
Guidance on Testing
Guidance of Risk
Risk Profile
UNDER CONSTRUCTION
Micheletti C, Joshi D, Suarez-Merino B



3.3 Results

3.3.1 Review on nanotechnology education at primary and secondary levels (or K-12)

Nanotechnology is recognised as a new modern science field, with a fast-growing associated market. The increasing demand for qualified nanotechnology workers and supporting jobs in nanotechnologies requires to build a suitable scientific workforce. Therefore, it is necessary to integrate nanotechnology-related concepts into students' curricula, in order to prepare an educated researchers and scientists workforce (Blonder and Sakhnini 2015). However, nanotechnology is highly interdisciplinary in the Science, Technology, Engineering and Mathematics (STEM) field as it integrates, among others, concepts from chemistry, engineering, physics, biology and computer science.

To date, education in nanotechnology occurs mostly in the system of postgraduate and doctoral studies, as the foundational knowledge related to nanotechnology is included in the standard curricula of university study. While the most significant education in the field of nanotechnology takes place at the university level, it is also of high relevance to include science curricula at the beginning of educational careers, hence to a full-spectrum of students from K-12 to postgraduate studies (Poteralska et al. 2007). Indeed, the need to scaffold STEM education in K-12 for next generations of careers is more apparent than ever (Curreli and Rakich 2020).

Using a google search (keywords "education" AND "nanotechnology") we have identified 151 Master degree programmes, 70 Bachelor degree programmes, 39 PhDs degree programmes and 30 other programmes like certifications currently available in 30 countries. However, we did not find a comprehensive and exhaustive list of training and educational activities for younger students in nanotechnology. This is mainly due to the fact that each school can decide to undertake "specific courses" as extra-curricular.

Experiences in nanoscience and nanotechnology education

The need of training and education activities is not a new issue for the European Commission. Indeed, in 2005 the Nanoscience and Nanotechnology Action Plan of the European Commission's strategy for nanotechnology aims to promote network and "dissemination of best practices for education and training in nanoscience and nanotechnology". Since 2005, a wide range of

educational activities on nanotechnology raised. For example, the European Project NANOYOU organised a range of education activities such as posters, films, games and lab experiments for students aged 11-18.

The EU project NANO YOU (Nano for Youth, https://nanoyou.eu/index.html) was founded by the European Commission's Seventh Framework Program and aimed to increase the basic understanding of nanotechnology for people aged 11-25, with two objectives: carrying out a strong curriculum education for students aged 11-18 and a wide variety of activities in science centres for people aged 18-25. The project also aimed to engage in the dialogue about its ethical, legal and social aspects. The associated web portal offers videos and posters informing about nanoscience and nanotechnology, online animations, and virtual experiments, as well as virtual dialogues to enhance students' discussion on the forum of the project website. Other activities include an introductory workshop to nanotechnologies and a role play workshop where participants are invited to play the roles of different stakeholders. It is worth noting that the website hosts a dedicated session for teachers where training kits for different age groups are available. An educator blog was also organised to share experience. The teacher training kit is a fundamental resource for whom attended the NANO YOU project; it covers both the fundamental concepts in nanoscience and nanotechnology and the applications of nanotechnology. Both modules include background materials, literature and specific case studies. By providing tools to both students and teachers, and integrating both theoretical and experimental approaches on various aspects of nanotechnology, the NanoYou web portal appears as a complete tool for nanotechnology training and education.

In a similar fashion, the TIME for Nano Project aimed at engaging the general public, with a special attention to young people, on benefits and risks related to nanoscale research, engineering and technology. Educational products and materials (i.e. NanoKIT) were developed and events (i.e. "Nanodays", days of seminars, workshops, theatre, board games) were organized in the science centres of the nine countries that collaborate in the project.

The concluded NanOpinion EU project developed an educational programme in collaboration with scientists and teachers. The programme offered modules with educational resources easy to implement in the science curriculum at secondary school level for all teachers and educators interested in teaching nanotechnology.

Despite the success of the above-mentioned EU projects in the time when they were conducted, to date, they are not active anymore, although NANO YOU still provides a wide range of tools on its website.

The National Nanotechnology Coordinated Infrastructure (NNCI) (https://nnci.net/about-nnci) is a U.S. Government research and development (R&D) initiative ongoing since 2000, involving 20 departments and independent agencies and built in an effort to support a network of stakeholders by providing a robust infrastructure and toolset. With the support of the NNCI, nanotechnology R&D is taking place in academic, government, and industry laboratories across the United States. The NNCI promoted several educative initiatives and its efforts span from pre-K to PhD students. Educational resources are also provided to teachers (K-12 classes). Each site within NNCI conducts its own education. For example, the Montana Nanoscale facility promotes education and outreach activities such as: short course for K-12 science teachers, short course for graduate students and one-week in-residence course to give participants a first-hand experience in nanomanufacturing. It also provides a web portal with digital library technologies supporting learning resources on nanotechnologies and instructional activities that integrate the basic science and pedagogic methods.

The non-profit organisation Omni Nano developed a methodology to introduce the fundamentals of nanotechnology to high school and undergraduate college students. The Omni Nano model was recently presented by (Curreli and Rakich 2020) as an experience that can enrich student learning experience at elementary and secondary levels, helping them with the necessary skills to tackle new challenges in nanotechnology.

The Omni Nano model is organized in online and in person workshops, structured as multimedia slide presentations. The workshops are structured in different sections, addressing nanotechnology history, the relation of the nanoscale to other dimensional scales, nano-specific properties and nano-applications.

Overall, education in the field of nanoscience and nanotechnologies is supported by advanced communications techniques and multimedia in the form of information portals, Internet databases, on-line seminars, training via Internet, education with the use of multimedia, etc. Table 1 describes a few initiatives providing resources for teachers and students. The list and the short description of the activities provided can be further discussed in view of the plausible role that organisational form for nano risk governance could play in education and training.

Table 1: Online resources for teachers and students nanoscience and nanotechnology education

Organisation	Description
UnderstandingNano	Lesson plans on three topics: Introduction to Nanotechnology, Nanotechnology in Medicine, Environmental Nanotechnology
Exploring the Nano World	Collection of videos and course material for teaching K-12 students about nanotechnology. Prepared by the University of Wisconsin.
National Center for Learning and Teaching in Nanoscale Science and Engineering (NLCT)	Courses and workshops available for teachers
National Nanotechnology Initiative (NNI)	Provide educational resources for K-12 students, K-12 teachers, college and postdoctoral opportunities
National nanotechnology coordinated infrastructure (NNCI)	K-12 reference sheets, resources for virtual classroom, curriculum material form elementary to high grade level
Nanotechnology Application and Career knowledge (NACK)	Teaching resources, Nanotechnology workshop, Nanotechnology and professional development opportunities
nanoHUB	Free platform for computational research, education, and collaboration in nanotechnology, materials science, and related fields. Provides nano-educational resource databases for students at several education grades
NanoYou	Tools for teachers and students aged 11-25. Videos, posters, virtual experiments, discussion forum
Irresistible Project	Teacher guide and student material – activities for nanoscience and nanotechnology education

Learnings and recommendations

There are several barriers to nanotechnology education in K-12 curricula. First, the need for a multidisciplinary approach makes it difficult to decide in which of the already defined subjects nanotechnology should be included. Second, the rapid pace at which nanotechnology is developing entails difficulties in keeping track of the latest developments. Third, the novelty of the field leads to the lack of teacher training, which has nevertheless been identified as one of the challenges to effective STEAM (Science, Technology, Engineering, Arts, Mathematics) education i.e. to classroom K-12 (Herr et al. 2019).

The present literature review therefore highlights the need of educational programmes at elementary and secondary level to prepare students with the necessary skills to be efficient workers in the nanotechnology field. Past experiences also teaches us that the effort of single projects are not enough, but longer-lasting organisations such as the NNI, where the different stakeholders of academia and industry are able to collaborate on the long term, seem to work better.

3.3.2 Workshops for training in nanotechnology safe-and-sustainability-by-design, risk assessment and risk perception and associated survey on risk perception

Questionnaire on perception of nanotechnology

The questionnaire on perception of nanotechnology was sent out to the 19 registered participants and sent back by 15 participants, who had various research topics in the fields of human and eco-toxicology, nanosafety, exposure assessment, law, modelling and environmental assessment. Respondents also had varying experience on nanotechnology, working for less than one year to 10 years in the field.

Among the topics addressed during the workshop, respondents were most familiar with human and environmental risk assessment, while safe-by-design was the least understood concept (Figure 1, Annex 1). All students agreed with the need of training on risk assessment for their work and seemed quite interested by sustainability and safe-by-design topics (40% and 30% of respondents answered "very useful", respectively). It is worth noting that the answers to this part of the questionnaire might be biased by the fact that these respondents already expressed their interest in such topics by registering to the workshop and might therefore not represent fully the community of early career researchers in the nanoscience field.

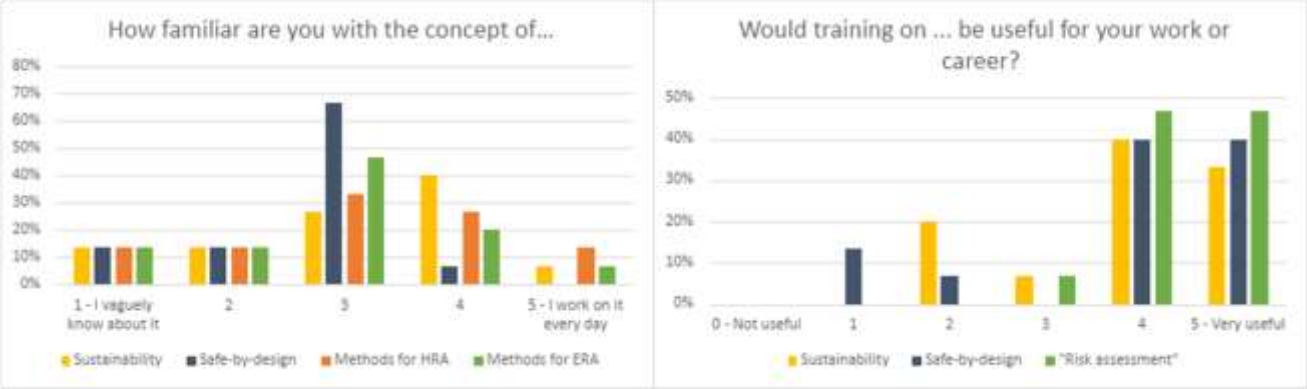


Figure 1: Familiarity and need for training on workshop topics as perceived by questionnaire respondents

Regarding the participants' perception of nano-applications benefits and risks, most of them recognised moderate to high risks towards human and environmental health (Figure 2, Annex 1). The highest risks were perceived for human health, for pesticides, cosmetics & sunscreens, medicine, and food (9, 8, 7 and 7 respondents, respectively, categorised the associated risks as "high"). Higher benefits were perceived for human health than for the environment, especially regarding medicine and electronics (8 respondents categorised the benefits as "high" for each of these product categories). The lowest benefits were found for pesticides and food (6 respondents categorised the associated benefits as "low").

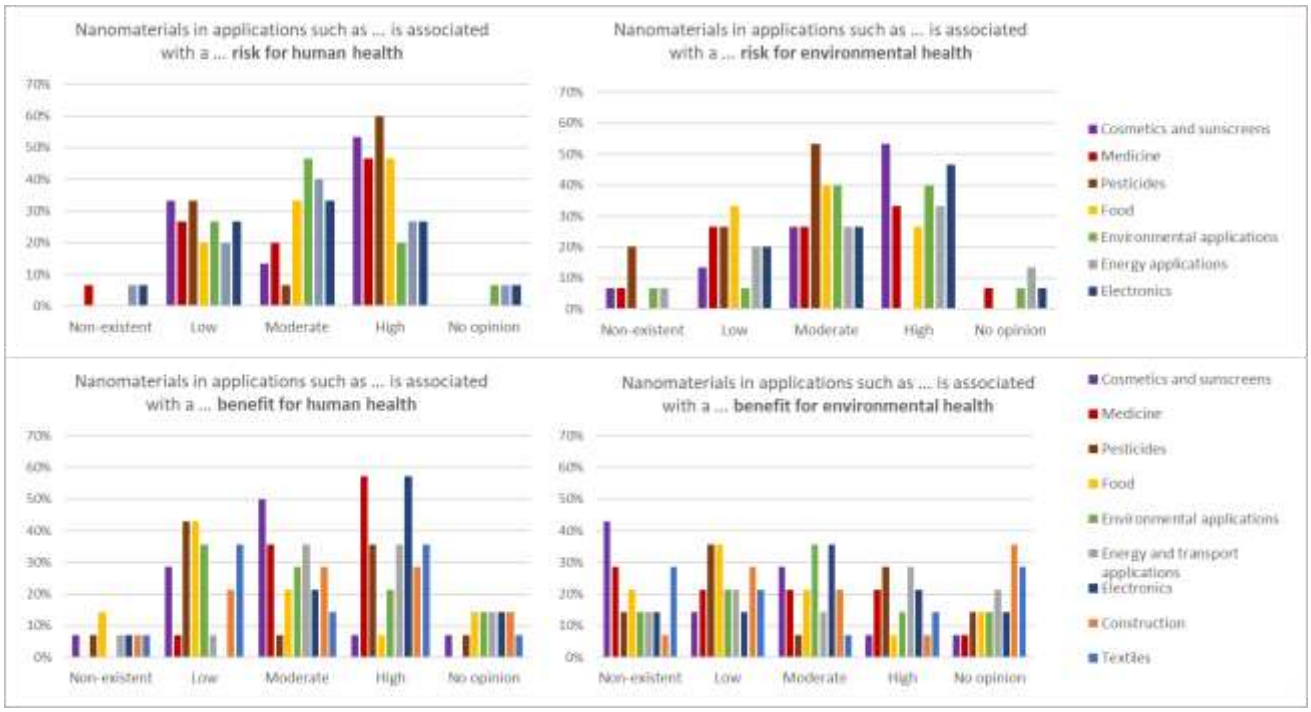


Figure 2: Benefits and risks perceptions of students for various nano-applications – answers from first questionnaire

Higher trust was felt towards public institutions than to industry (Figure 3, Annex 1). Sunscreen, cosmetics & hygiene products as well as food were the applications most avoided for purchase (40% and 33% of respondents, respectively, deliberately chose to avoid it), probably because of they are the product categories for which risks were most often related in the media.

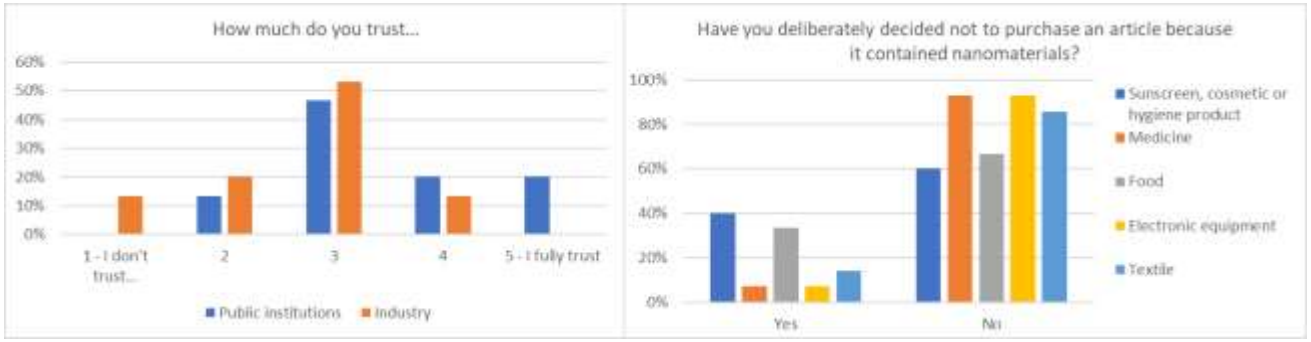


Figure 3: Trust in nanotechnology and associated stakeholders – answers from first questionnaire

Regarding regulatory tools that could be useful for nano risk governance, there is a strong agreement among respondents that labelling of nano ingredients in products should be mandatory (80% strongly agree, Figure 4, Annex 1). The best perceived option for effective nano risk governance is "continuous monitoring of health and safety risks carried out by a public authority – 13 respondents considered it a very good option.

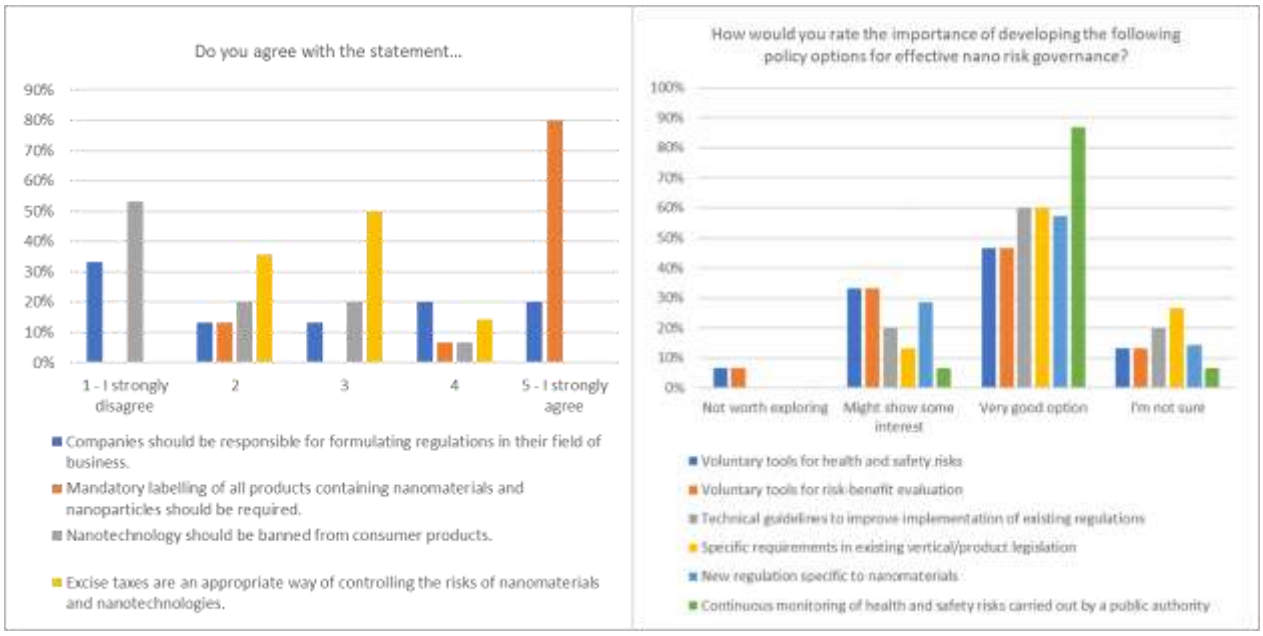


Figure 4: Opinions on regulatory tools – answers from first questionnaire

Workshop

14 participants attended the workshop. The introductory lecture included 24 slides, among which 8 were dedicated on risk governance and regulation, 12 and safe-and-sustainable-by-design and risk assessment, and 4 on introduction to the Gov4nano project and on the workshop. The slides are presented in Annex 2.

During the brainstorming session, 4 groups of 3 to 4 students actively discussed and exchanged their thoughts on the various topics of the workshop. Each group was provided a Mural board for support, where they could follow the exercises and write their thoughts down (Figures 5-10). Three trainers guided the participants through their assignments.

The last exercise of the workshop was on risk governance, where students were asked to reflect on what could hamper or improve the dialogue between different stakeholders. Interestingly, the students found that:

- Interactions between industry and regulators could be hampered by intellectual property; these interactions could be improved with transparency and a trusted environment;
- Interactions between industry and NGOs could be hampered by political differences or lack of trust; they could be improved with more openness;
- Interactions between consumers and scientists could be hampered by limited communication issues; these interactions could be improved by common platforms for discussions, minimum data requirements and increased funding;
- Interactions between researchers and industry could be hampered by safety, innovation or profit issues, as well as different interests at stake; these interactions could benefit from collaborative projects, conferences and workshops;
- Interactions between researchers and risk assessors could be hampered by issues on procedures safety, materials characterisation, validation or innovation; these interactions could be improved collaborative projects and awareness raising;
- Interactions between consumers and the media could be hampered by a misunderstanding of the scientific results or the influence of politics; while they could be improved with more fact checking and the influence of organisations to protect consumer interests, which could play the role of mediators.

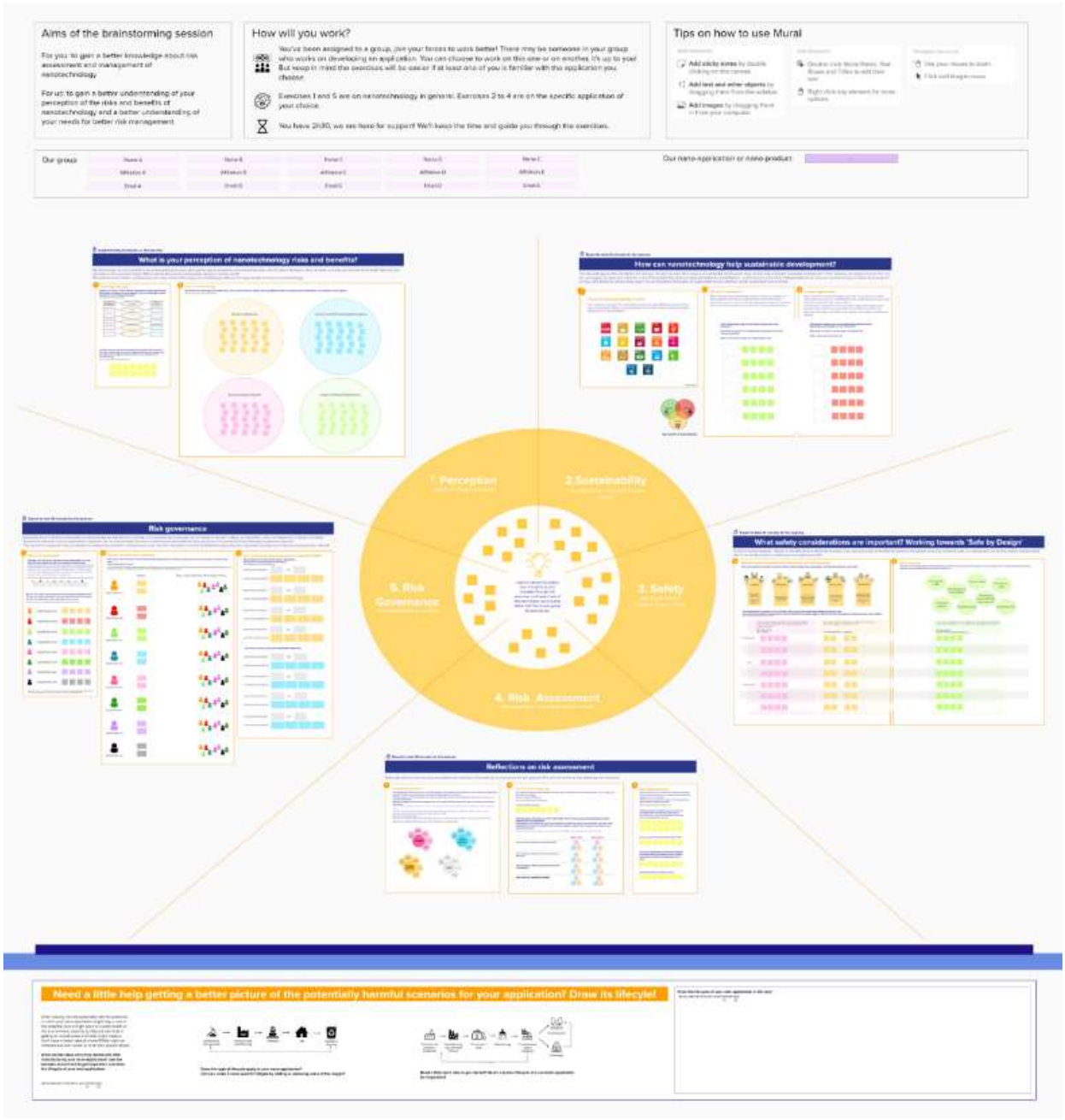


Figure 5: Overall view of the Mural board for training nanoscientists at early career stages

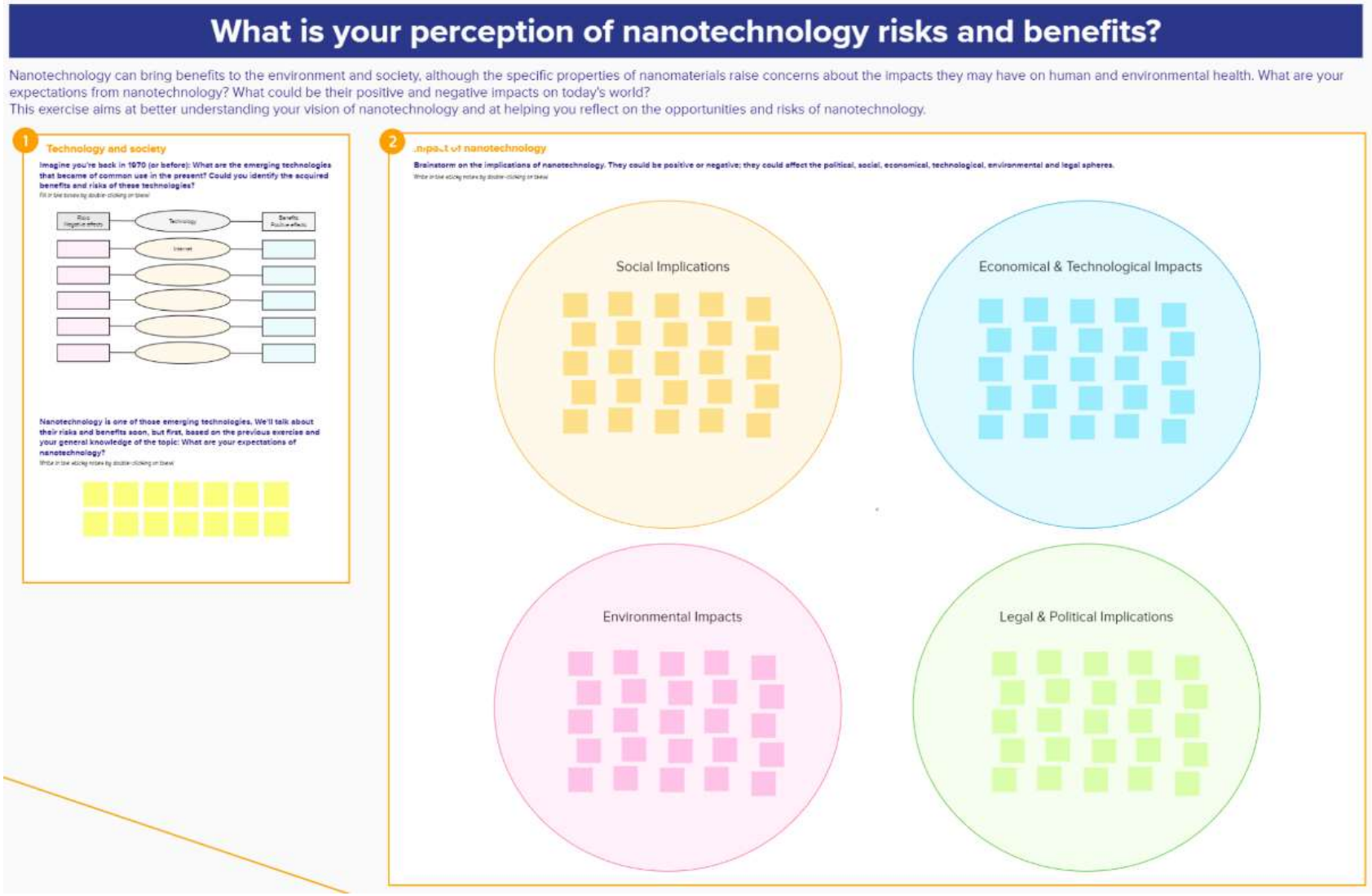


Figure 6: Exercise 1 of Mural board of training workshop for nanoscientists at early career stages – Perception of nanotechnology

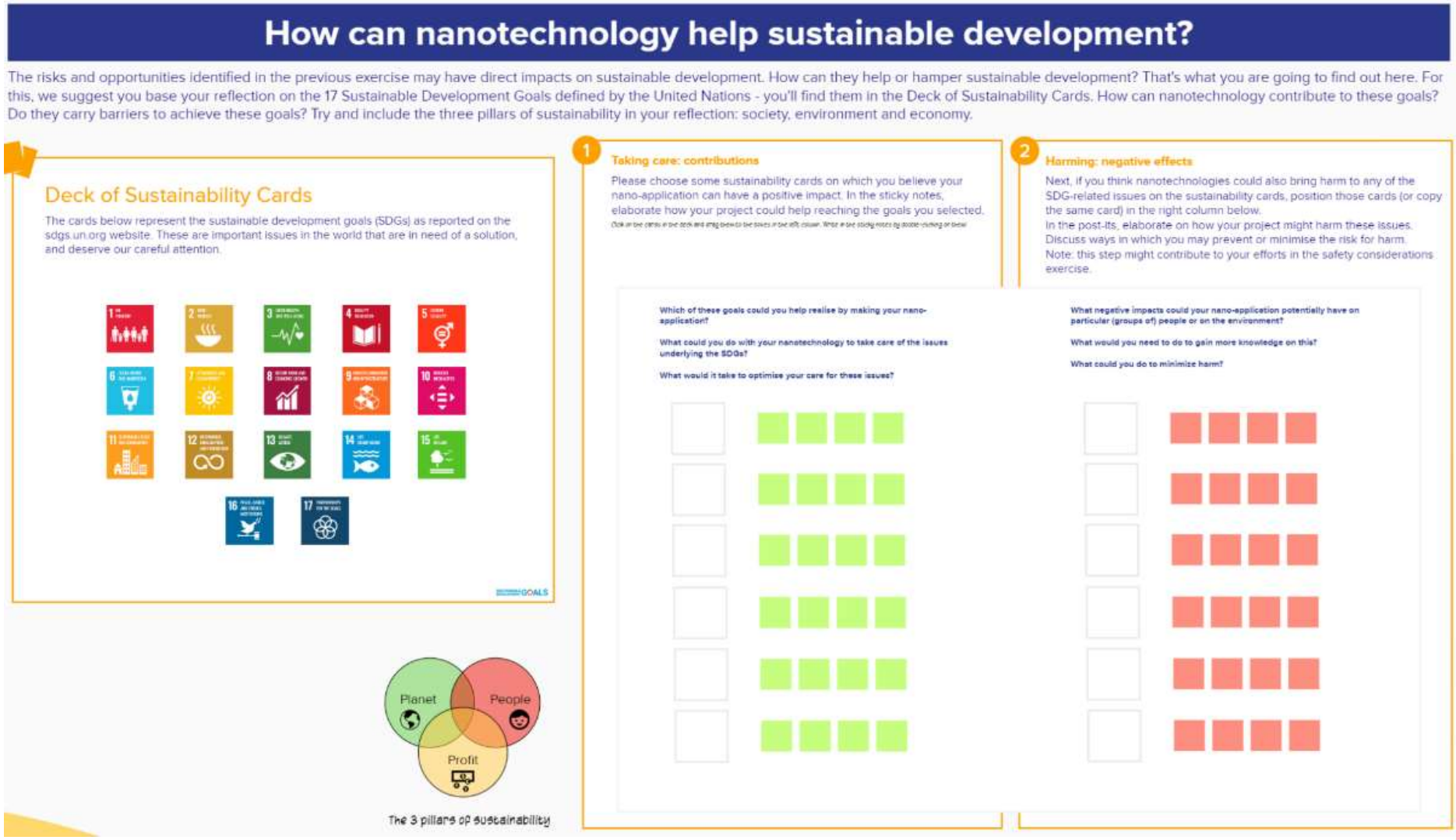


Figure 7: Exercise 2 of Mural board of training workshop for nanoscientists at early career stages – Sustainability

Figure 8: Exercise 3 of Mural board of training workshop for nanoscientists at early career stages – Safe-by-Design

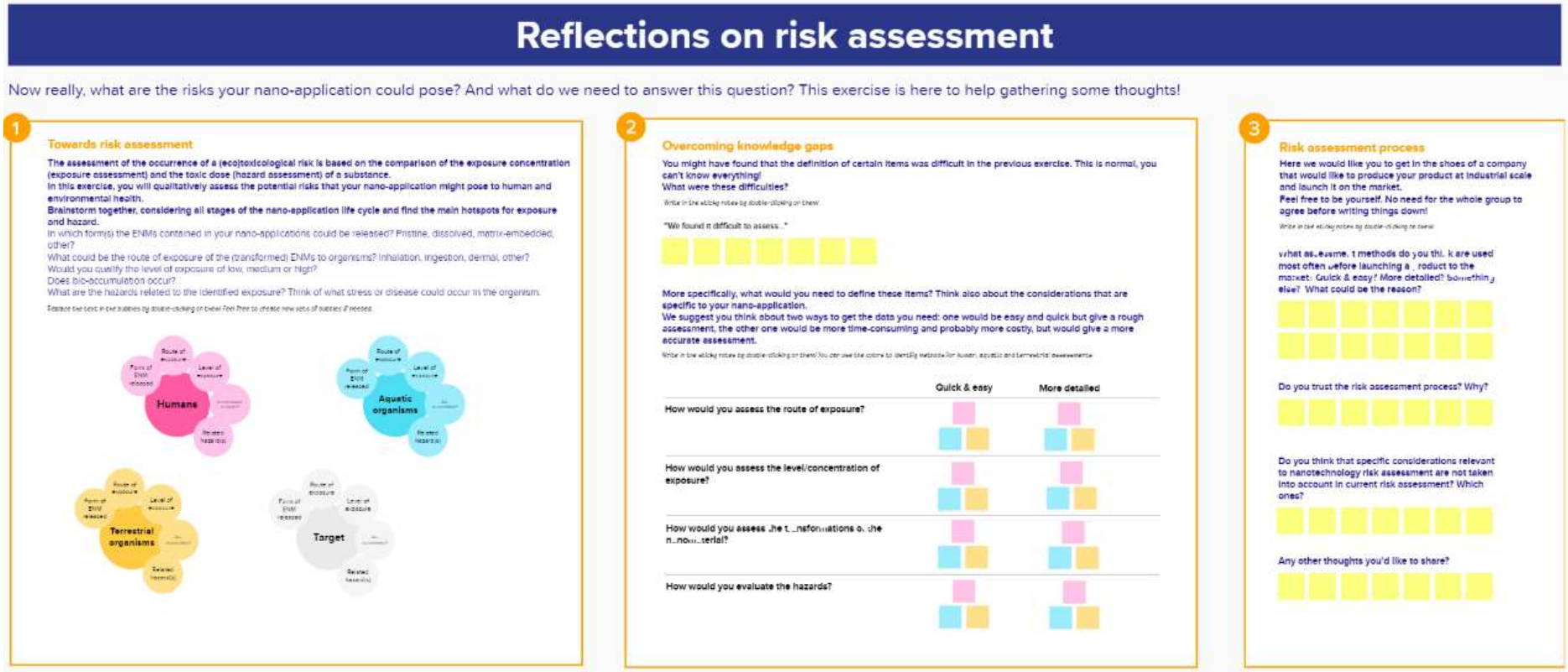


Figure 9: Exercise 4 of Mural board of training workshop for nanoscientists at early career stages – Risk assessment

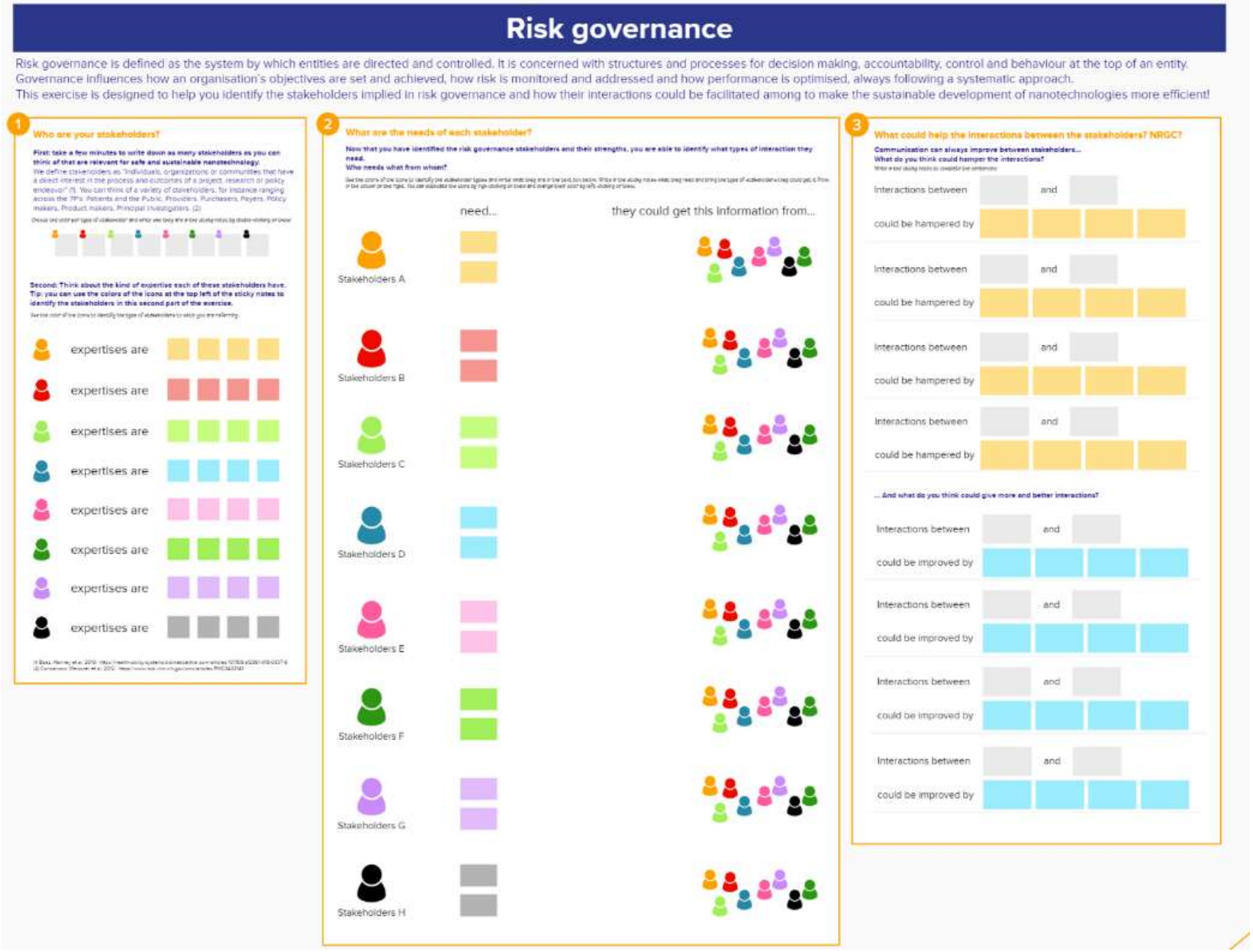


Figure 10: Exercise 5 of Mural board of training workshop for nanoscientists at early career stages – Risk governance

After the brainstorming session, groups were given a few minutes to gather their thoughts and one presenter from each group presented their reflections to all attendees. This enabled the participants to further broaden their views on the topics addressed in the workshop.

Feedback questionnaire

According to the 10 respondents to the feedback questionnaire, the workshop introductory lecture gave enough information for the brainstorming session, although attendees would have liked to learn more on safe-by-design and risk governance (Figure 11, Annex 3). 40% of attendees would have like the lecture to be longer.

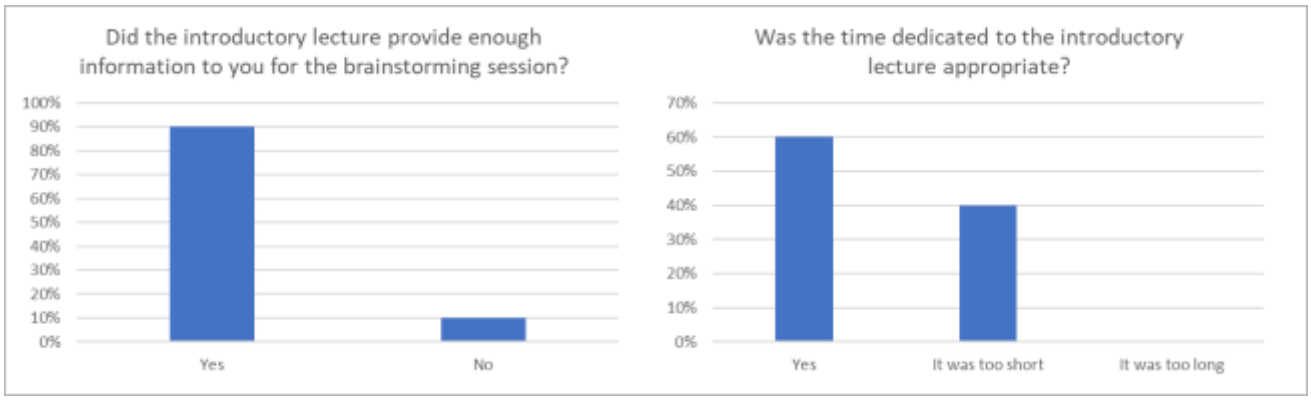


Figure 11: Answers from feedback questionnaire – workshop introductory lecture

Mixed feelings were reported regarding the brainstorming session (Figure 12, Annex 3), especially on the size of the groups that were formed (50% respondents considered it appropriate, while 50% considered it too small), and the times allocated to each exercise (56% considered they did not have enough time to complete the assignments). The wording of the assignments on the Mural board could also have been clearer, although the oral guidance provided by the trainers was appreciated.

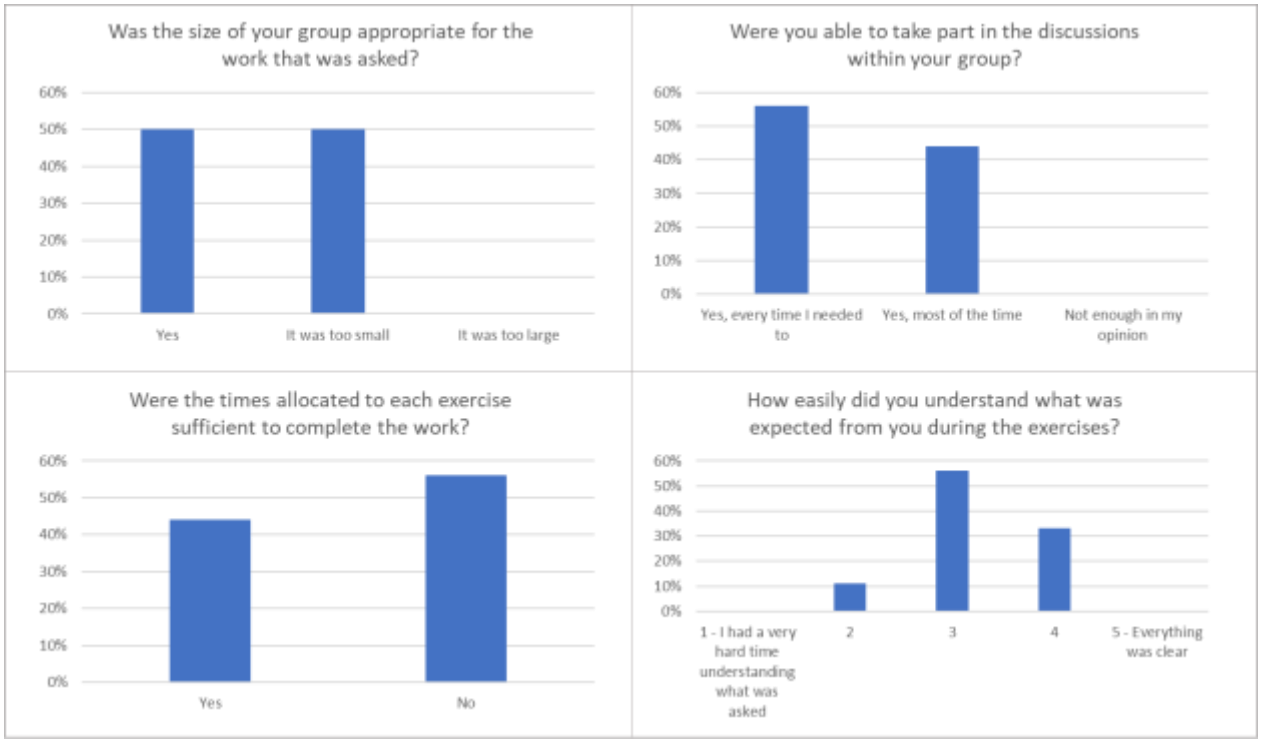


Figure 12: Answers from feedback questionnaire – workshop brainstorming session

Overall, the students' expectations from the workshop were generally met, although they expressed their regrets regarding the lack of time for discussion and reflection on each other's

thoughts and for interaction with experts (Figure 13, Annex 3). 60% of attendees would clearly recommend the workshop to their colleagues.

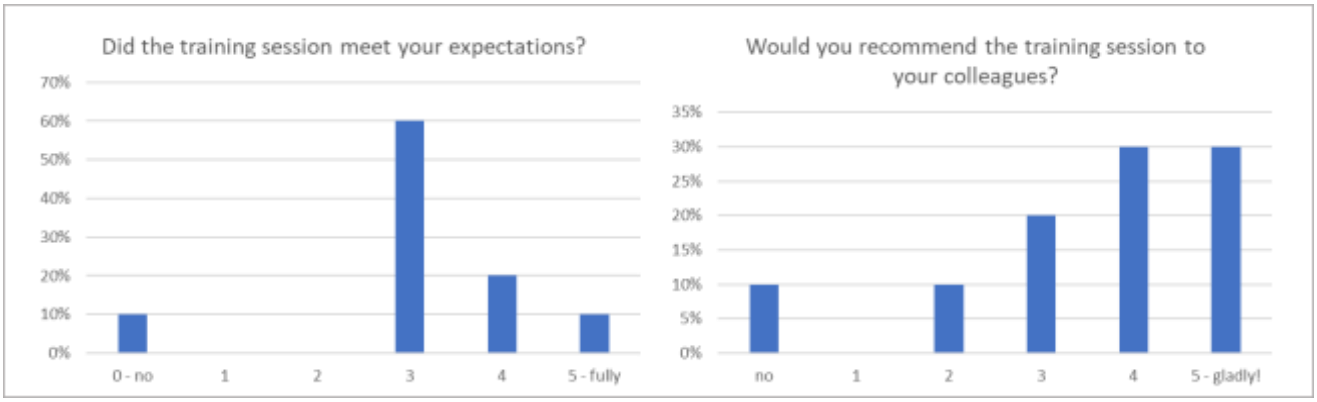


Figure 13: Answers from feedback questionnaire – general feedback

3.3.3 Insurance

The (re)insurance sector approached (see Gov4nano D3.5) was not necessarily aware of particular risks regarding nanotechnologies nor were they aware of key regulations such as REACH, or the specifications of some sectoral regulations/legislations regarding nanomaterials (Cosmetics, Medical Devices, Occupational, Biocides or Food). We only found the exception to this rule from a particular company, which was very active at workshops and conferences. Hence training and education for the (re)insurance sector starts from the perspective of nanotechnologies being key enabling technologies as well as the introduction of the particulars of the nanosize and their potential risks due to their unique functionalities. A review of the different regulations/legislations covering the different sectors is also necessary, for the (re)insurance sector to understand the wide impact of nanotechnologies. At the same time, while reviewing different pieces of regulation, the (re)insurance sector felt that there is enough control set into place and it is up to the companies to follow those regulations and keep themselves updated.

3.4 Recommendations on training and education of civil society and insurers

Elementary and secondary levels (literature review)

Implementation of training and education activities at elementary and secondary levels is not straightforward. It requires the consideration of the multidisciplinary character of nanoscience and nanotechnology, the fast pace at which new applications are developed, and the need for teacher training. To help in this direction, academia should not only focus on single projects but build longer-lasting structures, such as the NNI and the organisational form for nano risk governance that Gov4nano intends to build.

Higher levels of education (workshop)

The feedback questionnaire answered by the workshop attendees highlighted how much students value time for reflection and discussion after completing their assignments. Indeed, nano risk governance is a complex field, involving many different considerations on various topics; it therefore requires extended time for knowledge transmission and assimilation. Besides, the students appreciated working in multi-disciplinary groups, underlining the need for transdisciplinary approaches in nanotechnology training.

The organisational form for nano risk governance developed within G4N should take a role on training and education, taking into consideration the above recommendations: facilitating long-lasting projects on transdisciplinary education on nanotechnology, training not only at university level but already at high school and including the teachers themselves.

4 Data management – only for a limited number of tasks relevant

No experimental work was performed, and no data-management has to be reported.

5 Deviations from the work plan

No deviations to be reported

6 Performance of the partners

All partners performed as per agreement under the Grant Agreement

7 References

Blonder, Ron, and Sohair Sakhnini. 2015. 'The Making of Nanotechnology: Exposing High-School Students to behind-the-Scenes of Nanotechnology by Inviting Them to a Nanotechnology Conference'. *Nanotechnology Reviews* 4 (1): 103–16. https://doi.org/10.1515/ntrev-2014-0016.

Curreli, Marco, and Sladjana Sandy Rakich. 2020. 'An Integrated Approach to Teaching and Learning Nanotechnology: The Omni Nano Model'. *Journal of Research in Innovative Teaching & Learning* 13 (1): 141–45. https://doi.org/10.1108/JRIT-02-2020-0012.

Herr, Daniel J.C., Bushra Akbar, Jennifer Brummet, Sarah Flores, Ashley Gordon, Brian Gray, and James Murday. 2019. 'Convergence Education—an International Perspective'. *Journal of Nanoparticle Research* 21: 229. https://doi.org/10.1007/s11051-019-4638-7.

Poteralska, Beata, Joanna Zielinska, and Adam Mazurkiewicz. 2007. 'The Development of Education and Training Systems in the Field of Nanotechnology'. *Journal of College Teaching & Learning* 4 (6): 7–16.

8 Annexes

Annex 1 – Answers from first questionnaire

Number and percentages of respondents.

GENERAL

Number and % of respondents	How familiar are you with…							
Scale of familiarity	the concept of sustainability		the concept of safe-by-design		methods of RA for HH		methods of ERA	
	number	%	number	%	number	%	number	%
1- I vaguely know about it	2	13%	2	13%	2	13%	2	13%
2-	2	13%	2	13%	2	13%	2	13%
3-	4	27%	10	67%	5	33%	7	47%
4-	6	40%	1	7%	4	27%	3	20%
5- I work on it every day	1	7%	0	0%	2	13%	1	7%

TRAINING

Number and % of respondents	Would training on … be useful for your work or your career?					
Scale of usefulness	risk assessment		sustainability		safe-by-design	
	number	%	number	%	number	%
0- not useful	0	0.0%	0	0.0%	0	0.0%
1-	0	0.0%	0	0.0%	2	13.3%
2-	0	0.0%	3	20.0%	1	6.7%
3-	1	6.7%	1	6.7%	0	0.0%
4-	7	46.7%	6	40.0%	6	40.0%
5- very useful	7	46.7%	5	33.3%	6	40.0%

Which aspect of risk assessment be more useful than others?	
Aspect	Number of respondents
in vitro risk assessment	1
Exposure assessment	3
Choice of criteria in risk assessment	1
Environmental risk assessment	2
Influence to environment	1
Available tools and data requirements	1
Bulk synthesis vs. environmental benefit	1
in vitro to in vivo	1
Long term effects of nanoagrochemicals on human health	1

PERCEPTION

In my opinion, the production, use and disposal of nanomaterials in applications such as… is associated with a … risk for human health.					
(in number of respondents)	Non-existent	Low	Moderate	High	No opinion
Cosmetics and sunscreens	0	5	2	8	0
Medicine	1	4	3	7	0
Pesticides	0	5	1	9	0
Food	0	3	5	7	0
Environmental applications	0	4	7	3	1
Energy applications	1	3	6	4	1
Electronics	1	4	5	4	1

In my opinion, the production, use and disposal of nanomaterials in applications such as … is associated with … risk for environmental health.					
(in number of respondents)	Non-existent	Low	Moderate	High	No opinion
Cosmetics and sunscreens	1	2	4	8	0
Medicine	1	4	4	5	1
Pesticides	0	3	4	8	0
Food	0	5	6	4	0
Environmental applications	1	1	6	6	1
Energy applications	1	3	4	5	2
Electronics	0	3	4	7	1

In my opinion, putting manufactured nanomaterials in products such as … would bring a … benefit for human health.					
(in number of respondents)	Non-existent	Low	Moderate	High	No opinion
Cosmetics and sunscreens	1	4	7	1	1
Medicine	0	1	5	8	0
Pesticides	1	6	1	5	1
Food	2	6	3	1	2
Environmental applications	0	5	4	3	2
Energy and transport applications	1	1	5	5	2
Electronics	1	0	3	8	2
Construction	1	3	4	4	2
Textiles	1	5	2	5	1

In my opinion, putting manufactured nanomaterials in products such as … would bring a … benefit for environmental health.					
(in number of respondents)	Non-existent	Low	Moderate	High	No opinion
Cosmetics and sunscreens	6	2	4	1	1
Medicine	4	3	3	3	1
Pesticides	2	5	1	4	2
Food	3	5	3	1	2
Environmental applications	2	3	5	2	2
Energy and transport applications	2	3	2	4	3
Electronics	2	2	5	3	2
Construction	1	4	3	1	5
Textiles	4	3	1	2	4

TRUST

Number and % of respondents	How much do you trust public institutions to keep consumers, the general public and the environment safe from potential detrimental effects of nanomaterials?			
Scale of trust	Public institutions		Nanotechnology industry	
	number	%	number	%
1 - I don't trust…	0	0%	2	13%
2	2	13%	3	20%
3	7	47%	8	53%
4	3	20%	2	13%
5 - I fully trust	3	20%	0	0%

Have you ever deliberately decided (or would you decide) not to purchase an article because it contained nanomaterials? If yes, what sort of product?

Product category	Number of respondents	
	Yes	No
Sunscreen, cosmetic or hygiene product	6	9
Medicine	1	13
Food	5	10
Electronic equipment	1	13
Paint or coating	0	14
Textile	2	12

Are you aware of regulations applying to nanotechnology?		
	Number of respondents	%
Yes	5	33%
Partly	10	67%
No	1	7%

Do you agree with the statement… (in number and % of respondents)	1- I strongly disagree		2		3		4		5 - I strongly agree	
	number	%	number	%	number	%	number	%	number	%
"Companies should be held responsible for formulating regulations in their field of business."	5	33%	2	13%	2	13%	3	20%	3	20%
"Mandatory labelling of all products containing nanomaterials and nanoparticles should be required."	0	0%	2	13%	0	0%	1	7%	12	80%
"Nanotechnology should be banned from consumer products."	8	53%	3	20%	3	20%	1	7%	0	0%
"Excise taxes are an appropriate way of controlling the risks of nanomaterials and nanotechnologies."	0	0%	5	36%	7	50%	2	14%	0	0%

How would you rate the importance of developing the following policy options for effective nano risk governance? (in number of respondents)	Not worth exploring	Might show some interest	Very good option	I'm not sure
Voluntary tools for health and safety risks	1	5	7	2
Voluntary tools for risk-benefit evaluation	1	5	7	2
Technical guidelines to improve implementation of existing regulations	0	3	9	3
Specific requirements in existing vertical/product legislation	0	2	9	4
New regulation specific to nanomaterials	0	4	8	2
Continuous monitoring of health and safety risks carried out by a public authority	0	1	13	1

Annex 2 – Slides used for the workshop introductory lecture

Introduction

H2020 governance research projects are working to

- develop a broader risk governance framework
- including better the safe and sustainable-by-design concept
- to connect and interlink data, experiences and competences across research areas, regulatory domains and stakeholders

RISK GONE NANORIGO

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Miettinen, M (2021) doi:10.1017/err.2020.58
Porcari et al (2019) doi:10.1007/s11051-019-4689-9

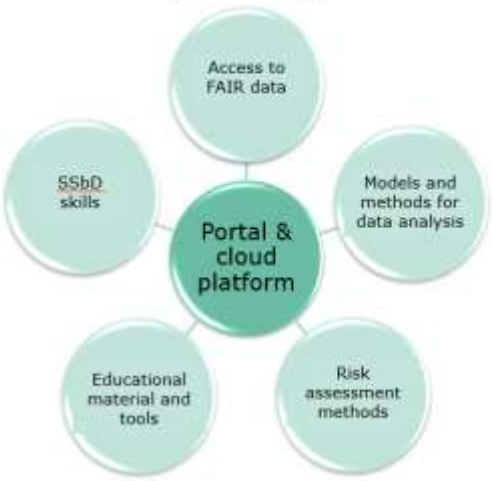
TEMAS Solutions Gov4Nano

Introduction

Gov4Nano

Risk governance house

Risk governance portal



To support chemical sustainable strategies

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions Gov4Nano

What is risk governance?

"Governance refers to the **actions, processes, traditions and institutions by which authority is exercised and decisions taken and implemented**. Risk governance applies the principles of good governance to the **identification, assessment, management and communication of risks**." (IRGC, 2017)

- What **societal, environmental and economic values** affect our willingness to accept the risk?
- To what extent should a **precautionary approach** be used to address uncertainty and ambiguity?
- How best should one **balance an inclusive approach to decision-making with the need to reach a decision**?

→ **Physical, economic and social aspects**

→ **Variety of stakeholders** (consumers, industry, scientists, policymakers, …)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Risk governance framework (IRGC, 2017)

Gain a thorough understanding of a risk

Develop adequate and appropriate options for governing it

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

www.epfl.ch/research/domains/irgc/concepts-and-frameworks/risk-governance-framework/

Risk governance and nanotechnology

- Nanotechnology = disruptive technology
  - Creates new markets and industries
  - In several economic sectors
- Risk governance: useful for disruptive technologies – integrates both physical and social risks

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Mäenpää M. (2021) doi:10.1017/err.2020.56
Malakar et al (2022) doi:s41599-021-01028-w

TEMAS Solutions Gov4Nano

Risk governance challenges for nanotechnology

- Diversity
  - In materials, products and applications
  - In production and manufacturing techniques
  - Multiple forms during life cycle
- Novelty & complexity
  - Difficult to identify, quantify and discriminate against natural nanomaterials
  - Difficult to characterise in tox studies, diversity of methods applied, so difficult to compare or combine results
  - Likely use of incomplete data sets – qualitative, semi-quantitative and quantitative; associated risks are difficult to evaluate, understand and manage

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Stone et al. 2018. 10.1111/risa.12954
Rodrigues. 2008. 10.1007/s11569-017-0296-3
Larsson et al. 2019. 10.1007/s11051-019-4498-1

TEMAS Solutions Gov4Nano

Risk governance challenges for nanotechnology

- Risk and toxicity assessment
  - Biological and pathological effects are determined by a variety of parameters, such as size, shape, basic chemical structure, charge and protein corona
  - Transformations during life cycle (i.e. different forms - pristine vs transformed material)
  - Standardisation of methods not sufficient yet

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Shane et al. 2018. 10.1111/ina.12554
Rodriguez. 2008. 10.1007/s11569-017-0296-3
Larsson et al. 2019. 10.1007/s11051-019-4498-1

TEMAS Solutions Gov4Nano

Regulation for nanomaterials – focus on REACH

REACH – Registration, Evaluation, Authorisation and Restriction of Chemicals (2006)

- Registration dossier for substances manufactured or imported at or above 1 tonne per year
- Chemical safety report for substances manufactured or imported at or above 10 tonnes per year

- **2008**: European Commission (executive branch of EU) declared the nanomaterials risks were **covered "in principle" in existing REACH regulation**. But:
  - NMs treated exclusively based on their chemical composition - no account for specific physical properties

- **2018: Nano-specific aspects included** in
  - Chemical safety assessment (Annex I)
  - Registration information requirement (Annexes III & VI-XI)
  - Downstream user obligations (Annex XII)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Rodriguez (2008) 10.1007/s11569-017-0296-3

TEMAS Solutions Gov4Nano

Regulation for nanomaterials

2008

Food additives. If new additive produced with "significantly different" methods, incl. nanotechnology:
- New safety evaluation
- New entry in the Community List

2009

Active and intelligent materials **articles intended to come into contact with food**

Nanoparticles risks assessed on a case-by-case basis until more information

Cosmetic products. If contain nanomaterials:
- High level of protection of human health ensured
- Mandatory labelling
- Product safety information provided to the EC 6 months prior to product being placed on the market

2011

Plastic food contact materials
- Nanoforms should only be used if explicitly authorised
- Case-by-case assessment before authorisation (by EFSA)

Food information to consumers

[nano] labelling after name of food ingredient

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Rodriguez (2008) 10.1007/s11569-017-0296-3

Regulation for nanomaterials

2012

Biocidal products

Notification, assessment and approval of nanoscale form of an active substance in addition to any existing non-nanoscale form

2015

Novel foods
- Most updated methods used for testing
- Explanation of scientific appropriateness for NMs

2018

"Nanoforms of a substance" added to REACH Annexes. Nano-specific aspects in :
- Chemical safety assessment (Annex I)
- Registration information requirement (Annexes III & VI-XI)
- Downstream user obligations (Annex XII)

2021

Ban of E171 from all food products

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Rodriguez. 2008. 10.1007/s11569-017-0296-3
EGA. 2018.

Introduction Safe by Design

- Safe by design is applied in several disciplines: biotechnology, software engineering, urban environment, aerospace engineering, construction engineering, chemical engineering , nano - engineering

All life cycle phases of product, process or system → Concentrates on the **plan and design phase** (at early stage of the innovation process)

Anticipate risk → **prevent the risk** from happening or to decrease their likelihood

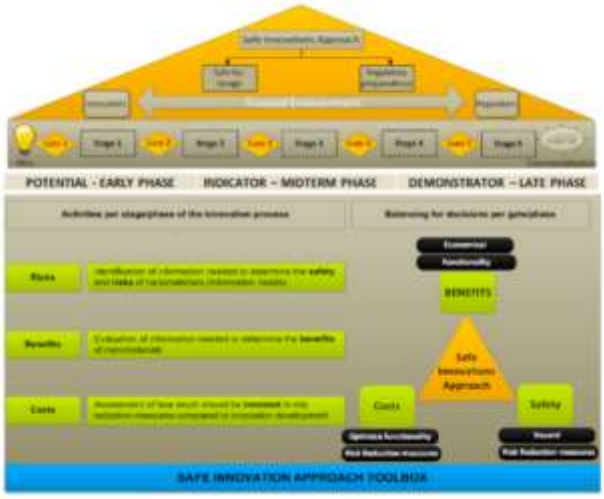
Address safety → **Control** of **recognized hazard** to achieve an acceptable risk

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions

Safe and Sustainable by design

- NANoREG and NanoReg2 supported the development of Safe and Sustainable by design
- Safe Innovation Approach (SIA) which combines SbD and Regulatory preparedness
- SIA aims to keep pace among regulators and innovators



Salieri et al., 2019. doi:10.1016/j.impact.2021.100325
Sanchez Jimenez et al. 2020 doi: 1031016/j.impact.2020.1000267
Sanchez Jimenez et al. 2022 doi: 10.1016/j.impact.2022.1000385
OECD, 2020, Moving Towards a Safer innovation approach (SIA) for more Sustainable nanomaterials and nano-enabled products

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions Gov4Nano

SSbD for nanotechnologies

- The project aimed to integrate sustainability into Sbd
- SSbD is a process that aims at identifying, estimating and **reducing** uncertainties and **risk** for **human and the environment** along the **entire value chains**, starting at an early phase of the innovation process»
- SSbD is a pre-market approach (regulatory comply)

NanoReg2

Environment

Health

Functionality

Lifecycle

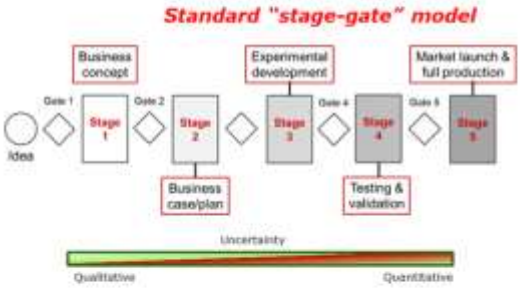
Saleri et al., 2019. doi:10.1016/j.impact.2021.100335
Sanchez Jimenez et al. 2020 doi: 1031016/j.impact.2020.1000367
Sanchez Jimenez et al. 2022 doi: 10.1016/j.impact.2022.1000385
OECD, 2020, Moving Towards a Safer innovation approach (SIA) for more Sustainable nanomaterials and nano-enabled products

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions

Safe and sustainable by design-Nanotechnology

SSbd is a «*process that aims at identifying, estimating and reducing uncertainties and risk for humans and the environment along the entire value chains, starting at an early stage of the innovation process*»



Safety: from control banding tool, up to quantitative evaluation of the RA

Sustainability: Life Cycle Assessment (LCA) and Socio-economic analysis

Saleri et al., 2019. doi:10.1016/j.impact.2021.100335

NanoReg2

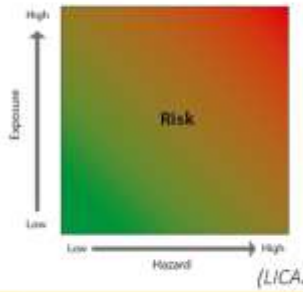
This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions Gov4Nano

Risk Assessment

HAZARD	&	EXPOSURE
Is there an adverse effect?		How much?
What effect?		Through air? Water? Soil?
At what dose?		To humans?
To whom?		To other organisms?

Qualitative



(LICARA NanoScan)

Quantitative

Predicted no-effect concentration (PNEC)

Predicted exposure concentration (PEC)

If PEC > PNEC

RISK

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions Gov4Nano

Risk assessment – challenges for nanomaterials

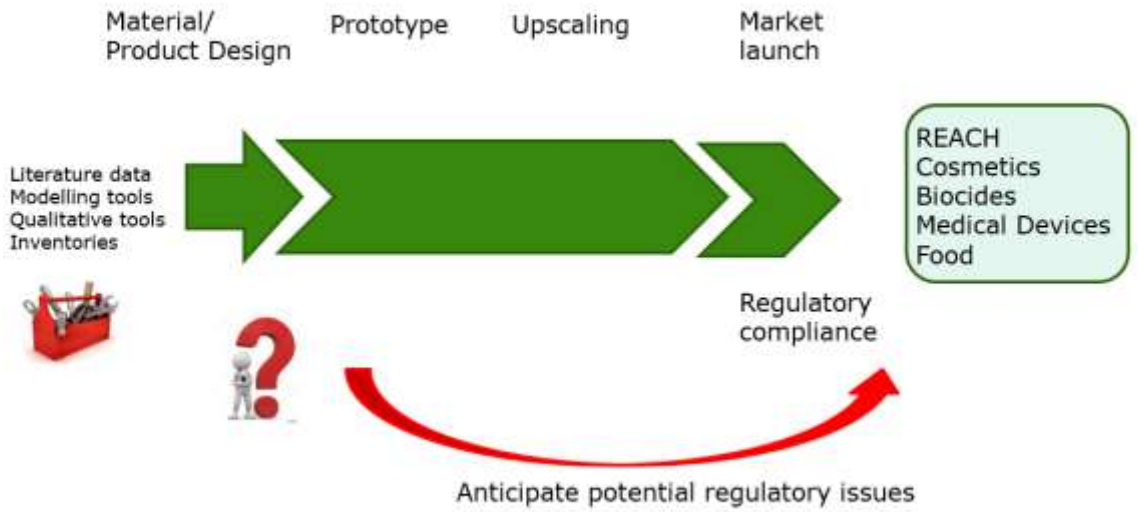
- High diversity in composition, sizes, shapes
- Transformations during life cycle
- Difficult to identify and quantify in the environment (and in body?)
- Standardisation of methods not sufficient yet

→ HIGH UNCERTAINTIES

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

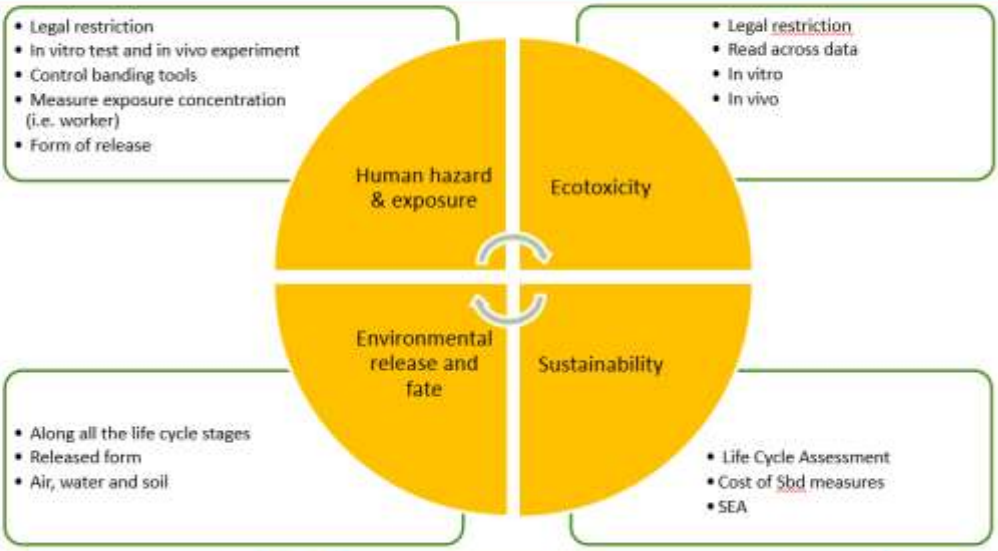
TEMAS Solutions Gov4Nano

SSbd as pre-market approach



This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Safe and sustainable by design



This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

SSbd- EU policy context

Figure Source: Goltsev et al. 2021, https://doi.org/10.1016/j.impact.2021.100297

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions

SSbd- EU policy context

- **EU Chemicals Strategy for Sustainability** (2020)
  - Ensure better protection of human health and the environment from hazardous chemicals
  - Boost innovation for safe and sustainable chemicals
  - Enable the transition to safe-and-sustainable-by-design chemicals
  - Commission will release sustainability criteria

They need to be adopted by the on – going project on SSbd

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

Rodrigues (2008) 10.1007/s11589-017-0296-3

TEMAS Solutions

Gov4Nano

SSbd- EU policy context

Chemical Strategies for Sustainability (**CSS**)

- The"**sustainable-by-design"** is a holistic approach to integrate **safety** , **circularity**, energy efficiency and **functionality** of chemicals, materials, products, and process through **their life cycle** and minimize the **environmental footprint** "

Safety

Circularity

Functionality

Lifecycle

Environmental footprint

EU- H2020 founded projects (SUNSHINE, HARMLESS) on-going on Safe and Sustainble by Design

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions Gov4Nano

SSbD-next challenges?

Legend: YES (already accounted in the SSbD), NO (not accounted and hence to be implemented)

Life Cycle Stage	Environmental criteria	Safety criteria	Social Criteria
Production stage	Emission to env. media (**YES**)	Restricted substance (**YES**)	**Social responsability (NO)**
	Resource consumption (**YES**)		
	Restricted substance (**YES**)		
	Sustainable sourcing of raw materials (NO)		
Use stage	Functionality (fitness for use)		Restricted substance (**YES**)
	Durability and reparability (NO)		
EoL	**Recyclability (NO) and waste (YES)**	Restricted substance (NO)	

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 814401

TEMAS Solutions Gov4Nano

Annex 3 – Answers from feedback questionnaire

GENERAL FEEDBACK

Did the training session meet your expectations?
(number and % of respondents)

	number	%
0 - no	1	10%
1	0	0%
2	0	0%
3	6	60%
4	2	20%
5 - fully	1	10%

What expectations did you have that were not met?

"The expectation which I had that wasn't met, was some build-in time to share and reflect on each others thoughts. The information presented by the trainers Veronique and Beatrice, and provided on the Mural, were both very useful. Unfortunately we did not find the time to integrate this properly into our assignment, and discuss this either during or at the end of the assignment."
"Maybe more time to exchange with different groups afterwards."
"There should be some discussion about the mural project and also the pros and cons in implementing those projects."
"I was expecting to have more interaction with organizers and experts."
"I was hoping a little more theory explanations and step-by-step or procedures to build a Sagfe-by-design product."
"I expected to gain knowledge about the current policies around risk governance and specific approaches to evaluating risk. The instruction was so basic and general, it could have been an undergraduate class and I did not learn anything new. In my opinion, having the entire workshop be an ongoing project fumbling with questions participants were ill-aquipped to answer in a purely hypothetical example was not useful."
"Sustainability"

Were there areas where you would have liked to learn more during the session?
(number and % of respondents)

Area	number	%
None	0	0%
Risk perception	0	0%
Sustainability	1	10%
Safe-by-design	3	30%
Risk assessment	6	60%
Risk governance	0	0%

Were there areas where you would have liked to spend less time?
(number and % of respondents)

Area	number	%
None	6	60%
Risk perception	1	10%
Sustainability	2	20%
Safe-by-design	0	0%
Risk assessment	1	10%
Risk governance	0	0%

Did your perception of nanotechnology risks and benefits change during the workshop? If yes, in which way?

"No" (3 participants)
"Yes, during the workshop I realised that the perception of risks by the public is also an important consideration in risk governance."
"Yes they changed in the way I saw how much work had to be done to make people aware about the risk perception."
"Yes, I saw different perspectives on the perceptions of nanotechnology problems and challenges."
"Yes."

Are you considering using any of the concepts or methodologies introduced in your current or future work? If yes, which one(s)?

"No."
"I will have a closer look, and also follow the development of the criteria for SSbD - I think this can aid in the discussion we sometimes have in our research group on the applicability of SSbD."
"Yes, most of them."
"I don't know yet!"
"Yes, the SSbD approach."
"Yes, I will take in consideration the risk governance in my work, since in the beginning it was not planned."
"Yes."

Would you recommend the training session to your colleagues?
(number and % of respondents)

	number	%
no	1	10%
1	0	0%
2	1	10%
3	2	20%
4	3	30%
5 - gladly!	3	30%

Do you have any other general comment about the training session?

"Thank you for organising the session! It was very informative, and - although I don't feel like I could integrate the knowledge directly into the assignment, I have learnt a lot about these concepts and the focus thereon in the Gov4nano project."
"It would be great maybe to have the materials of the training afterwards to remember what we talked about."
"None"
"A very interesting experience"
"Thank you for organizing the session. It was interesting to see how these various topics are closely related to each other."
"Yes, you could give us access to at least our mural or, if possible, everybody mural and to the presented slides during the first part of the training?"
"I am surprised this was marketed for postdocs and PhD students when it really did not feel designed for that level of prior knowledge and experience."
"no"

INTRODUCTORY LECTURE

Did the introductory lecture provide enough information to you for the brainstorming session?
(number and % of respondents)

	number	%
Yes	9	90%
No	1	10%

What were the concepts on which you would have needed more detail?
(number and % of respondents)

	number	%
None	0	0%
Risk perception	1	10%
Sustainability	1	10%
Safe-by-design	3	30%
Risk assessment	2	20%
Risk governance	3	30%

Was the time dedicated to the introductory lecture appropriate?
(number and % of respondents)

	number	%
Yes	6	60%
It was too short	4	40%
It was too long	0	0%

Do you have any other comment on the introductory lecture?

"If it is not possible to give us access to the introductory lecture slides, is it possible to give us the list of references used in the slides?"

BRAINSTORMING SESSION

Was the size of your group appropriate for the work that was asked?
(number and % of respondents)

	number	%
Yes	5	50%
It was too small	5	50%
It was too large	0	0%

Were you able to take part in the discussions within your group?
(number and % of respondents)

	number	%
Yes, every time I needed to	5	56%
Yes, most of the time	4	44%
Not enough in my opinion	0	0%

Were the times allocated to each exercise sufficient to complete the work?
(number and % of respondents)

	number	%
Yes	4	44%
No	5	56%

How easily did you understand what was expected from you during the exercises?
(number and % of respondents)

	number	%
1 - I had a very hard time understanding what was asked	0	0%
2	1	11%
3	5	56%
4	3	33%
5 - Everything was clear	0	0%

Do you have any other comment on the brainstorming session?

"It was very nice to work with other people that work on different fields."
"Although the exercises were not totally clear to understand, Veronique gave us the needed support to understand and move on. It was very nice that she showed up several times to support us."