Ref. Ares(2018)2843734 - 31/05/2018

UNDERSTANDING THE ROLE OF CULTURE, GENDER AND COMMUNICATION TRADITIONS, AND THEIR IMPLICATIONS FOR ENGAGEMENT METHODOLOGIES, COMMUNICATION AND DISSEMINATION

Deliverable 1.2

GoNano has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 768622.

Work Package:	WP1
Deliverable number:	D1.2
Partner responsible:	European Institute of Women's Health (EIWH)
Compiling author(s):	Vanessa Moore, Gerard Horgan, Rebecca Moore, European Institute of Women's Health (EIWH)
Contributing author(s):	Vanessa Moore, Gerard Horgan, Rebecca Moore, European Institute of Women's Health (EIWH)
Quality assurance:	Lise Bitsch, Ditte Degnbol, Helle Henriksen, Elias Mo Brøndum Gad, Danish Board of Technology Foundation (DBT)
Planned delivery date:	30 April 2018
Actual delivery date:	31 May 2018
Dissemination level:	PU

CONTENT

INTRODUCTION

1.1 BACKGROUND - GOVERNING NANOTECHNOLOGIES THOUGH SOCIETAL ENGAGEMENT

The GoNano - *Governing Nanotechnologies though societal engagement* - project is a 36-month long project which aims to improve the responsiveness of research and innovation processes to public values and concerns.

Part of the GoNano objectives are to create an engagement process which is cognisant of gender, diversity, culture and communication traditions across Europe. This engagement process will inform future nanotechnology development, by ways of public discourse and methodology development, as well as co-creation. In order to adequately align nanotechnology Research and Innovation (R&I) with societal needs, it is important to look at societal issues such as gender, culture, and diversity. These areas of focus present us with an opportunity to get a deeper insight into what motivates opinions, thoughts, needs, values and concerns -- are these the same, or are there differences between or within various groups? Does gender have any impact on how values, needs and concerns around nanotechnology are shaped; does demographic diversity influence such concerns? What information and knowledge can we glean from looking into divergences of opinions and differences in discourse? What can we gain from increased awareness and focus on these issues?

All these questions are pertinent to the GoNano project, as we will be able to use the responses to them in order to create, specialise and sharpen methodologies for engagement and co-creation. By being aware of what aspects of gender, culture, diversity and communication methods affect public discourse and public opinion, we can engage the public in a more immediate and significant way, and thereby develop a better and more effective communication and consultation methodology. Significantly, it will also assist in understanding and addressing values, needs and concerns that surround nanotechnology and its future development.

This report is divided into two parts, where the first part consists of a literature review where these issues of gender, culture and communication is investigated. The second part is an analysis of societal debates, where online tools are used for harvesting, mapping and analysing social data on social media and websites on national debates in five European countries – the Czech Republic, United Kingdom, Denmark, Netherlands and Spain.

The full description of our task as outlined in the GoNano project is as follows:

Task 1.2: Understanding the role of culture, gender and communication traditions, and their implications for engagement methodologies, communication and dissemination strategies. *Task 1.2 will analyse and map societal debates, and outline how culture, gender and communication traditions influence debates and the public understanding of nanotechnology research and innovation. The analysis will be used to provide recommendations for design requirements and methodology development in WP2 for the public engagement exercises in WP3 and WP4, and the communication and dissemination strategies in WP7.*

- *Citizen's concerns related to nanotechnology;*
- *Citizens needs and values related to future technology development;*

- *Gender and diversity issues related to nanotechnologies and other emerging technologies;*
- *Cultural, gender and communication differences important for methodology development;*
- *Methodologies previously used in public engagement in nanotechnology and how they can be optimised.*

In analysing societal debates, this task will make use of online tools for harvesting, organising, analysing and visualising complex social data on social media and websites. The mapping will be done on national debates in the Czech Republic, the UK, Denmark, the Netherlands and Spain. Furthermore, the will receive data from the interviews conducted in task 1.3, and will therefore provide questions for the interview design in task 1.3. The outcome of task 1.2 will be a briefing report on culture, values, communication and gender differences to be taken into account for methodology development in task 2.2, data for background production in task 3.1, lessons learned written for upload to the digital knowledge database, and the task will produce a visualisation of online debates, which will be used in the co-creation pilots of WP3 and WP4. Finally, the analysis of online debates will also create knowledge on where publics are already discussing nanotechnologies online. The knowledge will be used for the recruitment as well as consultation phase in 3.3.

1.2 PUBLIC DISCOURSE ON NANOTECHNOLOGY: DISCOVERING NEEDS, CONCERNS AND VALUES

One purpose of this report is to look at the public discourse around nanotechnology. To what extent is public discourse taking place? What needs, concerns and values are discussed, and what role do they play in framing the overall nanotechnology discussion? What other societal aspects play a role in public discourse? Are issues such as gender, diversity, and culture playing a part? Are their influence recognised in the discourse? What can the GoNano project learn from it, and how can interactions with the public be improved?

In order to address these questions, we began by drawing up an overview of nanotechnology and the public discourse surrounding it. The term nanotechnology refers to areas of science, engineering, research, and so on where the dimensions are so small that they are measured on the nanometre scale. The European Commission recommends the following definition to describe nanomaterial:

> *"'Nanomaterial' means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm- 100 nm [nanometre]"* (Rauscher et al., 2014, p.15).

The behaviour of materials on such a small scale can be different from those at the macro scale, and laws governing nanoscale behaviours of materials are constantly being investigated (Macoubrie, 2006). The special features and phenomena that are present in materials at the nanometre level differ from those of conventional materials, and have led to the development of many different kinds of high-performance nanomaterials (Gul, 2017). In nanotechnology, traditional disciplines – material science, molecular biology, chemistry, and physics – merge, and collaboration with other researchers is essential. Research in the field contributes to areas as diverse as medicine, electronics, robotics, cosmetics, metrology, instrumentation, and the environment (Villanueva-Felez et al., 2015). As nanotechnology continues to progress, new advances affect many different industries as it develops new methods of constructing products; it also affects basic science, as it crosses disciplinary boundaries (Macoubrie, 2006). Nanotechnology is not only a scientific breakthrough but is also regarded as an economic opportunity due to the potentially ground-breaking opportunities it provides, and its wide application to everyday life (Gul, 2017).

Because of the extensive scale of where it can be used, the prospects of nanotechnology are vast, and it has been applied in areas from healthcare, energy provision, food production and technology to cosmetics. Initially, however, when nanotechnology began to grow rapidly there were few debates about the social, ethical, and regulatory aspects of nanotechnology (Corley et al., 2009), despite its wide usage. Scientists and regulators were aware of the potential deleterious effects of nanoparticles on human health and the environment, and discussions began about the issue. However, not just scientists but also the public should be aware of the potential risks and adverse consequences of nanomaterials, not least because public opinion plays a role in policymaking (Yeo et al., 2014) and public awareness of benefits and risks of a new technology is crucial. Also, public opinion about nanotechnology is likely to have an influence on future funding-related policies (Ho et al., 2010).

Public opinion of nanotechnology is shaped by many different factors. The types of associations that a lay person has with nanotechnology can influence how perceptions of risks and benefits are utilised when the person forms opinions about nanotechnology; this influence of perceptions, good or bad, is a complicated phenomenon (Cacciatore et al., 2011). It is important to find out what makes the public form certain opinions about an area as specialised and dense as nanotechnology, as it is only through understanding this that we can adequately involve the public in communication, engagement and dialogue, and ensure that this dialogue addresses issues related not just to nanotechnology and risk in general but also where issues intersect, for example gender and diversity.

Literature review

2.1 Literature search methods

The literature review began with an exploration of the concept of nanotechnology, and engagement traditions and methodologies. A search of electronic databases was carried out in order to identify papers in peer-reviewed publications on the topic of nanotechnology, gender, culture, communication and engagement.

Databases used were Web of Science, PubMed, EMBASE, PsychINFO and CINAHL. These were searched using search terms including nanotechnolo* combined with gender, women, woman, female, diversity, race, culture, communication*, engagement, dissemination, among others.

In addition, conventional search engines were used to search for any additional grey literature on the topic.

2.2 Gender and diversity

2.2.1 Gender

In order to analyse the public discourse on nanotechnology, the issue of gender was a main point to be examined. One of the objectives of the GoNano project is to work together with science, industry, civil society and the public to develop Responsible Research and Innovation conditions in nanotechnology R&I; to do this successfully, we need to fully understand societal needs and concerns, such as the role gender plays in nanotechnology. The purpose of the following section is to examine the extent to which gender is a factor in public opinion, in research, in science, and as part of how citizens in general relate to nanotechnology.

As with any discussion on gender, it is important to ensure from the beginning that the terminology used is understood correctly. The term *gender* is not the same thing as biological sex – the two terms are often used interchangeably, which is incorrect. Gender refers to socially constructed roles, behaviours, activities, and attributes that a given society considers appropriate for men and women, whereas sex refers to the biological and physiological characteristics that define men and women, boys and girls (World Health Organisation, 2010). Both sex and gender have implications in relation to nanotechnology, as the below will make clear.

One of the biggest issues in terms of gender is the paucity of women in science. A large and growing body of research has charted the impacts of the underrepresentation of women in the science, technology, engineering, and mathematics (STEM) fields. The degree of women's underrepresentation increases with the level of occupational hierarchy in STEM, with statistical data showing women clustered in low-ranking positions in both the United States and Europe (Villanueva-Felez et al., 2015). There is a growing recognition of the benefit that the presence of female professionals in STEM brings, not least the fact that their mere presence may help to hasten the diversification of the sector by acting as role models for future entrants: nevertheless, women remain underrepresented at all levels (Sappleton and Takruri-Rizk, 2008).

The result of this is that the core values and assumptions in STEM fields, including nanotechnology, have been fundamentally shaped by men and male norms (Savath and Gage Brainard, 2013). This has a knock-on effect, not just in terms of the physical underrepresentation of women, but of the consequence this has on science and research, as the below paragraphs will outline.

The underrepresentation of women in the natural sciences contributes to deficits within a scientific enterprise (Toumey, 2012). By integrating sex and gender in not just the workforce, but also into research, value is added by allowing diverse and new viewpoints or ideas; by ensuring innovation, excellence and quality in outcomes and enhancing sustainability; and by making research more responsive to social needs (Schiebinger, 2017). While more research is needed on the issue of gender, both inside and outside the nanotechnology field, existing research suggests that when it comes to nanotechnology, strong gender-based variations can be found in risk perception, both among lay persons and nanotechnology/STEM scientists.

Public surveys of attitudes to nanotechnology reveal that men and women have differing attitudes towards the risks and benefits associated with nanotechnology, with women generally less familiar with nanotech, less enthusiastic about it, and less willing to tolerate nano-related risk (Toumey, 2012). Research suggests that the role of gender in perceived risk may relate to socio-political factors, such as the "white male effect" described by Finucane et al (2000). In a study on risk perception, gender and race, they found that while risk was judged as lower by men, it was consistently judged as much lower by white, well-educated, high-income, politically conservative males. Finucane et al speculate that this result is because the world seems safer, and hazardous activities more beneficial, to white men than to other groups. Women and males of colour tend to be in a position of less power and control, benefit less from technologies and institutions, are more at risk from discrimination, and are therefore more cautious when judging risks (Finucane et al., 2000).

In terms of scientists involved and working in the area of nanotechnology, again risk perception is different. Savath and Gage Brainard (2013) found that female and male nanoscientists think about the social and ethical implications of their work in different ways, with female scientists more likely to recognise nanotechnology as a unique risk and one that has potential downstream impacts on consumers. Women were also more likely to communicate risks openly and take on moral agency, suggesting the potential for tighter collaboration between policy-makers and the scientific community. The issue of risk perception will be discussed in more depth further on in this report.

Another issue caused by the underrepresentation of women in the STEM field in general is the impact it has on the process of scientific collaboration, to the disadvantage of female scientists. In a gender analysis of nanotechnology researchers' collaboration relationships, Villanueva-Felez et al (2015) found that science institutions reflect ingrained forms of male dominance in the field, and that the underrepresentation of women in positions of authority over STEM resources means that women have less influence over how resources are used, and by whom. Organisational and institutional contexts are thus systemically gendered, which has significant and inescapable effects on the social processes of working in nanotechnology. As Villanueva-Felez et al explain, collaboration relationships in science are crucial to access knowledge, information, research funding, support, peer networks, and technical skills, to mention but a few, and in a wide field such as nanotechnology inter-organisational cooperation is particularly important. Their study found that the structural underrepresentation of women in nanotechnology significantly genders the social process of collaboration, with men much more likely to collaborate with other men than with women, and women more likely to collaborate with the available women in the field. Interestingly, they also found that women have lower access to general-strategic information than men, despite almost three quarters of their reported collaborations being with men due to the low proportion of women. This confirms that access to this type of information has a gender dimension. Women were shown to be as effective as men within the social processes of scientific collaboration, but the structural underrepresentation of women in nanotechnology and STEM mean that women start from a disadvantage in terms of both their overall collaboration ties, and in their access to strategic information (Villanueva-Felez et al., 2015).

As the above example shows, gender is an issue in more ways than one. From underrepresentation of women scientists, to differences in risk perception among the public, gender is constantly present. Considering that women make up 50 per cent of the population, taking these issues into account and working to address them must be a priority. However, the role of gender does not stop there.

Men and women also play different roles as consumers, whether it is in relation to nanotechnology commercial goods like food or cosmetics, or as recipients of products containing nanotechnology in areas such as healthcare. Using healthcare as an example, there exists the possibility that men and women will be affected differently by nanotechnology products based on biological factors. Attention to sex and gender in biomedical, health and clinical research is an important quality and safety issue, and medicinal products are safer and more effective for everyone when clinical research includes diverse population groups; however, this is generally not the case. Female participation in clinical trials is low, and while it has improved in recent years, the assumption still exists that women do not differ from men except where their reproductive organs are concerned – using this logic and the assumption that being male is the norm, data obtained from clinical research involving men is simply extrapolated to women which is not always suitable (Health Canada, 2013). Low participation of women in clinical trials also results in a lack of awareness among doctors and health care professionals about the importance of sex-specific differences across the lifespan, as well as creating a situation where doctors cannot provide care for females that is evidence-based (Kim et al., 2010).

Not enough research has been done into how gender is considered in such applications of nanotechnology; risk assessment for when sex may be an issue needs to be done in relation to for example in-utero exposure of silver nano, which is widely used in cosmetics (Schiebinger, 2017). Cosmetics are one of the largest product categories of nanotechnology, being used in products such as moisturisers, acne treatments, exfoliants, eyeliners, and toothpastes, to name a few (Moore, 2012), products which are all predominantly used by women. Issues such as dermal absorption, inhalation and ingestion of the nanoparticles present are all important for risk awareness (Shokri, 2017).

Risk awareness is a crucial point when it comes to nanotechnology, however risk awareness should not equal unnecessary or unwarranted fear and suspicion. The usefulness of nanotechnology is well documented and in many cases improves the safety of a product; one such example is sunscreen. The risk of skin penetration of sunscreen that uses nanotechnology is often cited as a cause for concern (Moore, 2012, Schiebinger, 2017, Shokri, 2017). However, sunscreen produced with nanoparticles can enhance the effectiveness of the product, and do not carry with them issues of conventional UV filters which can cause skin irritation, allergies, need to be re-applied more frequently, and are absorbed into the skin to a greater extent, including some with potentially endocrine-disrupting activity (Wright, 2016). Also, studies have shown that nanoparticles used in sunscreen are very unlikely or unable to penetrate the viable skin or the lower layers of the skin (Katz et al., 2015).

The debate over sunscreen highlights the need to effectively and practically communicate such issues to the public, to allay fears but also to ensure that the public does not turn away from such sunscreen based on erroneous information. The danger of exposure to UV light in relation to skin damage and cancer is far greater than the risk of nano-enhanced sunscreen, and the perception of risk around sunscreen is not supported by the scientific literature (Wright, 2016). This communication must be targeted, to ensure that the specific group of consumers who buy sunscreen, for example mothers who buy it for their children, get the correct information.

Gender and sex needs to be included in every part of nanotechnology, from research and innovation to communication efforts and engagement methodologies, and it needs to be included from the very beginning. Only by doing this will we challenge and change the gender bias from the past, and if we do not manage to address the issue properly, it will morph into even more entrenched gender inequality in the future (Schiebinger, 2017). Also, the importance of gender as part of creating an efficient engagement methodology is clear - by recognising and understanding its role in societal needs and concerns, and seeing how this may translate in the co-creation process, the GoNano project can address not only gender inequality but also help create future nanotechnology development that listens to the public discourse on needs, values and concerns.

2.2.2 Diversity

Gender and sex are not the only factor which can have an impact on citizen’s understanding of and engagement with nanotechnology. A lack of diversity in the nanotechnology field, and the inability to take diversity into account when having a dialogue with citizens, is also a problematic area that needs attention. Diversity in both the public and scientific sphere is important, and has an effect on each other: increased diversity in the workplace creates a situation where policy-makers will have a more diverse pot of experts to reach out to when designing policies that will affect the broader population (Savath and Gage Brainard, 2013).

Diversity does not mean solely gender, and can be a difficult term to define – does it refer to gender, ethnicity, sexual orientation, age, ability, religion, social class? Diversity can mean many things, and a person may be diverse in one way and not in another; for example, does including a woman on a team make it diverse, even if she is from a white privileged middle-class background? Or is a team more diverse if it includes a privileged, middle class man but who comes from a minority background? When considering diversity, it is crucial to look at how these multitudes of social identities intersect with each other. Intersectionality is the interaction between gender, race, and other categories such as sexual orientation, age, disability, and so on, and the outcomes of these interactions in relation to power structures and oppression (Davis, 2008).

In terms of STEM in general, diversity is an issue in terms of a number of social identifiers, as this example from Corley et al. shows. In their 2016 study, they analysed the responses to eight questions from a postal survey sent to leading US nano-scientists. The scientists were defined as 'leading' as authors for the most highly cited nanotechnology publications (n=444). The response rate for the survey was 31.6%. Of the responses, 82.5% were male, and an overwhelming amount, 95.3%, were either white (63.5%) or Asian (31.8%), with only 2% Hispanic and 0.5% African-American (Corley et al., 2016). It is obvious that in this case, both gender and race diversity was sorely lacking. When a scientific community like the nanotechnology community lacks diversity it is less likely to consider the needs and concerns of all those potentially affected by future nanotechnologies, especially those in populations that have been historically vulnerable (Savath and Brainard 2013). Diversity is therefore helpful for more long-term and social benefit.

Including more diversity in the workplace would thus create scientists more aware of societal concerns, which is an essential part of effective dialogue. However, such diversity is not only beneficial for the general public. Nielsen et al (2017) note that modern scientific investigation is more and more dependent on well-run and well-performing research teams. Teams have been proven to benefit from diversity, including gender, ethnicity, nationality, scientific discipline and work experience, to name a few. Encouraging diversity creates an 'innovation dividend' for scientific organisations that lead to smarter, more creative teams with more new discoveries (Nielsen et al., 2017). To include and analyse not only gender but other intersecting factors such as ethnicity, socioeconomic background, and so on is therefore vital, as it improves science and innovation but also may reveal sub-group differences (Schiebinger, 2017).

Diversity also includes cultural differences and variation, which can be grouped using different variables such as culture, religion, and so on. The three pilot countries for citizen engagement in the GoNano project (Denmark, the Netherlands and the Czech Republic), for example, are grouped in different categories when it comes to culture, as outlined in the SATORI report (Brey et al., 2015). It shows that Denmark belongs to the Nordic Countries Cluster, which has a higher level of gender equality, lower level of individualism and conservatism compared to Western Europe, and with a broad egalitarian culture with political identity based on individuality, social incorporation, and with a 'consensual' political style. The Netherlands, on the other hand, is part of the Western European Countries Cluster, which, while valuing equality and social justice, always puts economic growth first, is very influenced by neoclassical economic ideals, and covers both traditional values and secular values, with the Netherlands belonging more to the latter than the former. Finally, the Czech Republic belongs to the Central European Countries Cluster, which consists of formerly Communist countries but that were not Communist between the wars. Despite their Communist heritage they have made rapid changes and moved to democracy and market economy, and are closer to Western European countries than their eastern neighbours (Brey et al., 2015). Insights provided by reports such as SATORI indicate that awareness of cultural differences between regions and countries, and the outlook of citizens of the relevant countries, can be put into context and variations in needs, values and concerns can be interpreted and understood more effectively.

With the main issues of gender and diversity in mind, the next few sections focus on a number of areas that we have chosen to analyse in-depth. These are differences in risk perception regarding nanotechnology, both among the general public and nanoscientists, and the gender aspect of this; media influence on the perceptions of nanotechnology, both for the general public, scientists, and policy makers; how these groups form opinions and why this is important to know in terms of effective engagement; how policy and governance keep up with the breakneck speed of nanotechnology; and how this influences public understanding and policy making. We have chosen these issues because they help us understand the needs, concerns and values that need to be addressed in our engagement methodologies and future nanotechnology development -- in other words, issues of public discourse that address societal concerns around nanotechnology.

2.3 Opinion formation

The opinion that the public have of nanotechnology is an important part of many issues related to nanotechnology. For instance, the public perception of the risk that something as specific as nanotechnology may pose to a person's health, or the environment, will influence how a person feels about interacting with a nanoproduct, whether it is as a consumer or in a healthcare setting. The complicated nature of nanotechnology means that understanding exactly what it is on a fundamental level is difficult for the vast majority of people who are not scientists – this can lead to fear and confusion. Knowledge of how the public approach an issue and understand it, as well as awareness of what causes certain judgements to be made, provides a good foundation for engaging with the public, in both methodology development and co-creation. By for example addressing risk in debates and conversations with citizens, and focusing enquiries and discourse on how risk perception is formed, what may be the cause of it, and how the public would like this to be addressed in relation to nanotechnology, we are both continuing a dialogue while also developing engagement methodology.

How something is understood by the public is a challenge in itself – how does an individual form an opinion on nanotechnology, which is a highly complex topic? One way is through cognitive 'shortcuts', used to make quick decisions about a complex topic, or through the portrayal of nanotechnology in the media. Another influencer of public perception of nanotechnology comes from how governance around risk or other issues is done. The extremely wide potential application of nanotechnology means its effects are difficult to predict, simply because of the vastness of where it can be used. This can be interpreted as both a positive – there are no limits to how much and in how many ways we can benefit from nanotechnology – or a negative – we do not know how it may affect us.

How are opinions on new, complicated or unknown technologies formed? Some argue that access to information will create an informed and engaged public; or that knowing more about a technology will make the person more open towards it; or that greater scientific literacy allows the public to sort out misinformation from reality in support of science. But other studies have found that factual and/or scientific knowledge has little or nothing to do with public acceptance of new technologies (Corley et al., 2016, Lee et al., 2005, Ho et al., 2010).

The public perception of the risk, real or otherwise, that nanotechnology may pose will in turn also affect policy makers. Policy makers are influenced by both the public and by scientists, and if there is a lot of fear and misunderstanding regarding nanotechnology and its applications, it may lead policy makers to create tight governance. This is not necessarily a bad thing, as a technology which is well regulated and governed will be more trusted by the public, again both as consumers and in relation to for example food additives or healthcare.

For this particular analysis, we were interested in finding out how the general public decides what to think of nanotechnology, as through understanding this we can begin to understand how best to approach specific groups and how to start a dialogue on their take on societal concerns relating to nanotechnology. Decades of research into political communication has shown that information can be presented in ways that change the interpretation among audiences; also, citizens will generally use their own pre-existing values to interpret information, no matter how neutral or balanced the information in presented (Scheufele, 2006). By seeing where there are differences and where certain sections of the public differ from each other in their opinions on nanotechnology, we get an insight into what is important for different groups and how to best reflect this in a variety of arenas: engagement methodologies, policy, regulations, and so on.

Demographics are an important part of opinion formation, and ensuring that demographics are varied and that opinions are listened to from all groups is crucial. For the GoNano project, including a representative demographic sample in citizen workshops and online engagement, as well as ensuring that questions that are important to different demographic groups are included as discussion points at these events, will be essential. This is partly as different demographic groups have different concerns, but also as the success of aligning nanotechnology R&I development with societal needs will depend on the level of which all segments of society, and all those in the public discourse, are represented. For example, numerous studies have shown that age, gender, and socioeconomic status are significantly related to public acceptance of nanotech (Ho et al., 2010). Also, in their 2005 study Lee et al found that older people, females and ethnic minorities were more likely to feel negative toward nanotechnology. This finding was consistent with previous studies about how demographic variables affect public perceptions of and attitudes toward technology-related issues (Lee et al., 2005). We will return to the issue of demographics later, as it has an impact on not only our understanding of the issue, but also on future engagement methodologies. Finally, understanding the dynamics of opinion formation provides important insights into sociocultural contexts in which nanotechnology research is conducted. This includes the societal benefits that people expect from nanotechnology, and ultimately, into the links between public attitudes toward nanotechnology and decision-making about science and technology (Lee et al., 2005).

2.3.1 Making decisions: heuristics, cues and affect

In order to be able to develop nanotechnology in ways that acknowledge societal considerations, it is essential to explore how the public acquire baseline information to help form judgements and perceptions about an issue like nanotechnology (Dudo et al., 2011).

Value predispositions have been shown to play a large role in shaping opinions towards emerging technologies. A person is more likely to select information in a biased fashion to match their cultural and political disposition (Cacciatore et al., 2011). This comes from the fact that the public will use what is known as *cognitive shortcuts* to form an opinion. We as human beings have to deal with thousands of pieces of new information every day, and need to establish patterns to do so quickly. It does not make sense for most to dedicate time to develop an in-depth understanding and knowledge of an issue, and instead a person will form an opinion on a dense issue like nanotechnology even in the absence of scientific information (Scheufele, 2006). This is by no means a claim that the general public are nonsensical, or do not want to have access to facts -- rather, it simply explains how immediate judgements are made, and thereby tell us how we can interact with such judgements, and with that how engage with them.

Persons make judgements about technologies using such cognitive shortcuts, or *heuristics*. Heuristics is an approach to problem solving where a practical method that is not optimal or perfect is used, as it is practical and sufficient for immediate decision-making, and also eases the cognitive load of making a decision. The general public rely on heuristics or cognitive shortcuts when making sense of technologies, as well as the extent to which they trust regulatory agencies, or the way that potential risks or benefits of for example nanotechnology is framed (Ladwig et al., 2010). Again, this is not accusing the public of being ill-informed or ignoring facts, but rather a description of the process of how initial judgements are made.

Opinion formation is thus to a large extent based on cognitive shortcuts and ideological predispositions. Such predispositions may be political alignment or religious beliefs, which will affect how a person decides what to think about a technology. More affective aspects also play a role in opinion formation; concerns or fear can precede cognitive evaluations and create a situation where opinions are based not on analytical judgement but on a general feeling about science and technology. Lee et al (2005) found that such variables played an important role in shaping perceptions of risks and benefits as well as general attitudes towards nanotechnology.

A number of studies have analysed the role religion plays in shaping perceptions of nanotechnology. Most of these have been done in the US, however Brey et al (2015) gives a broad overview of religion and science in Europe in general. They conclude that Western Europe is one of the least religious areas of the world. Within Europe, there exists a difference with religion playing less of a role in Western and Northern Europe compared to Southern and Eastern Europe. Europeans in general have a positive attitude towards science and technology, and a higher level of religiosity does not result in a negative attitude towards scientific research. Rather, what affects Europeans' trust in scientists negatively is if there is involvement with business interests that might influence the process of research and innovation (Brey et al., 2015). Scheufele et al (2009) compared public opinion surveys in the US and the European Union regarding public attitudes to nanotechnology. They found that US respondents were less likely to agree that nanotechnology is morally respectable than respondents in the EU, and religion was a part of the value system that was used to make sense of science and technology more broadly. Likewise, Brossard et al (2009) found a direct and negative relationship between strength of religious beliefs and support for funding of nanotechnology, whereas Ho et al (2010) found that religiosity is one of the major factors associated with public resistance towards new technologies. The fact that people use religion as an attitudinal filter when it comes to forming opinions about nanotechnology is not surprising, as religious people may put nanotechnology, biotech and stem cell research in the same negative light as something trying to enhance human qualities (Ho et al,. 2010).

Cognitive shortcuts are influenced by not only ideological predispositions, but also by cues from media (Lee et al., 2005). Media exposure is significantly related to both public and scientist perceptions about technological risks and benefits of nanotechnology, as well as policy decisions (Corley et al., 2016, Scheufele and Lewenstein, 2005). The public tends to reply on interpretative frames offered by the media when making decisions on opinion of nanotechnology (Corley et al., 2009). The influence of media on public opinion is nothing new, however what this knowledge underlines is the importance of science communication in order to invite and encourage dialogue to develop and sustain a genuine interest among the public in nanotechnology. Questions that need to be understood and addressed include what media frames regarding nanotechnology exist; how did they get on the media agenda; what dynamics link frames to public opinion and public decision-making; and finally, what role can scientists play in influencing these dynamics (Scheufele and Lewenstein, 2005). This is highly relevant to our task in this report, as understanding communication differences and the optimisation of public engagement with nanotechnology is part of the brief.

2.3.2 Media and communication

Media framing of the issue of nanotechnology effects how risks and benefits are perceived. Media, primarily referring to newspapers and television, frames issues and allows audiences use the heuristic cues that are part of the framing, such as the tone of the reporting, as shortcuts to process the information in short time (Ho et al., 2010). Media frames provide audience with cognitive shortcuts or heuristics to efficiently process new information, especially for issues that the public may not be overly familiar with, such as nanotechnology. This is done through visual or terminological cues: for example, referring to tax cuts as 'tax relief' (Scheufele and Lewenstein, 2005).

In the US, a pattern exists for nanotechnology media coverage: the volume of media coverage has been relatively modest over time, has been authored by a small group of journalists, and has generally carried a positive tone (Dudo et al., 2011). Other studies also found that the general tone of coverage was positive, emphasising the usefulness and economic potential of nanotechnology (Yeo et al., 2014, Scheufele et al., 2007, Cacciatore et al., 2011, Ho et al., 2010). While similar research is limited for Europe, Lee and Scheufele (2006) found that the US media framed nanotechnology in a more positive light that did the UK media.

The public's use of cognitive strategies to absorb the scientific information they get from media can also be associated with a more positive acceptance of a new technology like nanotechnology, and media use has had a positive association with public support for federal funding of nanotechnology (Ho et al., 2010). The positive opinion of nanotechnology that the media portrays is beneficial for the development of nanotechnology; however it also shows that if the portrayal was the opposite, then obviously negative opinions might prevail. It is therefore crucial that scientists and nanotechnology research in general are aware of the importance of specific and appropriate communication strategies.

Science communication practitioners should target their communication messages to fit with different demographics and social background for maximum effect (Ho et al., 2010). A well-established and properly functioning communication system also cultivates images of science and scientists in the public's mind and therefore influence perceptions of whether they can be trusted or not (Lee and Scheufele, 2006). This works both ways -- encouraging scientists to pay more attention to media focusing on the social and ethical implication of science can be linked with stronger social responsibility in relation to their own research (Corley et al., 2016). Science communication should also concentrate outreach efforts on tailored messaging for specific subgroups based on their levels of information, risk perceptions, and belief systems (Brossard et al., 2009).

All the discussion about media and framing has until now referred mainly to newspaper and television. As media is increasingly consumed online by all demographic groups, the ease of which information is accessed will undoubtedly have an impact (Dudo et al., 2011). Beginning on page 22 of this report, we further explore the discourse taking place online through mapping exercises, giving more insight into how information is consumed and to what extent communication online or through social media aids dialogue with the public.

2.3.3 Governance, policy making and trust

Suitable governance and regulation around nanotechnology is a crucial issue, as it is one of the main ways potential risk around nanotechnology can be estimated and acted upon. In this report our focus is on the perception of governance and policy making, and to what extent the general public and scientists are aware of its importance; the extent of trust in regulation, governance and policy making process; and why trust is imperative.

Trust in relation to emerging technologies can be defined as a citizen's willingness to rely on the endorsement of experts such as scientists and regulators, and/or institutions for example the government, to manage risk associated with new and emerging technologies (Ho et al., 2010). As discussed earlier, technical knowledge or scientific understanding does not equal increased support for nanotechnology among the public; rather, opinions are formed and decisions of trust are made dependent on what cognitive shortcuts and cues and frames are influencing the person. The importance of trust in governance is no different. Levels of trust in scientists and regulatory authorities could outweigh the role attributed to scientific knowledge (Brossard et al., 2009); in other words, trust may play a more important role than knowledge for the general public. In a similar vein, public trust in the management of technology-related risk can be more important than beliefs in the technology itself (Lee et al., 2005).

Why is it important for governance and policy making that the public has an interest or opinion in nanotechnology? The level of trust that people have for regulators influence risk perceptions, and if there exists a perception of a higher level of control regarding how technologies are regulated, individuals are more likely to accept the new technology (Dudo et al., 2011). However, the importance of public trust is more complex than just perception. Trust in nanotechnology is crucial to sustain public support, and without public dialogue or support policy-making is affected. Also, public opinion of the risks and benefits of nanotechnology has considerable bearing on research and development within the field (Nerlich et al., 2007).

This is especially significant, as there is still a lot of uncertainties surrounding nanotechnology and the risks and benefits it may have. As developments in nanotechnology move rapidly forward, policy-makers are determining how to formulate new regulations while high levels of uncertainty still exist, and they often end up relying on scientists' perceptions about risk and benefits while they wait for data on policy-relevant risk assessment to build up (Corley et al., 2009). Nevertheless, public policy requires some amount of public input. If the lay public does not have any perception or idea about nanotechnology or its potential risks, their input tends to be uninformed and the regulation may suffer as a result. Discussion and dialogue amongst the public regarding nanotechnology is therefore crucial (Yeo et al., 2014). Most government programmes set up to facilitate and nurture nanotechnology in the US do not include enough public input, which could cause members of the public to view policy decisions about nanotechnology with suspicion (Toumey, 2012).

The importance of trust in governance and regulation does not end there. When individuals make judgements on issues they are not overly familiar with or that can be highly complex, such as nanotechnology, they rely on trust to make up for the lack of information (Lee and Scheufele, 2006). It is therefore imperative that scientists, regulators and policymakers alike are cognizant of any development in media coverage of nanotechnology, and to keep track of public opinion. Media could also serve as a point of intervention for policy makers and public officials in order to provide accurate, up to date and unbiased information to the public (Ho et al., 2010).

It is also important that the scientists themselves stay involved in communication and keep dialogue open. A lack of scientific consensus on the full range of risks and benefits of nanotechnology can hinder developments of new regulations to deal with the technology; and a slow process of policy-making is a challenge for any emerging technology, as the science tends to move forward rapidly which regulation lags behind (Corley et al., 2016).

One interesting finding in issues of trust and governance and policy making was that gender plays a role. Corley et al (2009) found that in a representative study of nanoscientists in the US, male nanoscientists were less supportive of regulation than their female colleagues, both for academic nanotechnology research and commercial nanotechnology research. Even more striking than this, however, was the gender demographic of the sample of nanoscientists in this study. The data collected came from a postal survey to leading US nanoscientists, who were identified through being listed as first authors and contact authors for the most highly cited, recent nanotechnology publications indexed in the Web of Science. The final response rate was 40 per cent, and of these respondents an eye-watering 86 per cent were male (Corley et al., 2009), again highlighting the underrepresentation of women in nanotechnology.

2.4 Risk perception and nanotechnology

2.4.1 Public risk perception

So far, we have discussed how opinions on nanotechnology are formed, and what influences an individual to make a judgement or have an opinion on an issue like nanotechnology. The heuristics involved in opinion making and the influence of the media, as well as the importance of trust and governance have all been examined. However, the opinion the general public makes on nanotechnology is generally one of either a positive or negative disposition, and this is more often than not in relation to *risk perception*.

Risk perception can be defined as the judgement a person makes when they are asked to characterise and evaluate potentially hazardous activities and technologies (Ho el al., 2010). The perception of risk is crucial to an area like nanotechnology, where its applications in food, healthcare, or consumer products like cosmetics mean that any potentially negative effect will have a direct consequence for the individual.

The main finding with public risk perception of nanotechnology was that there exists a clear gender divide, with numerous studies showing that women have a higher level of risk perception. Toumey (2012) argues that perhaps it is not women that are different in terms of risk perception, but rather that politically conservative, authoritarian, high-income, highly educated while males are very risk tolerant relative to all others. Nevertheless, the difference is consistent in many studies. For example, women are less familiar with nanotechnology, less enthusiastic about it and, crucially, less willing to tolerate nano-related risk (Toumey, 2012). Cacciatore et al (2011) found that within the general public, men were more likely to express support for nanotechnology. Lee et al (2005) also found that females showed a higher level of risk perception in a representative telephone survey. Gul (2017) explored attitudes towards nanotechnology among university students and reached a similar result; even though both males and females were overall positive towards nanotechnology, the attitude was even more favourable among males as the females showed more risk perception. Nerlich et al (2007) showed that among young adults in university, male students were more optimistic about medical treatments with nanotechnology, the benefits it might have and the achievements of nanomedicine than their female counterparts. The female participants, while supportive of nanotechnology-based health interventions and treatments showed a higher level of risk perception and questioned the risk more (Nerlich et al., 2007).

The gender divide in risk perception among the public is not just a curiosity, but instead is evidence of the diversity of opinion that exists among different demographic groups, and highlights the importance of ensuring that a diverse public is represented in dialogues and engagements on nanotechnology. Studies have shown that age, gender and socioeconomic status were related to public acceptance of nanotechnology (Ho et al., 2010), and this must be taken into consideration at all times. Risk and benefit perceptions about nanotechnology are significantly related to perceptions about regulation of nanotechnology (Corley et al., 2016); therefore, if regulation is to be successful it needs public support from all areas.

The level of public acceptance, confidence and trust will largely determine the success of specific nanotechnology areas such as food nanotechnology (Dudo et al., 2011), and including all parts of the public in this and understanding why there are differences of opinion and ensuring these are addressed is therefore imperative. Increased perceptions of risk have been shown to lessen public acceptance of a new technology (Cacciatore et al., 2011), so effective outreach to all demographic groups by scientists, researchers and governance and regulatory bodies is more important than ever.

2.4.2 Nanoscientist risk perception

Generally, scientists have less risk perception of the technology they are involved with, whereas the public are more likely to be sceptical about risks associated with a new, unknown technology. However, the situation with nanotechnology is a bit more complex. Risk perception has been found to be greater amongst scientists compared to the general public, especially when it comes to specific nanotechnology areas, for example pollution and health - comparisons of opinion surveys have shown that the public are less concerned about such risks (Yeo et al., 2014).

This does not mean that scientists are not optimistic about the benefits of nanotechnology, but rather points to a strong risk awareness amongst the scientists when it comes to specific applications of nanotechnology. A large proportion of the research on public opinion and nanotechnology has focused on general usages of nanotechnology and not on its particular applications (Dudo et al., 2011), probably largely due to the public's limited knowledge of detailed or highly specific applications. Nevertheless, the stronger concern about potential risk area expressed by the scientists compared to the general public is unusual for an emerging technology. This points to deficits in communication methods, as these strong variations in risk perceptions is indicative of the fact that the public are not sufficiently engaged in meaningful dialogue by scientists and other stakeholders (Scheufele et al., 2007).

While scientists are crucial to establishing trust and providing clear communication to inform the public, they are not immune to the heuristics and opinion formation of the general public. Value predispositions affect scientist' opinions about technology as well; however, while both the public and scientists rely on heuristic deliberations and value predispositions when forming opinions about nanotechnology, experts tend to rely less on it than the public (Corley et al., 2016). Nevertheless, economically conservative scientists are less likely to support regulation, while economically liberal are more likely to support it. This finding highlights the need to develop a full and systematic understanding of the demographic makeup of not just the general public, but also of nanotechnology scientists (Corley et al., 2009).

In their 2016 study, Corley et al findings highlight the gender issue of risk perception. As we saw earlier in this report, women are more likely to have a higher risk perception of nanotechnology both among the public and among nanotechnology scientists. Gender is one of a number of factors which influences how scientists view and form their commitment to society. Corley et al found that female nanoscientists were more likely to agree that federal agencies should require funded nanotechnology laboratories to implement guidelines to protect lab workers from unhealthy exposure to nanomaterials. They also found that risk perceptions were positively correlated with their social and ethical responsibilities -- in other words, respondents with higher risk perceptions were more likely to believe that scientists are responsible for any use or misuse of their research, and were less likely to think that scientists should be free to carry out any research they wish. These findings were made on a sample where males made up 84 per cent of respondents -- more research on where gender differs but with a sample stratified across gender is necessary to get further information (Corley et al., 2016). Nevertheless, the findings still raise interesting points and highlight again the benefit of a diverse workforce in terms of providing different opinions from the prevailing ones.

2.5 Discussion - Lessons on needs, concerns, values, culture, gender and diversity issues in nanotechnology

The areas explored in the literature review highlight how citizens relate to nanotechnology and other emerging technologies; what cultural, gender and communication differences are important; and what societal concerns exist about nanotechnology. The gender divide in relation to risk perception is particularly interesting, especially as it remains for both the lay public and scientists. In addition, the extent to which ideological predispositions, cognitive shortcuts and media influence all play a part in a person's opinion on nanotechnology provide a valuable observation into why cultural and gender differences are imperative to encourage and improve public engagement in nanotechnology and communication methodology development. The same goes for issues of governance and trust -- again, the background of how opinions are reached and how important trust is all highlight the relevance of understanding the citizen's needs, values and concerns relating to nanotechnology.

While varied, all these themes point to one direction, and that is to communication and public engagement. By knowing how a lay person reaches an opinion on nanotechnology, the next step can then be to ensure that the information which reaches the person, how it is framed, and the extent to which attempts are made to engage the person in genuine conversation, are done correctly and with differing cultural and varying social identities in mind. The literature clearly tells us that opinions on nanotechnology diverge amongst different demographic groups, and even scientists are influenced by predispositions. In order to hear these groups and listen to their thoughts and concerns about societal issues, there must be an effective communication strategy genuinely reaching out and engaging with them.

As the example of the nano-sunscreen showed, effective science communication is not simply a matter of releasing a statement or debunking a popular belief in a journal article. The fears surrounding the potential health hazards of nano-sunscreen were proven to be unfounded, however the belief that such sunscreen is dangerous was stubborn (Wright, 2016). In order to effectively reach out to the lay public and alleviate such fears, effective engagement and science communication needs to specifically target those who would buy sunscreen, for example women who take responsibility for their family's health, and look at how to best engage with this group and how they can begin and continue a genuine conversation.

Nanotechnology is just one of many complex issues that the general public are asked to form opinions on, and the extent to which public opinion about nanotechnology can be properly understood and addressed meaningfully lies with those responsible for science communication. When there is a lack of dialogue and meaningful engagement, the problem lies not with the public or how they get their information, but rather with how scientists and other stakeholders communicate with the lay person (Scheufele et al., 2007). If we are to properly understand how culture, gender and communication traditions influence debates and the public understanding of nanotechnology, we must have a truly engagement-focused dialogue with the public, not just one where for example the strong gender-variations in risk perceptions are accepted with a shrug. Rather, such a divergence is an opportunity to realise that this points to a deficit in communication methods, as it indicates that the public are not sufficiently engaged in communication (Scheufele et al., 2007).

With this knowledge, how can the lessons from the literature review be explicitly connected to the GoNano projects aims and objectives? Specifically, how can we best apply them to co-creation activities, methodology development, and content for citizen/stakeholder workshops? How can we translate the societal issues raised into a discourse with participants around their concerns, values and needs regarding nanotechnology? The following table gives an overview of how some of the issues can connect together and inform this, both regarding the citizen/public for the engagement activities but also for communication strategies:

Table 1 - Overview of engagement methodology, co-creation and communication issues connecting to concerns, values and need in relation to gender, diversity and culture in nanotechnology

GoNano aims	Concerns	Values	Needs
Engagement methodology and co-creation - citizen/ stakeholder workshops	Risk perception - gender split on issues of trust; risk to health (personal and family health, public health); uncertain nature of nanotechnology	Safety; responsibility (personal and professional); consumer awareness; preserving health; scientific advances vs. public good; speed of development vs adequate risk assessment	Safe environments; trust in procedure; access to knowledge; access to health care
	Male domination of	Equality is affected - how	Equality; inclusion.

	nanotechnology/STEM field	do citizens feel about the underrepresentation of all groups except white males in nanotechnology research? Are they aware/worried about the knock-on effect this has? Can this be explored further in the co-creation process?	Include gender and diversity from beginning of all R&I and co-creation to ensure that needs and concerns of all populations affected by future nanotechnologies are included
	Trust	Trustworthy governance in place as a 'guarantee' that values (safety, health, protection of consumer and so on) are safeguarded	Strong governance; suitable and transparent regulation; effective policy making
	Heuristic/ cognitive shortcuts	How are these judgements made? What values prompts each citizen? How aware is the citizen of the influence of values? Will this affect co-creation process?	Recognition of values and their importance in the discourse; evaluation of influence on nanotechnology R&I issues/development
Communication	Reaching all groups	Equality	Strategise to specifically connect with women/diverse groups
	Inclusive discourse	Inclusivity	Involve scientists and stakeholders in dialogue; acknowledge gender and diversity
	Extent of discourse	How much dialogue to we want/can we expect?	One way/two-way communication

While the societal issues raised in the literature review gives us plenty of knowledge and ideas, the next part of this report, the mapping of online societal debates, will give us even more insight into the level of engagement that currently exists, the extent to which societal concerns such as gender and diversity is represented, and provide information on how to best structure communication efforts.

Online social data mapping exercise

3.1 Introduction

As part of the overall task 1.2, a societal mapping of conversation was carried out. The GoNano Description of Works specified that: "*In analysing societal debates, this task will make use of online tools for harvesting, organising, analysing and visualising complex social data on social media and websites. The mapping will be done on national debates in the Czech Republic, the UK, Denmark, the Netherlands and Spain*".

The role of social media in today's world is impossible to underestimate, and has changed not only how people communicate with each other, but also how people search for and find information. Online media, both newspapers and specific social media platforms, allow users to seek for certain aspects of an issue, such as health-related information about nanotechnology, rather than having preselected content delivered to them through newspapers or television as was the case with traditional media (Anderson et al., 2010). Moreover, the internet and social media are important sources of, and provide access to, scientific information to the general public (Yeo et al., 2014).

A number of tools were used to pull together data from both social media and online resources in order to map the discussions and see if any of the issues mandated by T1.2 were part of such a debate; namely citizen concerns, gender and diversity issues, communication and dissemination issues.

3.2 Methodology

This chapter will outline the overall search and mapping strategies as well as the type of mapping tools used, how they were used, and why they were used. More detailed descriptions of the technical procedures can be found in Appendix A.

3.2.1 Choice of social media

When approaching this task, one of the first decisions made related to what social media platforms to use to find and harvest data. The most popular social media platforms, such as Facebook, Instagram, Twitter, Snapchat and so on were all considered. However, not all social media platforms are suitable for data mapping exercises.

Our first consideration was, did the social media platform have a publicly accessible Application Programming Interface (API)? An API is a software intermediary that allows two applications to talk to each other -- this is necessary for a mapping exercise as we have to be able to communicate with the platform to retrieve the desired data. Instagram shut down their API in early April and are no longer accepting submission of new apps (Constine, 2018). Without the ability to create an app, communicating with the Instagram API was rendered impossible. Snapchat does not have any documentation for an API, meaning that it would not be possible to mine any data from it.

Facebook and Twitter both have the ability to create apps on their platform and connect with their API, making them both suitable for data mining. However, Facebook is less open than Twitter when it comes to sharing information, and privacy is a concern because people share more personal data on Facebook. These privacy issues are more complex than Twitter's, meaning that a lot of status messages are harder to obtain than tweets, requiring 'open authorisation' status from users. This becomes even more problematic considering that as per the task brief to focus on debates in the five specific countries, we would have to drill down into users' settings to pull its location coordinates. Facebook was therefore also deemed unsuitable.

YouTube comments was also considered as an option for data mining societal concerns, however as with for example Instagram and Facebook a number of obstacles made it a non-feasible alternative. Channel searches for the different countries was carried out manually by looking at the "About" section on YouTube. Initially, using Python, a project was set up with the YouTube API, which has a parameter for location, and a search was carried out by location, returning very low number of channels. Despite our attempts to find different ways of accessing and mapping data from YouTube, we could not find a way of yielding useful and significant data and therefore decided to not include YouTube searches in this report. We did, however, attempt to look at the larger science channels to see they extent to which nanotechnology was being discussed -- this can be found in Appendix B at the end of the report.

Twitter is considered the most open social media platform, and it does not have the plethora of privacy settings that Facebook has. Users can generally follow any account except if the account is protected, in which case permission needs to be granted. One drawback of the open nature of Twitter is that it is estimated that up to 15 per cent of all Twitter accounts are bots (Varol et al., 2017). Nevertheless, as it is the most open platform, it is the best option for data mining.

Twitter is a unique platform for studies of popular discourse for not only its distribution of information but also for its ability for real-time interaction among lay audiences, scientists, and other audiences worldwide (Yeo et al., 2014). The popularity of using Twitter for social media research, both in academia and in industry, remains high; no other platform has attracted as much attention from academics. Nevertheless, Twitter is not the most popular platform in terms of monthly active users, being ranked at eighth in the overall list, while Facebook and WhatsApp are the top two (World Economic Forum, 2018). However, as mentioned above, many of the platforms with the highest number of monthly active users do not make their data available on a similar scale to Twitter, which is what makes Twitter an ideal platform for research.

It has been argued that there is no other social media platform with an infrastructure like Twitter. Twitter is unique in the sense that it is structured to allow any user to be able to follow another user, and it provides a rich source of data through its API. The Twitter API serves up latitude and longitude coordinates when location services are enabled, allowing country by country analysis, which was a necessity for this project in order to follow the brief for T1.2. The accessible data enables us to retrieve data as well as perform data mining and Social Network Analysis (SNA) on it.

Due to these factors, Twitter was chosen as the social media platform to analyse for this task. One of the primary reasons for choosing the Twitter platform was the above mentioned ability to geolocate where tweets originated. Geolocated tweets help us to understand the role of geography in predicting and explaining different outcomes of interest. One drawback is that according to Leetaru et al (2013) only 1.6 per cent of Twitter users have location services turned on. Due to privacy terms, Twitter offers it on an opt-in basis, which explains the low level of take up. Fortunately, the API also searches the “Bio” and “Profile” fields automatically which, when combined, brings the geo-locatable tweets up to 34% (Twitter, 2018).

Twitter does have some drawbacks. For example, the issues with geolocation limitations inevitably raise a sampling bias, as only tweets that are either geotagged or had the location field filled out in their user Profile/Bio can be mined. Another drawback with Twitter is that the API limits the amount of data we could mine. The Twitter API only allows harvesting tweets from the previous 7 days (Twitter, 2018). Although this still gives us a good indication of public perception, it is only a snapshot in time and this should be remembered during analysis. The limited time frame of the API also proved problematic for the countries with smaller populations, such as Denmark and the Czech Republic, to gather enough data. Nevertheless, this snapshot was able to give us a good overall insight into what type of networks existed, how communities within the networks were structured, what topics were discussed, how they relate to each other, and what the overarching themes were.

In addition to Twitter, we also used Web of Science (journals) and ProQuest (newspapers) in order to harvest further information from websites. This was done to further map the dialogues on societal concerns regarding nanotechnology, as debated and communicated by other actors - the more data we could mine, the more information we could gather from it for the mapping exercise.

Newspapers can indicate the social and cultural feelings towards a particular topic, and as previously discussed, they play part in the *framing* of an issue and informing the public. Although not as rigorous as journals, newspapers can generally be relied upon to be trustworthy sources of information. They have a wide reach and the reporting of the topic of nanotechnology by newspapers can play a large part in informing and influencing people’s opinion of nanotechnology (Ho et al., 2010).

In order to mine data from newspapers, we used the ProQuest International Newsstream Database for data collection. The ProQuest Global Newsstream allows users to search global news content from nearly 3,000 news sources such as newspapers, newswires, news journals, and so on. The International Newsstream Database provides one of the largest collections of news from the whole world, and all titles are cross-searchable on the ProQuest platform (ProQuest, 2018).

To see what the extent of the discussions on societal concerns were in the scientific world, we turned to Web Of Science. Web of Science is a scientific citation indexing service, which provides the user with regional citation indexes, patent data, specialized subject indexes, and an index of research data sets, totalling over 33,000 journals, which allows for in-depth exploration of specific disciplines (Clarivate, 2018). Web of Science provided a rich source of data for the keywords in conjunction with nanotechnology, and the database, through field codes, allowed us to search by country, indicating that societal concerns were being discussed in academia.

3.2.2 Search terms

The mapping analysis was carried out on the collected data using the following search terms: nanotech* AND (gender OR risk OR public opinion OR communication OR culture OR diversity). These search terms were derived from the GoNano Description of Works for T1.2, as well as the preliminary findings from the literature review for T1.2, which indicated further areas of interest where societal debates were taking place.

The search terms were also translated into the five languages, with input from the relevant partners:

Table 2 - Social Media Analysis search terms

Search terms	CZ	DK	NL	ES
	Term	Term	Term	Term
Gender	Pohlaví	Køn/kønsdebat	Geslacht	Género
Risk/risk perception	Vnímání rizik	risiko, tvivl, usikker	Risicoperceptie	Percepción del riesgo
Diversity	Rozmanitost	diversitet	Diversiteit	Diversidad
Culture	Kultura	Kultur	Cultuur	Cultura
Communication	Komunikace*	Kommunikation, kommunikere	Communicatie	Comunicación
Public opinion	Veřejné mínění	Offentlige mening	Publieke opinie	Opinión pública
Nanotechnology	Nanotechnologie	Nanoteknologi	Nanotechnologie	Nanotecnología

As will be shown in the Findings, we were not always able to use these terms, especially with the Twitter data, as there simply were not enough conversations taking place that used these words. This indicated at an early stage that the general public were not engaging with societal issues of nanotechnology -- this will be examined further in the below Findings section as well as the Discussion.

3.2.3 Types of analysis

Different Social Network Analysis (SNA) were carried out on data gathered from the three online sources: Twitter, ProQuest, and Web of Science. SNA is a tool with wide applicability, yet it is often presumed to mean social media analysis only. While SNA is used on social media it is not limited to it, but is also performed on areas of societal concerns in other data sources, such as newspapers, journals, and so on.

For our purposes, as our task was to "*map societal debates and outline how culture, gender and communication traditions influence debates and the public understanding of nanotechnology research and innovation*", SNA was used as a tool to understand patterns and identify how individuals interact. The software package chosen to carry out the SNA on the Twitter data, Gephi, was the one recommended in the GoNano Description of Work. Gephi is an open source software tool used for SNA, and has powerful visualisation capabilities when it comes to networked graphs, in our case a social network. In addition, sentiment and wordcloud analysis was also used.

For the ProQuest data, SNA was carried out after text mining the articles for important topics: The software used for this was CorTexT, which highlights important words/phrases and how they are mapped through a semantic analysis logarithm. The nodes in this case were words/phrases.

The SNA performed on the Web of Science data was similar to the newspaper analysis but instead of newspapers, journals were text mined for keywords and phrases. The software tool used on the data was VosViewer, which produces a map of important keywords and terms to give a visual overview of the various communities in the network, and how they connect and relate to each other.

SNA was thus carried out on all the data. For detailed technical explanations of each type of analysis, outlining what they are, how the data was harvested and how the analysis was carried out, please see Appendix A at the end of this report.

3.3 Findings

3.3.1 Social network analysis of Twitter data

For our social network analysis (SNA), data was harvested from the Twitter platform using the Twitter API. Nanotechnology was searched with the different combinations of the keywords. However, nanotechnology searched for together with the keywords did not discover an appreciable amount of data to work with.

To harvest more data, nanotechnology OR nanoscience OR nanoparticle* OR nanomaterial* OR nanoenergy OR nanomedicine was searched for without the keywords, to broaden the search, which did return sufficient data in three out of the five countries. Our brief was to perform these searches geolocated specifically to the five countries, and these restrictions meant that harvesting a large amount of data was problematic: interpretation should therefore come with a health warning.

As an example, to give an indication of the frequency of the conversation around nanotechnology (without the keywords; their use would reduce the dataset further), a geolocated search was done from what is generally considered the geographical centre of Europe (Suchowola) to include a 2000 miles radius, thereby capturing all of Europe. The search returned less than 1000 tweets on nanotechnology. This indicates that the subject of nanotechnology is still removed from the general public, and that not enough proactive engagement is taking place in this scientific communication challenge: rather, the low numbers indicate that experts are talking to experts on a much smaller scale.

Finding sufficient data proved to be a challenge in light of the paucity of societal debates. As indicated above, we therefore broadened the search terms and search types as much as was possible while remaining within the brief given, until we got sufficient bulk to carry out meaningful analysis. Below are the resulting findings from the five countries: the UK, the Netherlands, Spain, Denmark, and the Czech Republic.

3.3.1.1 United Kingdom

As described above, using the term nanotechnology and the specific search terms, we did a search geolocated to the UK on the data mined from Twitter. We did not find enough tweets to carry out a meaningful analysis using the keywords and nanotechnology, indicating that societal concerns as indicated by the presence of the search terms were not debated much on Twitter. We then widened the search, using the term nanotechnology (and the related terms mentioned above) on its own but geolocated to the UK.

The data returned was imported into Gephi to carry out social network analysis. The imported data consisted of 352 nodes and 367 edges. *Node* is another word for individual user account, and *edges* is each tweet/retweet/mention coming out from each individual user and their interaction with other accounts. The amount of edges coming out of a node therefore represents mentions or interactions between accounts. A modularity report was run and 68 communities were identified; see Figure 1.

Figure 1 - Modularity of UK tweets (modularity applied)

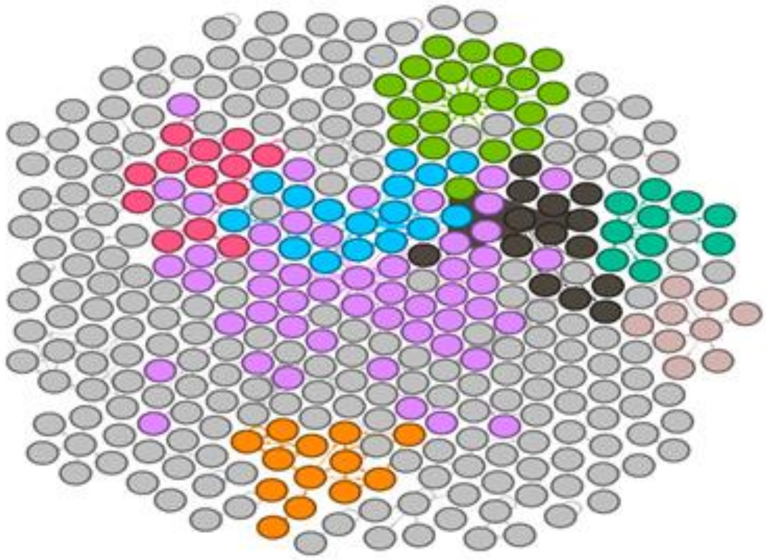


Figure 1 is a visual representation of the different communities that are talking about nanotechnology on Twitter in the UK. The labels naming each node (equivalent to the Twitter handle of the account, for example @GoNano_EU) were omitted as they rendered the graphic illegible due to the amount of nodes. Each circle represents a node, the individual user, and the different colours represent different communities. The communities are defined by looking at who is talking to whom and how they are connected to each other. *Modularity* is what is used to detect this community structure within the network: *network* is simply the term given to the graph visually representing the overall data set.

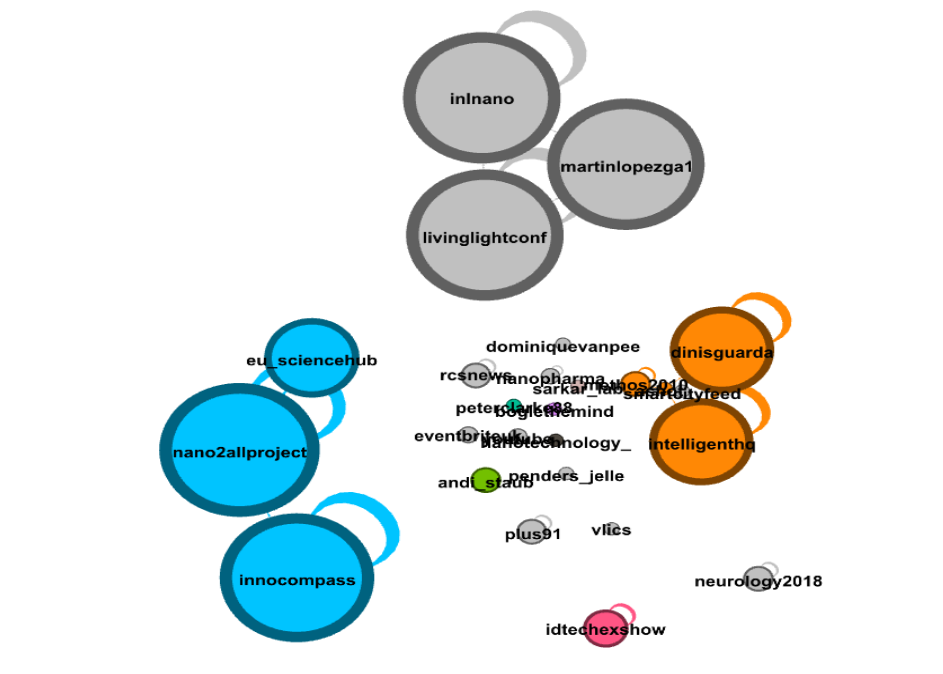
Modularity tells us which individual accounts have relatively dense connections; in other words, which accounts communicate often with each other. Modularity further helps us to see how the communities are related to each other by colour -- each community is given a colour, and we can thereby see that for example the purple community could have a sparse connection to the green community, but a close one to the red community, and so on. But they are still in the same network, in this case the network of nanotechnology in the UK.

We applied a degree range filter to eliminate nodes with less than 4 edges, to focus more on the accounts that were more active. When the degree range filter was applied, the community obviously became smaller -- see Figure 2 below. This indicates that it is not a very dynamic community with a lot of interactions, but rather there seems to be a low engagement consisting mainly of organisations retweeting other organisations.

Eigenvector centrality was then run on the remaining nodes and edges to identify important nodes by size, where the more important individual accounts are made bigger by the software (Figure 2).

The importance is decided by statistical analysis (Eigenvector) which works like the Google page rank. In short, the size of the node represents the importance within the network and communities are identified by different colours.

Figure 2 - UK SNA of nanotechnology on Twitter (Eigenvector centrality and modularity applied)



These visual representations of the SNA as represented by the two figures help give an overview of the nanotechnology conversation within the community in the UK, and how they interact within the network. They shows us that there is little interactions where communication is done in actual direct text responses to tweets (the visual network is accompanied by a spreadsheet which allows us to differentiate the type of interaction); rather, it is almost exclusively retweets. This may be an indication of a weak engagement strategy, where no one is directly responsible for social media activity -- the assumption seems to be that retweets or posting links to interesting articles is enough to create a lively account. However, this is not the case, as it does not engage lay people or start an actual conversation but rather speaks “at” the person as opposed to “with” them.

Looking at the information in Figure 2, the blue community in the UK discussion contains the account of the EU science hub. It has nearly 20,000 followers on Twitter. In its overview page, it describes its mission to collaborate with the international research community, and works with over a thousand partners worldwide, mainly in the UK and the US.

Another part of the community was an account called nano2allproject, which, according to its Twitter bio, has a goal of “increasing engagement of society in nanotechnology R&I, enhancing dialogue between members of the nanotechnology R&I community in Europe” (Nano2All, 2018). It has strong ties with a similar organisation called Innovation Compass, which describes itself as an EU funded project to foster responsible research and innovation in SMEs. The community in general aims to enhance the perception of nanotechnology. While this sounds promising, the data shows us that there does not seem to be any structure or strategy in place to facilitate genuine engagement and thought-out science communication effort: rather, these social media accounts seems to be an afterthought as opposed to an actively used and efficiently utilised tool to reach the general public.

The grey community concerns a conference in Cambridge, England focusing on light-matter interaction in living organisms. It is connected to laboratory in Portugal. The orange community contains user accounts that mainly identify themselves with cryptocurrencies, and are not related to nanotechnology. The reason it shows up here is that the term nano is used for cryptocurrencies as well.

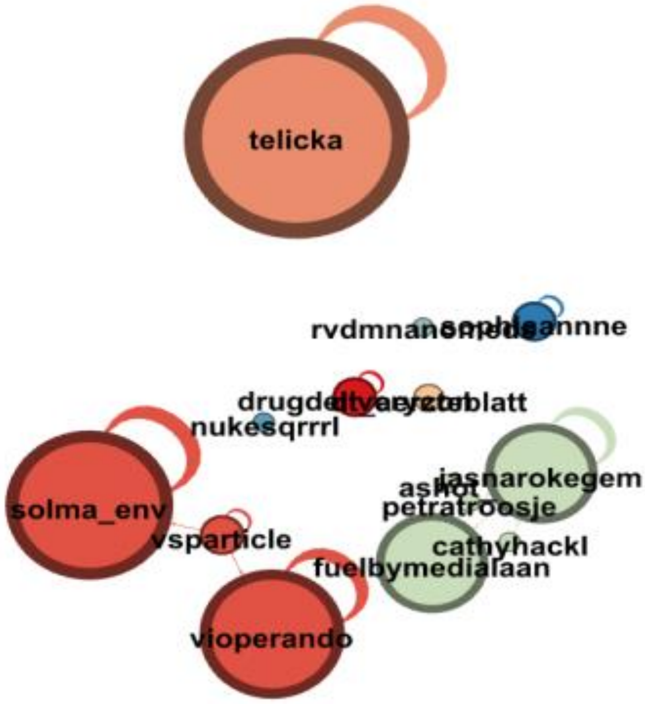
Of all the countries, the UK provided the most data to work with, however this data showed a glaring absence of dialogue or debate on societal concerns, especially from lay person's accounts. The network as a whole mapped in the UK seems to be an insular network communicating mainly with each other and through retweets, and not through active two-way communication. They deal primarily with innovation and the science of nanotechnology, and from what they are tweeting about they do not appear concerned with issues such as gender, culture, public opinion, and so on.

3.3.1.2 The Netherlands

The search term for the Netherlands was Nanotechnologie and Nanotechnology combined; again, searches with the keywords and nanotechnology did not generate enough tweets to carry out a meaningful analysis. This means that for the Netherlands, we did a search on nanotechnology/nanotechnologie only (and the associated additional nano-related terms described in section 3.3.1). The lack of tweets dealing with issues related to the keywords and societal concerns of nanotechnology in general shows that this conversation is not being had on Twitter.

The information mined and mapped from the Dutch Twitter returned 44 nodes and 51 edges, and the modularity report recognised 9 communities. This is a small number in comparison to the above UK findings, which had 352 nodes, 367 edges, and identified 68 communities. This is most likely due to population size, 17 million in the Netherlands compared to the UK's 65.6 million people (Centraal Bureau voor de Statistiek, 2018; Office for National Statistics, 2018). The degree range filter was again applied to eliminate nodes with less than 2 edges - see Figure 3.

Figure 3 - Dutch SNA of Nanotechnology/Nanotechnologie on Twitter (Eigenvector Centrality and Modularity applied)



We used 2 edges rather than 4 as with the UK sample, as the data set was significantly smaller than the UK one. Nevertheless, with only 90 tweets returned for the search, identifying the different communities proved difficult and unreliable. This is because such a small data set makes it very difficult to infer anything from the findings. The important individual user accounts that did show in the network with a substantial following were Pavel Telicka, a MEP and Cathy Harckl, whose area of expertise is Augmented Reality.

As this is a snapshot of the conversations and potential societal concerns in the Netherlands, making definitive conclusions based solely on the information provided is not advisable. However, the lack of tweets does indicate, again, that dialogue between lay persons about societal concerns is not taking place.

3.3.1.3 Spain

The search term used was Nanotecnología and nanotechnology combined (and the related terms mentioned in section 3.3.1), as again searches with the keywords and nanotechnology did not generate enough tweets to carry out a meaningful analysis. 135 nodes and 240 edges were returned -- a larger dataset than the Dutch mapping exercise, but smaller than the UK one. The modularity was run and 26 communities were identified, see Figure 4. Labels were again omitted for clarity.

Figure 4 - - Modularity report of Spanish tweets (modularity applied)

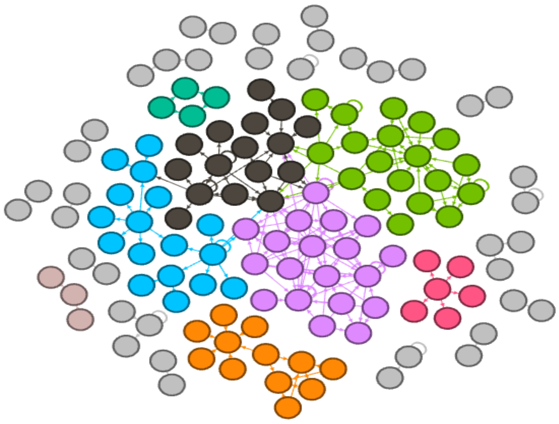
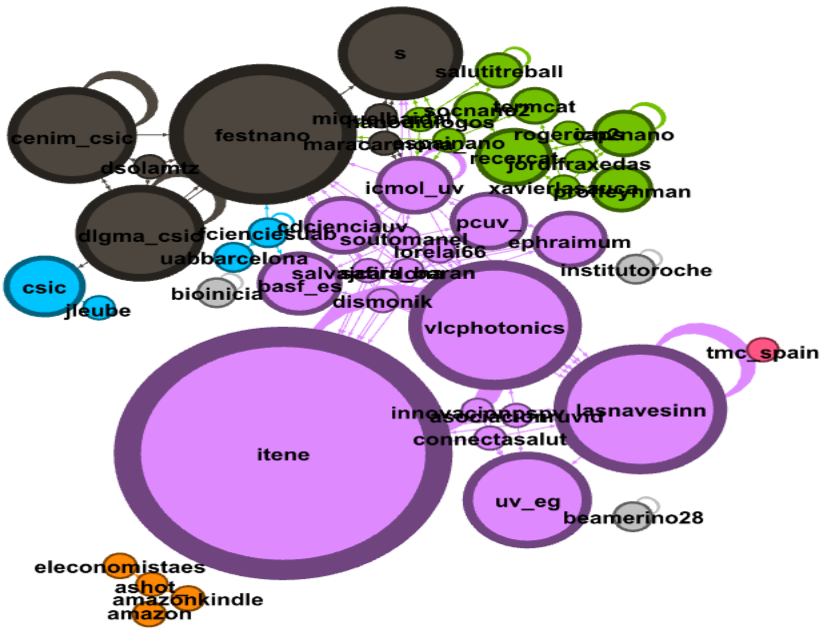


Figure 4 shows us that there is a higher connectivity between the communities (represented by colour) in the Spanish nanotechnology network. Nodes (the individual user accounts) were closer connected both within and between the communities, indicating that there was more dialogue and interaction taking place between the different Twitter communities.

The degree range filter was applied to eliminate nodes with less than 4 edges, rather than 2 as the sample was large enough for this. Eigenvector Centrality was then run on the remaining nodes and edges to identify important nodes by size, see Figure 5.

Figure 5 - Spanish SNA of nanotechnology/nanotecnología on Twitter (Eigenvector centrality and modularity applied)



As we can see from both Figure 4 and Figure 5, the connection between the communities is closer. For example, the icmol_uv node is the Twitter account for the Institute of Molecular Science at the University of Valencia. This account has edges (tweets/retweets) connecting to three different communities, indicating that it is in conversation with many parts of the network.

The reason for this closeness may be down to the fact there was a nanotechnology festival taking place in Barcelona during the time of our data mapping exercise. This is represented by the grey community, centred on this national nanoscience festival called Nanofest. The purple community is more concerned with innovation with Lasnavesinn, an innovation centre in Valencia, having a substantial following of nearly 9,000 people. The green community consisted of universities and institutes in Catalonia, with the University of Recerca being central in the community. Figure 4 and Figure 5 both show that the different communities are well connected to each other with easy passage from one community to another.

While this all indicates a good connectivity between the different nanotechnology centres in Spain, there was no data indicating that any societal concerns from lay people existed in terms of dialogue or debate. Research centres and universities are communicating well with each other in this dataset, but again there is no conversation about societal concerns and nanotechnology taking place among lay persons. As the Spanish nanotechnology network is more connected already, this may make it easier to start a dialogue and proactive communication with the general public.

3.3.1.4 Denmark

Searches were carried out in English and Danish using nanotechnology/nanoteknologi and the search terms, which gave no results. Single figure tweets were returned when we widened the search using only the terms nanoteknologi and nanotechnology (including the related terms mentioned in section 3.3.1) - this, unfortunately was not enough data in order to be able to text-mine.

3.3.1.5 Czech Republic

Searches were carried out in English and Czech using nanotechnology/nanotechnologie and the search terms, which gave no result. Single figure tweets were returned when we widened the search using only the terms nanotechnologie and nanotechnology (including the related terms mentioned in section 3.3.1) - this, unfortunately was not enough data in order to be able to text-mine.

3.3.2 Sentiment and wordcloud analysis of Twitter data

Our findings so far from the Twitter data mapping show that little if any dialogue or debate is happening on societal concerns relating to nanotechnology, especially amongst the lay public. As our task clearly outlined a brief to find data on citizen's concerns, needs, values, opinions and so on, we decided to use an additional approach to identify and map sentiments towards the topic of nanotechnology in the data mined from Twitter. We did this through *sentiment and wordcloud analysis*.

Sentiment analysis tells us what emotions exist in the tweets that were mined from the five countries. This is done through software that analyses the bodies of text and the measurement of emotions using ten categories: joy, sadness, anger, disgust, trust, fear, anticipation, surprise, negative, and positive. These emotions strongly reflect the key words used in the task description such as opinion, understanding, needs, values, and so on. As the key search terms in conjunction with nanotechnology and associated terms had not generated enough data to analyse and reach concrete results, sentiment analysis was a good additional tool to get insight into emotions expressed in the data.

3.3.2.1 United Kingdom

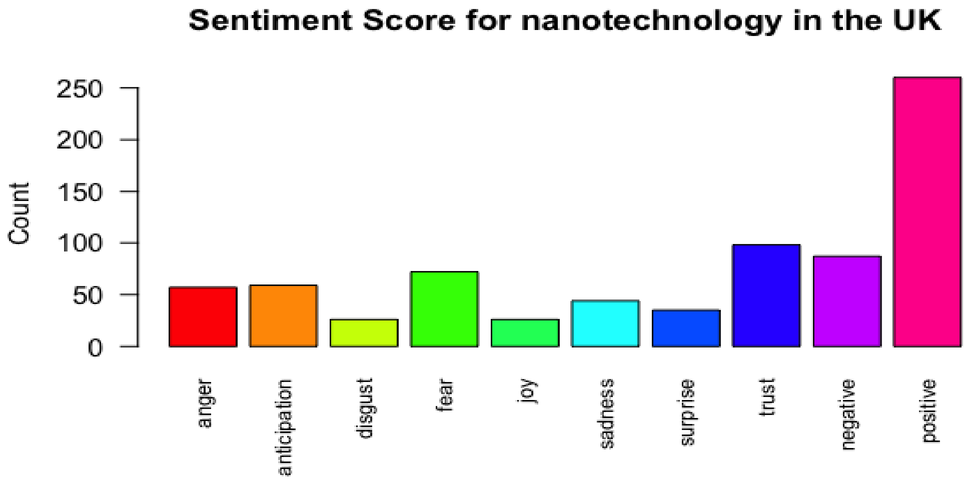
672 tweets were returned for the search word nanotechnology in the UK. The UK wordcloud (see Figure 6) returned vocabulary associated with the cryptocurrency community, and tweets of this kind tended to come from accounts predicting ‘the next big thing’ where nanotechnology was grouped together with blockchain. There is also a cryptocurrency called nano, which undoubtedly influenced the vocabulary.

Figure 6 - Wordcloud on UK data

Apart from the cryptocurrencies, medical and biological words dominated, such as antibiotics, anticancer, biosensors, and so on. This indicates that the discussion was concerned with nanomedicine, however, yet again societal concerns seem to be absent from the conversation.

Figure 7 shows the Sentiment Score for the UK. From the wordcloud in Figure 6 we can see it is likely the sentiment score will be affected by the cryptocurrency vocabulary.

Figure 7 - Sentiment score for nanotechnology in the UK



The overall positive score is still quite high, but it is easy to understand how emotions like anger and fear figure quite prominently, considering the speculative nature of cryptocurrencies. It is therefore difficult to draw any conclusion from these findings as the emotions surrounding the cryptocurrency market may be influencing the overall results.

3.3.2.2 The Netherlands

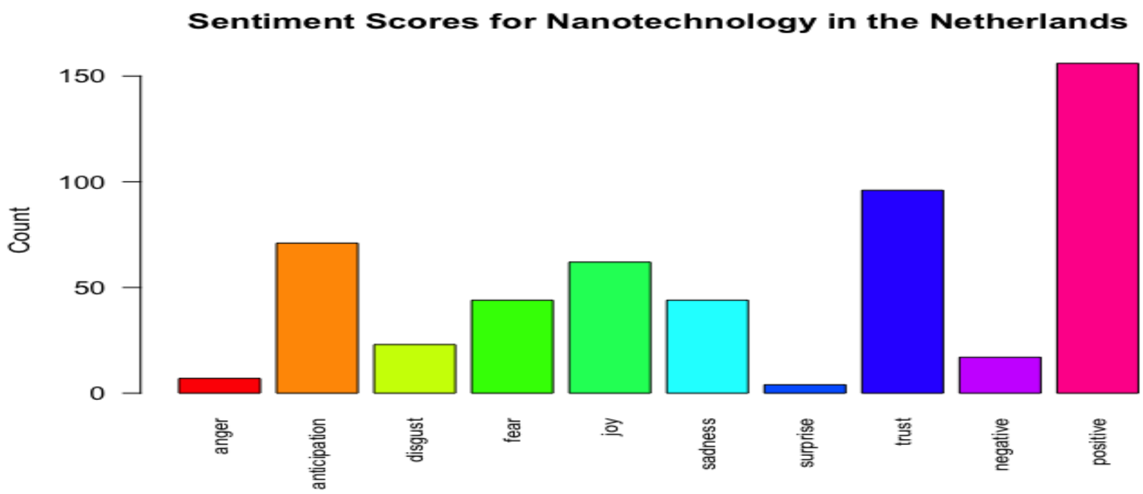
In analysing the Dutch data, searching with nanotechnology/Nanotechnologie in tandem with the other key search terms didn't produce enough data to any meaningful analysis. Using only the terms nanotechnology/nanotechnologie and related terms returned 187 tweets. More of these tweets were in English (130 tweets) than in Dutch (57 tweets), allowing us to do a sentiment analysis using the lexicon.

Figure 8 shows the wordcloud generated from the text mining package. The result gives us a flavour of the topics being discussed in the Netherlands with regards to nanotechnology. The theme of the cloud is primarily research orientated. Universities and institutions are prominent, as is topics like funding. The cloud is scientific in nature and none of the search keywords enter the cloud. Again, this indicates that dialogue is chiefly concerned with issues relating to research and institutions, indicating very limited public input. Nevertheless, the wordcloud does show some discussion regarding issues of risk, with the words safety, responsiveness, reality, improvement all part of the wordcloud, alluding to a discussion of risk being had between the various research organisations and institutes that are predominant in the Dutch conversation.

Figure 8 - Wordcloud on Dutch data

With little data to work with as regards to the key search terms, sentiment analysis is a useful tool to indicate the emotions, public perception and trust with regards to nanotechnology. Figure 9 shows the sentiment analysis results for the Netherlands. Trust has the highest count from the lexicon, and the next highest scores were the categories of anticipation and joy, which indicate a very positive sentiment. Sadness and fear are not insignificant and are the primary contributors to the negative metric.

Figure 9 - Sentiment Analysis for the Netherlands



Again, the data is a snapshot in time and caution should be taken interpreting the results as definitive. One reason for a high positive metric might be the type of accounts on Twitter that tweet about nanotechnology. From our SNA (Social Network Analysis) we discovered, the important nodes (the nodes important to the community and with the largest number of edges) tended to be accounts of institutions with a vested interest in nanotechnology. Also, research institutes and universities may be more likely to portray their research and information in a positive light, thereby further highlighting the fact that the dialogue in the Netherlands seems primarily driven by research institutes and universities, and little input from or engagement with the general public on areas of societal concern.

3.3.2.3 Spain

As with the other countries, carrying out a search with nanotechnology/nanotecnología in conjunction with the other keywords harvested very little data. Broadening our search to only nanotechnology/nanotecnología and the associated terms returned enough data to do analysis on. The search term Nanotecnología (567 tweets) returned more tweets than the English equivalent, and using both languages the wordcloud in Figure 10 was generated. As most of the tweets were in Spanish we could not carry out a sentiment analysis, as the sentiment algorithm only works in English.

Figure 10 - Wordcloud on Spanish data

This wordcloud shows us that much like the Dutch findings, the Spanish dialogue is centred on research, institutes and organisations dealing with nanotechnology rather than debates or dialogues between lay people. The tweets are concerned with research or the science of nanotechnology, and the festival also makes an appearance in the wordcloud. Again, the findings here continue to point towards a lack of dialogue or debate relating to societal concerns amongst the public, and a complete absence of culture, gender or other societal influencers in any discussion.

3.3.2.4 Denmark

Searches were carried out in English and Danish using nanotechnology/nanoteknologi and the search terms, which gave no results. Single figure tweets were returned when we widened the search using only the terms nanoteknologi and nanotechnology (including the related terms mentioned in section 3.3.1) - this, unfortunately did not generate enough data in order to be able to text-mine.

3.3.2.5 Czech Republic

Searches were carried out in English and Czech using nanotechnology/nanotechnologie and the search terms, which gave no result. Single figure tweets were returned when we widened the search using only the terms nanotechnologie and nanotechnology (including the related terms mentioned in section 3.3.1) - this, unfortunately did not generate enough data in order to be able to text-mine.

3.3.3 Mapping and SNA of concerns from newspaper articles

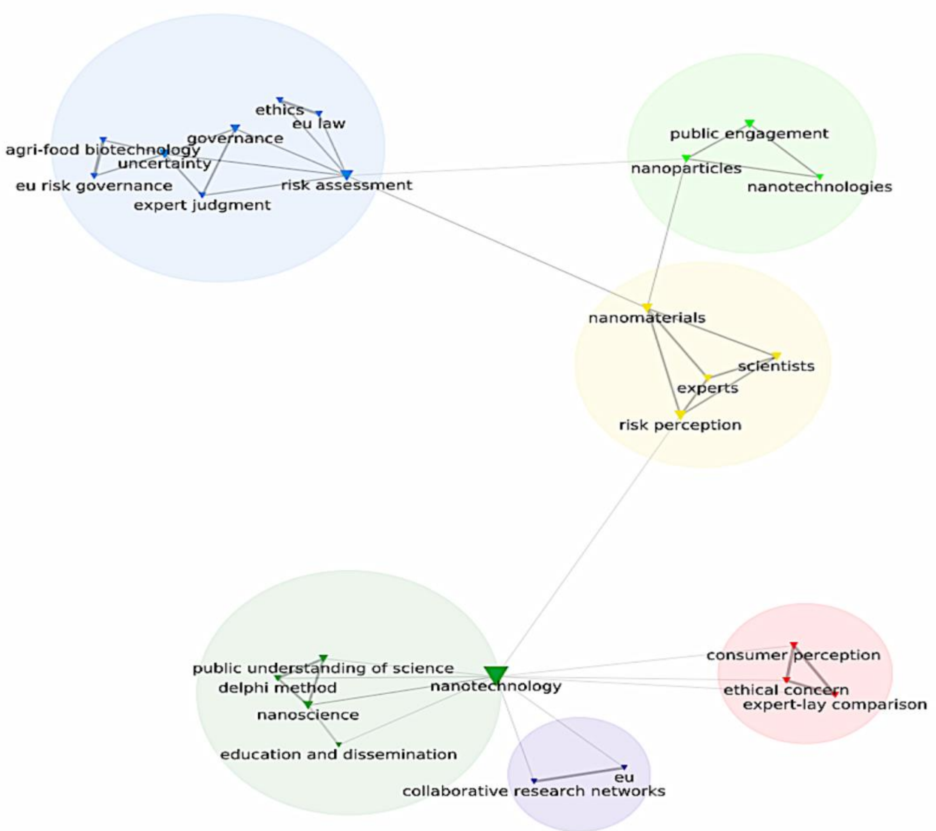
A text mining analysis on newspaper articles was done to provide more insight into where the dialogue on societal concerns was being held. Newspapers may be more likely to cover issues of societal concerns, and to look into areas such as risk and opinion. In order to find a suitable body of text to gather data to perform SNA, we used the ProQuest International Newsstream database.

Using the following search terms, we searched the ProQuest International Newsstream Database: nanotechnology AND (gender OR public opinion OR culture OR communication OR diversity OR risk). There was no language, geographic, or time restrictions on the search.

The search yielded 285 newspaper articles. We removed all articles that were not from the UK, the Netherlands, Spain, Denmark or Czech Republic, leaving us with 91 articles. Of these 91 articles, all were from the UK -- none were found from the other four countries.

We also carried out searches using the same search terms as above but in Dutch, Czech, Danish, and Spanish. These searches returned zero results in Dutch, Czech, or Danish, but did find 22 articles in Spanish. However, these were not from Spain but instead from Argentina (1), Colombia (1), United States (3) and Mexico (17) and were therefore excluded.

Figure 11 – ProQuest newspapers – keyword cluster

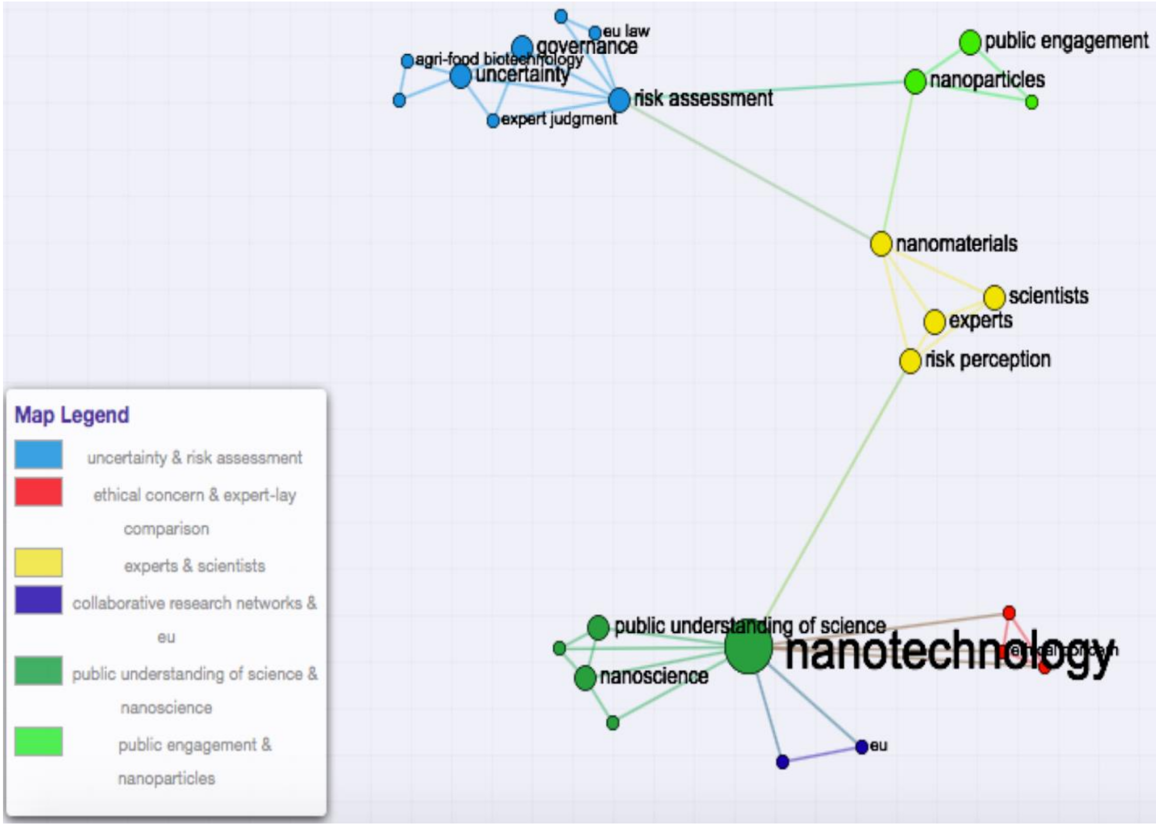


As can be seen from Figure 11, the data has been grouped together into topical clusters by means of semantic analysis. This is done in order to present a visual overview of issues that come up in the newspaper search in relation to nanotechnology and the specific search terms used. The clusters identify what the main areas of conversation are, what the content is within each area, and how they relate to each other and what proximity they are in.

The lines both within and between the clusters signify that the terms are likely to show up close to each other in a sentence or article, suggesting that they are somehow related issues or entities, or at least that they are being discussed in the same article, and may therefore be somehow connected.

Below, Figure 12 shows the same data in a less detailed cluster but with a map legend, providing additional information.

Figure 12 – ProQuest newspapers keyword cluster with map legend



The map legend terms for each cluster colour come from the software, which highlights important words/phrases and how they are mapped onto the map legend. Looking at both data maps, with the help of the cluster layout, the colour and the positioning between the clusters and the lines between them, we can make the following observations:

- Uncertainty and Risk Assessment (blue cluster) – this cluster is the largest, and has main keywords like ethics, EU law, risk assessment, uncertainty, and expert judgement. This signifies that most articles in our sample were concerned with these issues, and that they relate to each other repeatedly. It is interesting to note the positioning of the term governance, which is in the middle of the cluster and thus at the heart of it. Also, risk assessment as a term comes up more often than other (as determined by the size of the triangle by the term) and is connected by lines to both the Expert and Scientists cluster and the Public Engagement cluster, signalling that it is related to these issues as well. These societal concerns are thus a large part of the newspaper reporting on nanotechnology.

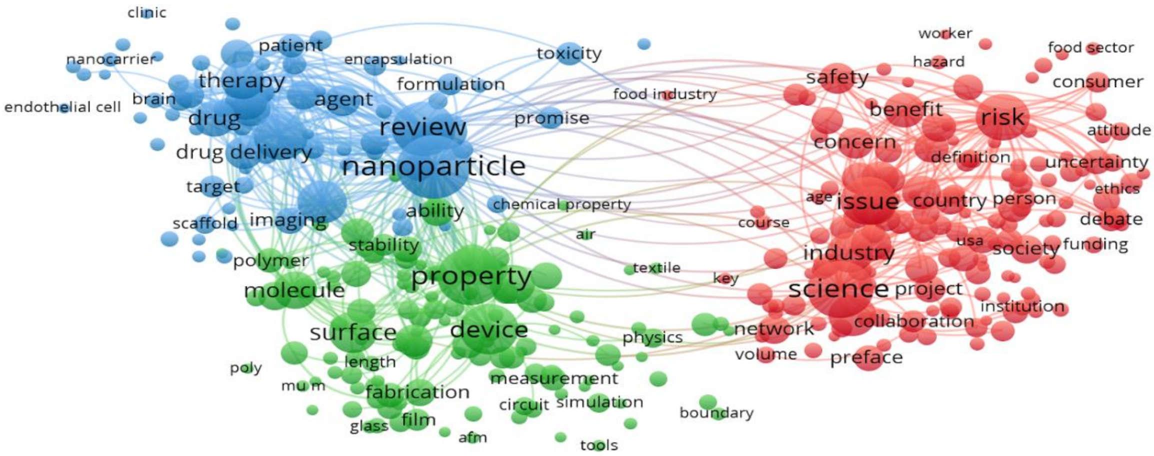
- Public Understanding of Science and Nanoscience (dark green) – although the second largest, this cluster is at the bottom of the visual in relation to the blue cluster, signifying that they are not closely related. The main term in this cluster is nanotechnology; this together with the distance from the blue cluster hints to these specific articles being more concerned with the science of nanotechnology rather than more engagement topics. Nevertheless, it includes terms such as education and dissemination and public understanding of science, both relevant societal and engagement issues. Interestingly, this cluster also includes the term Delphi method, which is a systematic forecasting method relying on expert panels and their group response.
- Public Engagement and Nanotechnologies (light green) – this cluster only has three terms, nanoparticles, nanotechnologies and public engagement. However, its positioning between the blue Uncertainty and Risk Assessment cluster and the yellow Experts and Scientists cluster, and its connection to both through lines, signify that it is closely connected to these issues. We can therefore draw the conclusion that this particular cluster represents articles that discuss overall public engagement with issues in nanotechnology and nanoparticles, again pointing to newspapers being involved in the public debate about societal concerns and nanotechnology.
- Experts and Scientists (yellow) – While small, this cluster relating the terms *nanomaterials with experts*, *scientists*, and *risk perception* clearly represents articles where experts and scientists have been mentioned alongside risk perception, again highlighting risk as a main overarching issue of societal concern reported by the newspapers.
- Ethical Concern and Expert-Lay Comparison (red) – this second smallest cluster is positioned in the bottom right corner of the visual, connecting only to the dark green cluster of Public Understanding of Science and Nanoscience. With its main key terms being consumer perception, ethical concern and expert-lay comparison, again this cluster seems to be concerned with the overall risk issue from a citizen and scientist point of view. However, as is clear from the positioning of the cluster these particular articles were heavier on science, as opposed to societal risk.
- Collaborative Research Networks and EU (purple) – the smallest cluster, this only has two key terms, collaborative research networks and EU. This, combined with its visual positioning just next to the dark green cluster of Public Understanding of Science and Nanoscience, is representative of EU research networks concerned with nanotechnology and public understanding, rather than the issue of overall risk.

3.3.4. Mapping and SNA of concerns on Web of Science

In order to keep searching for data that may show more debates and conversations about societal concerns, we mined the Web of Science for data, endeavouring to find out what types of discussions were being had in academia, and the extent to which these included societal concerns.

Initially, all the countries in the EU were included for a general search on the topic of nanotechnology using data harvested from the Web of Science Core Collection using the search term nanotechnology. Nearly two thousand document types were returned. This dataset was text mined and mapped using VOSviewer, and Figure 13 was generated.

Figure 13 - A term co-occurrence network map based on text - all EU states



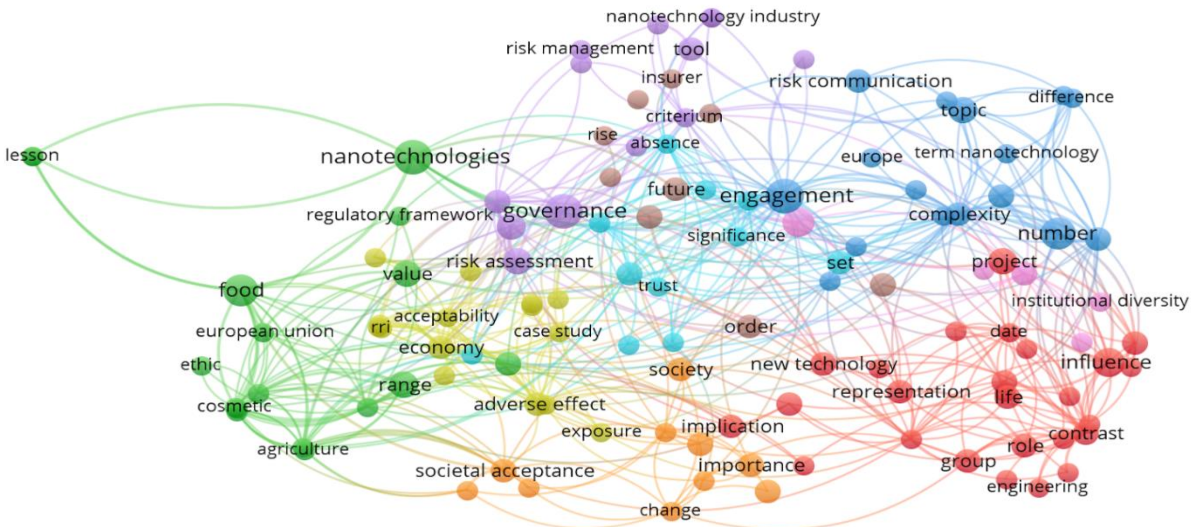
The algorithm generated three distinct colour-coded communities for nanotechnology. The blue cluster is concerned with medicines/health; the green with the physics of nanotechnology; and the red with community. The red group has most in common with our key search terms (diversity, culture, risk, public opinion, communication, risk perception). Each cluster (community) generates keywords from the body of text mapped such as risk, issue, safety, uncertainty and attitude.

It is important to note that this community was generated from the single search term "nanotechnology" with no promptings of our other keywords. With just three communities generated, the red community represents quite a significant cluster implying a healthy discussion on the topics of nanotechnology and societal concerns that we are interested in is taking place in science and academia. However the terms gender, diversity or culture are all missing, and the red cluster seems to focus mainly on issues relating to risk.

From the edges (lines connecting communities) we can see they are more conversations between the blue and red clusters than the green and red. Considering this, it could be argued that the concerns of nanotechnology are primarily to do with aspects of medical care, where the blue community keywords are drug, therapy, drug delivery, imaging, patient and so on. The communities all have a high degree of modularity, meaning that the nodes have strong connections within the communities. It is sometimes useful to highlight the main nodes that connect communities, in order to see what overarching discussion topic seem to be the point of connection.

A more targeted search was then performed on each of the countries. The search term used was nanotech* AND (gender OR risk OR public opinion OR communication OR culture OR diversity). The UK returned 39 documents, Spain seven, Czech Republic one, Denmark two and the Netherlands 14. The results generated were then analysed together, as it was not possible to do any meaningful analysis on a country by country basis as the results were too small. Figure 14 shows the output from the text mining in VOSviewer

Figure 14 - - A term co-occurrence network map based on text - countries chosen for national debate



This visual overview shows a more spread out network, where the communities are not as closely clustered, but are instead spread over a wide area. This is to be expected, as the smaller dataset from the five countries cannot assemble an equally cohesive picture of network and the community as a larger dataset can. Nevertheless, there is plenty of interaction between the communities, telling us that despite being less clustered, the dialogue in academia in the five countries is interconnected, interwoven and engaged.

The colour-coding of the communities is not as clear as in the previous figure, but is rather more spread out, indicating that the communities here, while distinct, seem to interact more with each other and thereby the usage of specific terms is not as distinct. While it is clear that for example the green community is more concerned with the science behind nanotechnology (using words such as *food, cosmetic, agriculture, value, and range*) it nevertheless also includes ethic and regulatory framework, and connects to the purple, orange and yellow clusters, which in turn all connect to each other.

3.4 Discussion

The snapshot offered by the data harvesting outlined above provides us with interesting insights into how social media debates are, or in some cases, are not, taking place.

In terms of issues of societal concerns, the foremost discussion found in the literature review has been around the public perception of risk connected to nanotechnology, and how the public form opinions on risk regarding a subject as complex as nanotechnology – what influences and shapes their opinions. The findings from the literature review show that while there has been research, discussion or debate regarding more fundamental social issues such as gender, diversity and culture, more research is needed in order to map out in more detail the role played by these issues. However, the existing research is still able to provide a good foundation for the GoNano project to adequately analyse and apply findings to our methodology development, citizen engagement efforts, and our efforts to align R&I in nanotechnology with societal needs, values and concerns.

The social media mapping exercise mirrors this, with findings from the analysis coming up short when it came to the specific search terms. The SNA was able to show how the different countries' Twitter communities interacted with each other and what they were primarily concerned with, and the emphasis was generally on the science of nanotechnology. The UK data provided a certain cognisance of RRI issues and citizen awareness. The wordcloud analysis were mainly research and institution-related and showed very limited interest in societal issues apart from risk; however, that was from data mined using the overarching nanotechnology search terms, as very little data was retrieved using the specific search terms that were part of the task.

The red cluster in the SNA of Web of Science and a number of the SNA of the newspaper article clusters did show more awareness of and engagement with societal issues and citizen involvement. However, the data used for these two types of analysis was taken from journals and media sources. The analysis of the Twitter data provided clear indications that the lay citizen is not as involved in the debate as could be hoped. Again, this is mirrored in the literature review, where we can see that in a study of tweets sent between 2010-2013, posts about national security made up the largest proportion of all relevant data (23.3%) while EHS (environment, health and safety)-related content comprised the lowest proportion (9.7% on average) (Yeo et al., 2014). In another study on online audiences and content relating to nanotechnology, Anderson et al found that government and regulation were the least-searched themes in relation to nanotechnology, and social implications were the least mentioned of all themes (Anderson et al., 2010).

Twitter lets an individual user follow a person or an organisation that covers topics that are issue-based, such as nanotechnology, and not media-based – this allows users to focus on specific areas of interest. Also, the ability for organisations to create specifically targeted messages to their followers has led Twitter to be deemed essential to strategic science communication (Yi-Fan Su et al., 2017). However, as was shown in the SNA of Twitter data in the UK, terminology is not always straightforward. Figure Two showed that the third largest node surprisingly proved to be concerned with Bitcoin and cryptocurrency, a seemingly strange development until we realised that Nano is the name of a type of cryptocurrency that is also an online payment platform for cryptocurrency use. Thus, even in Twitter where specific issues can be followed and hashtags used to zone in even more specifically on particular issues, dialogue is not as clear-cut as might be believed.

As with the representation of nanotechnology in more traditional media, discussions on nanotechnology online and on social media have moved on from the initial nearly exclusively positive framing and become increasingly balanced in terms of mentions of risks and benefits (Runge et al., 2013). In their study on how public discourses about nanotechnology develop on Twitter, Runge et al (2013) found that while it is a topic that is discussed, the number of nanotechnology tweets is small compared to the sheer number of Tweets posted every day, and still has low overall numbers. Their study also found a geographic clustering of tweets around nanotechnology innovation centres, which is consistent with other studies and with our SNA findings.

While this study is five years old, it still nevertheless highlights questions with social media use and nanotechnology, as well as also clarifies why our findings were very limited in terms of gender, culture and diversity issues in the five countries. The debate on nanotechnology that does exist on social media is concerned more with science issues and may simply be a glimpse into a community of like-minded nanotechnology innovators who are using Twitter for the purpose of communicating with each other (Runge et al., 2013), rather than a citizen-led debate on societal issues. Of the findings from the social media mapping exercise, the Spanish word cloud shown in figure 10, and the SNA for the UK and the Netherlands are all clear representations of this.

Despite not being discussed to a large degree overall, in both the literature review and the social media mapping, the societal issue that is the most examined is that of risk perception and awareness. Risk is the one concern that continuously reappears in the social media mapping exercise, in one of the clusters in the UK SNA, the Dutch wordcloud (*safety, responsiveness, reality, improvement*) and also primarily in the newspaper and journal clusters. Nevertheless, the two latter examples are based on traditional print media which is now hosted online – newspaper articles or journals do not provide the same interaction opportunities like a social media platform does, and do not facilitate reaching out and discussing with citizens in the same way that online communication and social media can.

Based on the findings from this data-mapping exercise, we can come to the conclusion that there seems to be an information gap. We know lay persons use the internet and social media to find information and engage with it, but we do not know enough about how they do it and how we can involve them in communications and discussions. This insight is important for the co-creation effort central to the GoNano project, as by effective communication we are one step closer to understanding the values, needs and concerns that surround nanotechnology. Evidence from our findings show that many of the important nodes in our SNA had a quite poor following; even accounts with EU funding had only a few hundred followers. For example, in the UK the Nano2All project, which receives funding from Horizon 2020 and is tasked with improving citizens' awareness and increasing trust, only has 349 followers on their Twitter account which was opened in January 2016 (Nano2All, 2018). In terms of social media, what do we know about how lay people and scientists engage with platforms such as Twitter? How can discussions be successfully initiated, expanded and improved? What can we learn from our findings, and how can we use them to improve engagement methodologies and communication strategies?

One potential answer can be found in what science communication literature calls active public participation. In a fascinating study, Yi-Fan Su et al (2017) analysed the use of Twitter in scientific institutions' use of science public relations. Their findings highlighted what our findings also show – that the emphasis and effort of social media must employ not only the more common one-way public communication, but also two-way communication. This may seem obvious, but by looking closely at the following examples the complexity of the issue becomes clear.

As mentioned previously, some of the key features of Twitter allow for specific and much targeted information dissemination. Many organisations and individual users include hyperlinks in their tweets to bypass the character limit, and are thereby able to share for example a paper with comprehensive information on an issue, a relevant online news article, an events page, and so on. Retweets (RTs) and/or modified tweets (MTs) are also a way in which Twitter users can communicate directly with each other, as is the hashtag feature. Finally, the @mentions mechanism is a way to directly approach another user and invite conversation.

So far, all these communication methods seem efficient – however, only a few offers genuine dialogue. Using a hyperlink to spread information, while very practical, is a one-way communication mode, as it drives users to external sources and mainly reflects the organisation's interest in sharing official information or promoting their own agenda. The @mentions are very much a two-way communication, however most tweets from the largest US organisations seldom mention other users and this mechanism quickly becomes overlooked – similarly, hashtags, RTs and MTs, while promoting two-way communication, are not being used to build and maintain relationships between organisations and the general public (Yi-Fan Su et al., 2017). This all tallies with the Twitter data that we analysed, with the main communities in a network being dominated by scientific research centres, universities or institutes who mainly connect with each other and do not engage in proper dialogue.

In addition to the problem of not engaging efficiently enough in two-way communication, Yi-Fan Su et al also argue that while two-way communication has traditionally been the most efficient form of entering into a debate, there is little empirical evidence of how well this two-way model of public relations may manifest itself in positive results, such as for example increased online public participation. There is limited ability to assess the effects on lay audiences of tweets that incorporate different communication functions (Yi-Fan Su et al., 2017). This, they argue, stems from the limited stakeholder-oriented variables in studies, thereby making it difficult to explain the relative lack of public participation in Twitter conversations. It also makes it difficult to assess how, and how much, two-way public relations efforts may increase public engagement online.

What does this mean for GoNano - how can we use this information to move forward in our quest for an engagement strategy with citizens? How can we use it to explore societal needs, concerns and values, and to design an engagement strategy that includes diversity, culture and gender? It means that in order to provide an efficient methodology for engagement, stakeholders must be involved and efforts to communicate must be made with a goal to actively engage with citizens, not solely provide them with information. Both of these aspects – one-way and two-way communication models – are vitally important to science communication efforts such as dissemination, encouraging science learning, or participation or increasing public trust in science (Yi-Fan Su et al., 2017). Active engagement is necessary – having a social media account and tweeting out news stories and/or information, or retweeting something from an organisation similar to your own and hoping somehow the general public will get involved is not enough. Engagement must take place not only between other like-minded organisations or projects, but must truly reach out to the lay public – the tweets must be not “at” them but “with” them.

How can this be done? Communication activities must make significant efforts and be encouraged and facilitated, and not be stretched too thin. This is especially important for science communications in areas like nanotechnology, as positive attitudes towards, and close connections with, a scientific institution tends to increase the perceived credibility of the information it communicates, and encourages public engagement with science more generally (Yi-Fan Su et al., 2017). This means that an institution or organisation that wishes to focus on public concerns around nanotechnology must put nearly as much work into communication as they do on the science. Crucially, Yi-Fan Su et al argue, is that while an organisation’s presence on Twitter may signal that they are open for interaction with stakeholders, underusing the tools provided for two-way communication will not provide any benefits – engagement, dialogue and connection will take place only if it is reflected in the content of social media posts and the choice of effective and active management of two-way communication tools.

Finally, Yi-Fan Su et al sound a note of warning – while social media can draw audiences to online conversations and help improve their understanding of science and increase their trust levels in scientific institutions, it cannot be assumed to be a panacea for complex issues of public engagement. While it is undoubtedly beneficial and facilitates reaching the public, it is only as useful as how well an organisation uses the tools it provides.

In order to effectively connect with citizens and get a grasp of their thoughts around societal concerns, it is essential we understand how lay persons form their opinions and how they engage with organisations. This should be part of the focus of the citizen consultations, as this is a chance for us to learn from them what matters and how they communicate – how they get “stuck in” to an issue, and what makes them interested in participating in a debate on something complicated and scientific that may or may not pose a risk to them. A parallel can here be drawn to scientific forums. They are a great opportunity to engage highly interested citizens in scientific decision-making and allowing individuals to raise thoughts and concerns; however, if you as an organiser do not understand the mechanism behind how the public make decisions on complex issues like nanotechnology, you risk your scientific forum to have a detrimental effect on opinion by making the already information-rich more informed but not engaging and potentially alienating the vast majority of citizens attending (Scheufele, 2006).

CONCLUSION

In conclusion, the findings from the data-mapping exercise pointed towards what the literature is also recognising – organisations have a very important role to play in disseminating information and building trust with the general public on topics like nanotechnology, and if the aim is to start a dialogue, dissemination needs to be both one-way and two-way in order to have an impact beyond those who already have an interest in the issue at hand. Public opinion can be influenced and change from a generally positive attitude towards nanotechnology to a hostile and negative perception – it is only by having a solid, facts-based communication channel that is effective in its reach that this can be avoided.

Anderson et al summarised the situation by stating that uncovering the online information context for nanotechnology is absolutely critical for researchers and policymakers when they look to the Internet as the medium of choice for information dissemination and to develop new tools to communicate with the public (Anderson et al., 2010). Stakeholder involvement and a serious emphasis on two-way communication which engages the person and speaks “to” them rather than “at” them must be done to ensure that citizen engagement in debates on anything from risk perception to gender will actually take place, and that governance and policymakers can use the public’s informed concerns and worries productively.

The information in this report provides the GoNano project with a great opportunity to really focus on engaging the public and use our knowledge to improve and streamline communication, as we move into the next parts of the project involving face-to-face consultations with citizens and the co-creation process. The questions posed in the outline of this task were concerned with how culture, gender and communication traditions influence debates and the public understanding of nanotechnology, and focused on citizen concerns, needs, and values, as well as looking for gender and diversity issues and cultural, gender-based and communication differences. These questions have been answered in that the online social data mapping exercise showed us that the level of engagement with the public, and the debates that should be happening, are not taking place to the extent that they should be. However, there is plenty of scope for improvement and we have a good possibility of really achieving improvement in engagement methodologies in the lifetime of this project.

In addition to this, the literature review informed us of how the lay public form opinions, how they are influenced, how they assess risk, and how gender and diversity play out in this area. We can now take the lessons of this to listen closely to not only the lay citizen's societal concerns, but how they prefer communication to take place, and to take this chance to improve communication coming from the scientific side and truly connect with citizens in a meaningful and engaging manner. In doing so, we will be able to inform the GoNano engagement methodology, co-creation activities, citizen input and help our effort to align nanotechnology R&I with societal needs. To conclude, the following list of recommendations summarises some of the main points of how this may be achieved:

- Acknowledge and highlight structural underrepresentation of women in STEM/nanotechnology, and the lack of diversity
- Include and incorporate gender and diversity in all aspects of nanotechnology development from the beginning - a lack of diverse insights will make nanotechnology applications less likely to consider the needs of those who will be in contact with them, especially vulnerable groups.
- Maintain awareness of how opinions are formed and what influences them. The lack of country-specific data to detail what cultural or other factors predispose citizens to make certain judgements in the three pilot countries is simply a chance for the GoNano project to ensure that this is explored in even more details in the citizen consultation.
- Risk perception, and the divergence of levels/reasons relating to risk, such as gender and diversity, is a crucial point of engagement both with the general public and with stakeholders.
- Strategise engagement from the outset, deciding on the level of engagement to be achieved and how vibrant the discourse should be, and adapt relevant tools in accordance (e.g. two-way communication, engage scientists in dialogue with public).
- Target all demographic groups (e.g. gender, diversity, age) and interact "with" them, not "at" them, in engagement methodology development.

BIBLIOGRAPHY

Anderson, A. A., Brossard, D., Scheufele, D. A. (2010). The changing information environment for nanotechnology: online audiences and content. *Journal of Nanoparticle Research,* 12(4)**,** 1083-1094.

Bandyopadhyay, S., Rao, A. R., Sinha, B. K. (2011). *Models for Social Networks with Statistical Applications.* New Delhi: Sage Publications.

Brey, P., Reijers, W., Rangi, S., Toljan, D, Romare, J., Collste, G., Warso, Z., Sczaniecki, M., Gurzawska, A, de Sola Perea, L., Martin Arribas, C., Herrero Olivera, L. (2015). International differences in ethical standards and in the interpretation of legal frameworks. University of Twente: SATORI/European Commission.

Brossard, D., Scheufele, D. A., Kim, E., Lewenstein, B. V. (2009). Religiosity as a perceptual filter: examining processes of opinion formation about nanotechnology. *Public Understanding of Science,* 18(5)**,** 546-558.

Cacciatore, M. A., Scheufele, D. A., Corley, E. A. (2011). From enabling technology to applications: The evolution of risk perceptions about nanotechnology. *Public Understanding of Science,* 20(3)**,** 385-404.

Centraal Bureau voor de Statistiek (2018). *Population; key figures* [Online]. Available: https://opendata.cbs.nl/statline/#/CBS/en/dataset/37296eng/table?ts=1526572233620 [Accessed 23 April 2018].

Clarivate (2018). *Web of Science* [Online]. Available: https://clarivate.com/products/web-of-science/ [Accessed].

Constine, J. (2018). *Instagram suddenly chokes off developers as Facebook chases privacy. Techcrunch* [Online]. Available: https://techcrunch.com/2018/04/02/instagram-api-limit/ [Accessed 05 April 2018].

Corley, E. A., Kim, Y., Scheufele, D. A. (2016). Scientists' ethical obligations and social responsibility for nanotechnology research. *Science and Engineering Ethics,* 22(1)**,** 111-132.

Corley, E. A., Scheufele, D. A., Hu, Q. (2009). Of risks and regulations: how leading U.S. nanoscientists form policy stances about nanotechnology. *Journal of Nanoparticle Research,* 11(7)**,** 1573-1585.

Cortext (2018). *CorTexT platform* [Online]. Available: https://www.cortext.net/ [Accessed 12 April 2018].

Davis, K. (2008). Intersectionality as buzzword A sociology of science perspective on what makes a feminist theory successful. *Feminist Theory,* 9(1)**,** 67-85.

Dudo, A., Choi, D.-H., Scheufele, D. A. (2011). Food nanotechnology in the news. Coverage patterns and thematic emphases during the last decade. *Appetite,* 56(1)**,** 78-89.

Feinerer, I. (2017). *Introduction to the tm Package Text Mining in R* [Online]. Available: https://cran.r-project.org/web/packages/tm/vignettes/tm.pdf [Accessed 12 April 2018].

Finucane, M.L., Slovic, P., Mertz, C.K., Flynn, J., Satterfield, T.A. (2000). Gender, race, and perceived risk: The 'white male' effect. *Health, Risk and Society,* 2(2), 159-172.

Gentry, J. (2016). *Package 'twitteR'* [Online]. Available:
https://cran.rproject.org/web/packages/twitteR/twitteR.pdf [Accessed 24 April 2018].

Gul, S. (2017). Development of an attitude scale to measure the undergraduate students' attitudes towards nanobiotechnology. *Journal of Science Education and Technology,* 26(5)**,** 519-533.

Health Canada (2013) *Guidance Document: Considerations for Inclusion of Women in Clinical Trials and Analysis of Sex Differences* [Online]. Available: http://www.hc-sc.gc.ca/dhp-mps/prodpharma/applic-demande/guide-ld/clini/... [Accessed 18 May 2018].

Ho, S. S., Scheufele, D. A., Corley, E. A. (2010). Making sense of policy choices: understanding the roles of value predispositions, mass media, and cognitive processing in public attitudes toward nanotechnology. *Journal of Nanoparticle Research,* 12(8)**,** 2703-2715.

Jockers, M. (2017). *Introduction to the Syuzhet Package* [Online]. Available: https://cran.r-project.org/web/packages/syuzhet/vignettes/syuzhet-vignette.html [Accessed 12 April 2018].

Katz, L.M., Dewan, K., Bronaugh, R.L. (2015). Nanotechnology in cosmetics. *Food and Chemical Toxicology*, 85, 127-137.

Kim, A.M., Tingen, C.M., Woodruff, T.K. (2010). Sex bias in trials and treatment must end. *Nature*, 465(7299), 688–689.

Ladwig, P., Anderson, A. A., Brossard, D., Scheufele, D. A., Shaw, B. (2010). Narrowing the nano discourse? *Materials Today,* 13(5)**,** 52-54.

Lee, C.J., Scheufele, D. A. (2006). The influence of knowledge and deference toward scientific authority: A media effects model for public attitudes toward nanotechnology. *Journalism and Mass Communication Quarterly,* 83(4)**,** 819-834.

Lee, C.-J., Scheufele, D. A., Lewenstein, B. V. (2005). Public attitudes toward emerging technologies. *Science Communications,* 27(2)**,** 240-267.

Leetaru, K. H., Wang, S., Cao, G., Padmanabhan, A., Shook, E. (2013). Mapping the global heartbeat: The geography of Twitter. *First Monday,* 18(5-6).

Leiden University, Centre for Science and Technology Studies (2018). *VOSviewer* [Online]. Available: http://www.vosviewer.com/ [Accessed 22 April 2018].

Macoubrie, J. (2006). Nanotechnology: public concerns, reasoning and trust in government. *Public Understanding of Science,* 15(2)**,** 221-241.

Mohammad, S. (2018). *NRC Word-Emotion Association Lexicon* [Online]. Available: http://saifmohammad.com/WebPages/NRC-Emotion-Lexicon.htm [Accessed 12 April 2018].

Moore, J. (2012). New Zealand's regulation of cosmetic products containing nanomaterials. *Bioethical Inquiry,* 9(2), 185-188.

Nano2all. (2018). *Nano2All* [Online]. Twitter: Twitter. Available: https://twitter.com/nano2allproject?lang=en [Accessed 20 April 2018].

Nerlich, B., Clarke, D. D., Ulph, F. (2007). Risks and benefits of nanotechnology: How young adults perceive possible advance sin nanomedicine compared with conventional treatments. *Health, Risk & Society,* 9(2)**,** 159-171.

Nielsen, M.W., Alegria, S., Börjeson, L., Etzkowitz, H., Falk-Krzesinski, H.J., Aparna, J., Leahey, E., Smith-Doerr, L., Woolley, A.W., Schiebinger, L. (2017). Gender diversity leads to better science. *Proceedings of the National Academy of Sciences of the United States of America*, 114(8), 1740-1742.

Office for National Statistics. (2018). *Population estimates* [Online]. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates [Accessed 23 April 2018].

Proquest. (2018). *Global Newsstream* [Online]. Available: http://www.proquest.com/products-services/globalnewsstream.html [Accessed 15 April

2018].

R Project for Statistical Computing (2018). *What is R?* [Online]. Available: https://www.r-project.org/about.html [Accessed 17 April 2018].

Rauscher, H., Roebben, G., Amenta, V., Boix Sanfeliu, A., Calzolai, L., Emons, H., Gaillard, C., Gibson, N., Linsinger, T., Mech, A., Quiros Pesudo, L., Rasmussen, K., Riego Sintes, J., Sokull-Klüttgen, B., Stamm, H. (2014). Towards a review of the EC Recommendation for a definition of the term "nanomaterial" - Part 1: Compilation of information concerning the experience with the definition EUR - Scientific and Technical Research series. Luxembourg: European Commission.

Rdocumentation. (2018). *searchTwitter* [Online]. Available: https://www.rdocumentation.org/packages/twitteR/versions/1.1.9/topics/searchTwitter [Accessed 23 April 2018].

Rogers, I. (2018). *The Google Pagerank Algorithm and How It Works* [Online].

Available:http://www.cs.princeton.edu/~chazelle/courses/BIB/pagerank.htm [Accessed 17 April 2018].

Runge, K. K., Yeo, S. K., Cacciatore, M. A., Scheufele, D. A., Brossard, D., Xenos, M. A., Anderson, A. A., Choi, D.-H., Kim, J., Li, N., Liang, X., Stubbings, M., Yi-Fan Su, L. (2013). Tweeting nano: how public discourses about nanotechnology develop in social media environments. *Journal of Nanoparticle Research,* 15(1)**,** 1381-1388.

Sappleton, N., Takruri-Rizk, H. (2008). The Gender Subtext of Science, Engineering, and Technology (SET) Organizations: A Review and Critique. *Women's Studies,* 37(3), 284-316.

Savath, V., Gage Brainard, S. (2013). Managing nanotechnology risks in vulnerable populations: A case for gender diversity. *Review of Policy Research,* 30(5)**,** 549-565.

Scheufele, D. A. (2006). Five lessons in nano outreach. *Materials Today,* 9(5)**,** 64.

Scheufele, D. A., Corley, E. A., Dunwoody, S., Shih, T.-J., Hillback, E., Guston, D. H. (2007). Scientists worry about some risks more than the public. *Nature Nanotechnology,* 2(12)**,** 732-734.

Scheufele, D. A., Corley, E. A., Shih, T.-J., Dalrymple, K. E., Ho, S. S. (2009). Religious beliefs and public attitudes toward nanotechnology in Europe and the United States. *Nature Nanotechnology,* 4(2)**,** 91-94.

Scheufele, D. A., Lewenstein, B. V. (2005). The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research,* 7(6)**,** 659-667.

Schiebinger, L. (2017). Expert Paper: Gender-responsible research and innovation for small and medium-sized enterprises: Nanotechnology, ICT and healthcare. Vienna: COMPASS/European Union.

Shokri, J. (2017). Nanocosmetics: benefits and risks. *Bioimpacts,* 7(4), 207-208.

Toumey, C. (2012). Does nanotech have a gender? *Nature Nanotechnology,* 7(7)**,** 412.

Twitter. (2018). *Standard Search API* [Online]. Available: https://developer.twitter.com/en/docs/tweets/search/api-reference/get-search-tweets [Accessed 15 March 2018].

Varol, O., Ferrara, E., Davis, C. A., Menczer, F., Flammini, A. (2017). *Online Human-Bot Interactions: Detection, Estimation, and Characterization* [Online]. Cornell University Library: Cornell University Library. Available: https://arxiv.org/abs/1703.03107 [Accessed 22/04/2018 2018].

Villanueva-Felez, A., Woolley, R., Cañibano, C. (2015). Nanotechnology researchers' collaboration relationships: A gender analysis of access to scientific information. *Social Studies of Science,* 45(1)**,** 100-129.

World Economic Forum (2018). *The world's most popular social networks, mapped* [Online]. Available: https://www.weforum.org/agenda/2017/03/most-popular-social-networks-mapped/ [Accessed 17 April 2018].

World Health Organisation. (2010). Gender, women and primary health care renewal A discussion paper. Geneva: World Health Organisation.

Wright, P. (2016). Potential risks and benefits of nanotechnology: perceptions of risk in sunscreens. *Medical Journal of Australia*, 204(10), 369-370.

Yeo, S. K., Xenos, M., Brossard, D., Scheufele, D. A. (2014). Disconnected discourses How popular discourse about nanotechnology is missing the point. *Materials Today,* 17(2)**,** 48-49.

Yi-Fan Su, L., Scheufele, D. A., Bell, L., Brossard, D., Xenos, M. A. (2017). Information-sharing and community-building: Exploring the use of Twitter in science public relations. *Science Communications,* 39(5)**,** 569-597.

APPENDIX A - DETAILED METHODOLOGY OF SNA

Social Network Analysis of Twitter data

Social network analysis (SNA) means analysing various characteristics of the pattern of distribution of relational ties and drawing inferences about the network as a whole or about those belonging to it considered individually or in groups (Bandyopadhyay et al., 2011). The data used for SNA on a country by country basis was harvested from Twitter.

To do this, we created a Twitter App to talk to the Twitter API. The app allowed access the Twitter API through an Access Token and Consumer Key generated on application by Twitter.

From the R Statistical Programming Language console (Computing, 2018), using the Key and the Token, connection was made to the API. Different search terms (see Findings) were queried and tweets up to 7 days were captured.

The Twitter R package, twitteR (Gentry, 2016) has a function called 'searchTwitter' (RDocumentation, 2018) with an attribute for coordinates. The coordinates chosen were the centre of the country and a radius around those coordinates. The coordinates were obtained from Google maps. The radius chosen included the main population area of the country. The search terms in English and the native languages were queried with these coordinates. The API returned the queried results.

The next step was to import the Twitter data into the network visualisation tool, Gephi. Gephi is an open-source software used for network visualisation and analysis. The Twitter data was split in to 2 files, one file called nodes and the other called edges. Gephi is powered by a two-dimensional data system powered by two core items, nodes and edges. Nodes are the entities we are evaluating (People, Pages, Handles, Groups, Organisations, and so on) and edges are the connections between them (Likes, Following, Retweets, and so on). These are simple text files that contain a list of all the nodes and the relationships/edges between them.

With the data imported in to Gephi, some of the statistical functions and layouts offered by Gephi were utilised. The Forced Atlas 2 layout was chosen for all the graphs. ForceAtlas2 is a force-directed layout algorithm used for network spatialisation. It assigns forces to the nodes and the edges which reduces clutter. It has a gravity attribute to prevent overlapping of the nodes. It results in a more aesthetically pleasing visual.

A Modularity report was then run on the network. Modularity looks for the nodes that are more densely connected together than other parts of the network. The different colours generated identify different communities/groups.

Besides discovering communities in a network, it is also important to find how important a node is to the network. To do this, Eigenvector centrality (EC) was applied to the nodes in the network. In graph theory, Eigenvector centrality is a measure of the influence of a node in a network. A high Eigenvector score means that a node is connected to many nodes who themselves have high scores. This is similar to how Google's PageRank Works: PageRank can be calculated using a simple iterative algorithm, and corresponds to the principal eigenvector of the normalized link matrix of the web (Rogers, 2018). In our graphs, the higher the EC value, the more important the node is to the network. Colour are for communities, and size for the importance to the network.

Filtering was also applied to reduce less important nodes to the network. This was done using a filter called degree range. The degree range is the amount of edges a node has, i.e. connections to other nodes.

Sentiment and word cloud analysis of Twitter data

Data for the sentiment and wordcloud analysis was harvested from Twitter using the same procedure as outlined in section 2.3.1 above. A collection of tweets from the different countries was returned from the API to the R console. The results were converted to a dataframe.

A data frame is a data structure in R. It shares properties of a list and a matrix. R has a Text Mining package called tm (Feinerer, 2017). This package was used to perform a series of text mining operations on our dataframe to prepare it for wordclouds and sentiment analysis:

- Converted the dataframe to a Corpus (body of text)
- The text in the Corpus was converted to a plain text
- The text was converted to lowercase
- Punctuation was removed
- Stopwords were removed (common English words: the, a, us, and so on)
- Stemming was performed (Learning -> learn, Running -> run)

Further packages were downloaded into R to assist in generating word clouds and to perform sentiment analysis.

Word clouds show the frequency of the words in the tweets by varying the size of the words in a visualisation. It gives a qualitative view of the collection of tweets. The bar plots serve a similar purpose, giving a visualisation of common words in the tweets.

While word clouds and bar plots give us a lot of information about the data, sentiment analysis gives insight to the emotion of the tweets. Sentiment Analysis is the process of determining whether a piece of writing is positive, negative or neutral. It is also known as opinion mining, deriving the opinion or attitude of a speaker. A common use for this technology is to discover how people feel about a particular topic.

The Syuzhet package (Jockers, 2017) in R was used to carry out our Sentiment Analysis. It offers a few different algorithms for sentiment scoring, and we used the NRC emotion lexicon (Mohammad, 2018). It is a tool for emotion analysis and has ten categories: joy, sadness, anger, disgust, trust, fear, anticipation, surprise, negative, and positive. The results from our sentiment analysis were delivered using bar plots.

Mapping and SNA of concerns from newspaper articles

Online newspaper articles were harvested for mapping on the subject of nanotechnology with regards to the keyword search terms (diversity, culture, risk, public opinion, communication, risk perception). The data was collected from the newspaper database ProQuest. The platform chosen was the open sourced CorTexT (Cortext, 2018) platform, which is a semantic analysis platform with a particular emphasis on network mapping of textual data. Since we are dealing with a body of text rather than a connected/networked map such as our Twitter dataset, CorText is a better fit than Gephi.

The corpus (body of text) was uploaded via the Cortext Manager. Parsing took place and a script called Network Mapping was executed on the CorTexT servers. The network mapping highlights important words/phrases and how they are mapped through a semantic analysis logarithm. It also generates clusters, grouping together different nodes in to distinctive communities. CorTexT has an online console that serves up the analysis from its servers and allows for results to be downloaded.

Mapping and SNA of concerns on Web of Science

The data from Web of Science was analysed using a type of SNA. The search returned from a query in Web of Science can be formatted to a text file compatible with different SNA tools, in our case VosViewer, to produce a map of important keywords and terms. Keywords like "risk" and "public opinion" in the field of nanotechnology were queried and found in the database. This allowed us to generate a linguistic corpus, which is a set of structured texts in one file. A co-occurrence logarithm then churned through the data to reveal patterns and clusters of cases within the data. The data was served up to VosViewer, a network mapping tool, to visualise the important terms recognised by the algorithm.

VosViewer, developed in Leiden University, is a software tool for mapping and visualising bibliometric networks (Leiden University, 2018). VOSviewer also offers text mining functionality that can be used to construct and visualise co-occurrence networks of important terms extracted from a body of scientific literature. Co-occurrence networks provides a graphical visualisation of relationships between entities, in our case, keywords in a body of literature. Co-occurrence networks are the aggregate interconnection of terms based on their paired presence within a corpus . An EU wide co-occurrence of keywords, for the topic of nanotechnology, was generated first. Then a more targeted search, limited to the selected countries and the key search terms, was carried out.

Appendix B - YouTube Analysis

We initially wanted to see if we could find any YouTube channels in the five countries, so a manual search was done on YouTube using the terms nanotechnology and the relevant country. This returned more channels than the original API search mentioned in section 3.2.1, indicating that the European channels were not giving up their geographical location on their channel.

The channels that had listed their location in their "About" section and that were relevant in terms of nanotechnology did not have sufficient comments to datamine - generally, there were very few to no comments on the channels. This was reflected also in the low number of views. Broadening our search to non-country specific but nano-specific YouTube channels did not help, as even though the number of views increased there was still a paucity of comments on videos, which made datamining futile.

The biggest audience for nanotechnology on YouTube are the channels that serve up general content, for example Ted Talks. These big channels with lots of subscribers are mainly located in the US, with a global audience, and that combined with the difficulty of geolocating individual user accounts commentators made country-specific or even region-specific mapping of the conversations unworkable.

Therefore, with little found on searching nanotechnology-specific channels we decided to broaden our search to include the most popular science channels on YouTube to examine if nanotechnology was being discussed in the broader context of science. Channels chosen were some of the biggest (by subscribers) science channels on the platform. These channels have millions of subscribers, with views also going in to the millions. The channels were:

- Numberphile
- Tom Scott
- Veritasium
- Vsauce
- SciShow
- Physics Girl
- The Brain Scoop
- Kurzgesagt
- SmarterEveryday
- StandUpMaths
- Periodic Video

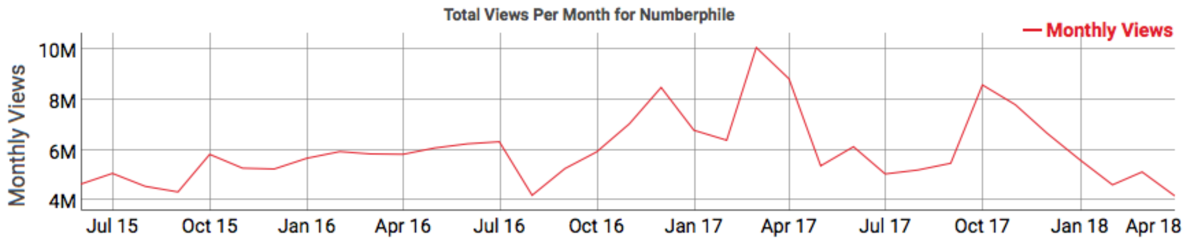
These channels were categorised differently. YouTube channels have a mandatory field to describe the channel type; while all the channels were down as "Science", they were categorised as either Technology, Education, or Entertainment. All channels had the non-mandatory field of Country of Origin filled in, telling us that five channels were from the US, one was German, and five from the UK.

We then performed Social Network Analysis on the UK channels: NumberPile, Tom Scott, StandUpMaths, Periodic Videos and Vsauce.

YouTube Social Analysis Results

Beginning with NumberPhile, it has 475 videos uploaded, nearly 2.5 million subscribers, 340 million video views and has the channel category Technology. The channel was created in 2011. The following shows the total views per month for NumberPhile:

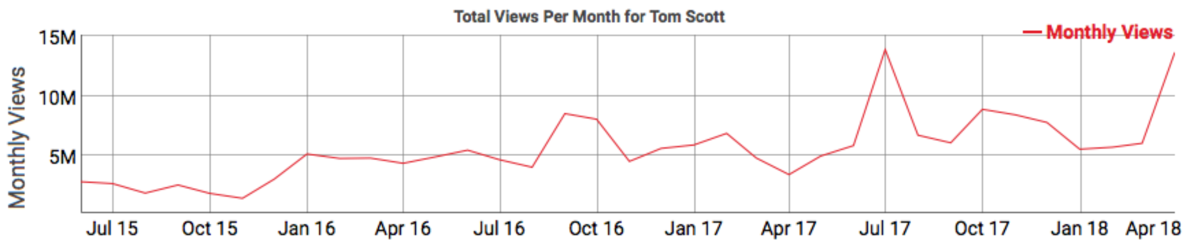
Figure 15 – Total views per month - NumberPhile



With views going in the millions each month, the channel has a wide audience. As YouTube allows searches to be performed within the channel, we did a search using the term *nanotechnology*. The query returned 0 videos.

The next channel was Tom Scott, with 441 video uploads, 1.2 million subscribers, 236 million video views and the channel type Education. The channel was created in 2006. The following shows the total views per month for Tom Scott:

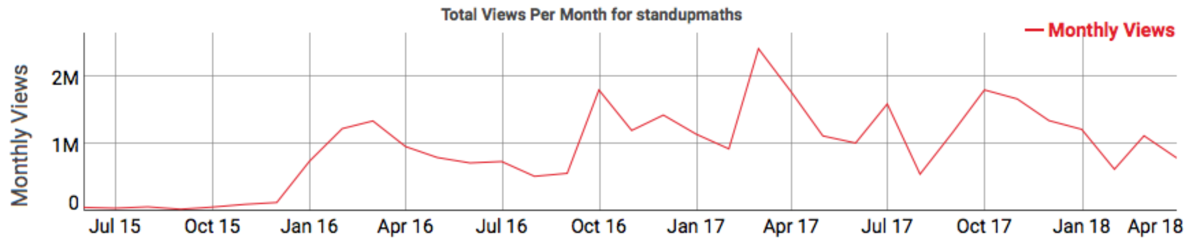
Figure 16 – Total views per month Tom Scott



As expected, the channel has millions of views each month. A search was performed for nanotechnology, which returned one video called “How to make something one atom thick”.

The third channel, StandUpMaths, has 121 uploads, 386,000 subscribers, 34 million views and the channel type is described as Entertainment. The channel was created in 2009. The total views per month for StandUpMaths is:

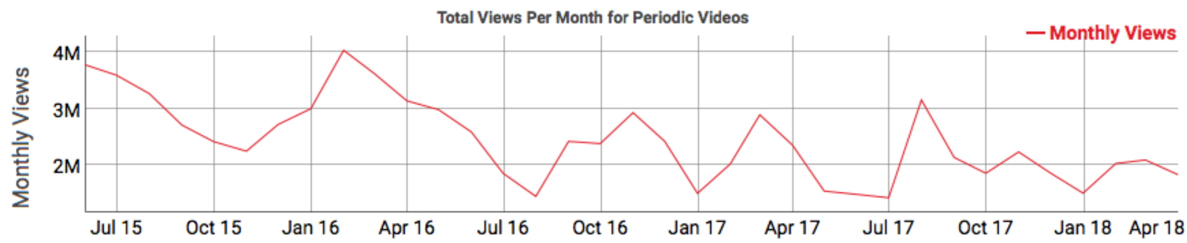
Figure 17 – Total views per month - StandUpMaths



Its view count performs strongly throughout the year. A search for nanotechnology was queried within the channel, with no videos returned.

Channel number four on our list, Periodic Videos, has 636 uploads, a million subscribers, 180,000 views and is described as Technology. The channel was created in 2008. The following is the total views per month:

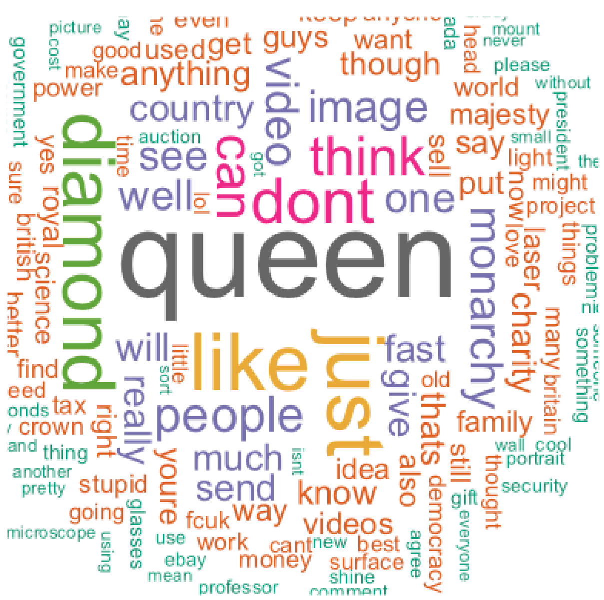
Figure 18 – Total views per month – Periodic Videos



Again the total views per month do not fall below a million. A search was done for nanotechnology with in the channel. One video was returned called "Queen's Portrait on a Diamond" which had 142K views, 1.6K likes and 39 dislikes.

Data mining of the comments was carried out, and a wordcloud was generated:

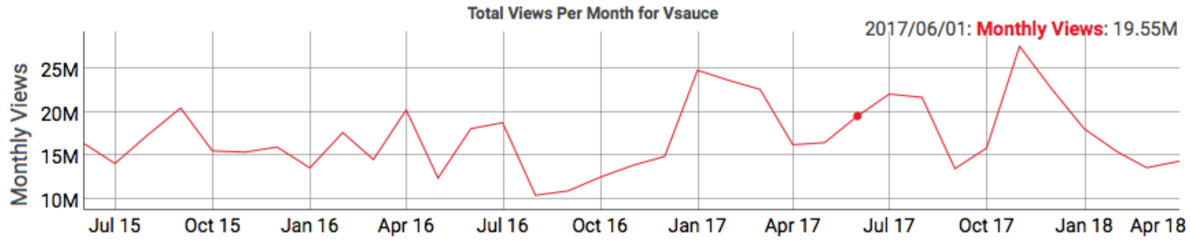
Figure 19 – Wordcloud on "Queen's Portrait on a Diamond" Periodic Videos YouTube video



This wordcloud in the context of nanotechnology does not give us any real insight. The nature of the channel describe somewhat difficult concepts, with easy to understand practical examples. The practical comparisons dominate the language in the comments. Vulgar language also appears in the cloud indicating the unseriousness of the conversation. In addition to this, we have no way of knowing where the individual comments were based geographically.

The fifth and final channel we looked at was also the biggest, Vsauce. It has 360 uploads, 13 million subscribers and nearly 1.5 billion views. The channel is described as Entertainment and was created in 2007. The total views per month for Vsauce are:

Figure 20 – Total views per month – Vsauce



A search was done for nanotechnology within the channel. One video was returned called "What is the rarest precious metal". The video has nearly 10 million views, 135K likes and 3.4K dislikes. The video comments were datamined and a wordcloud and a frequency plot were created to gain insight into the conversation.

Figure 21 – Frequency Plot on "What is the rarest precious metal" Vsauce YouTube video

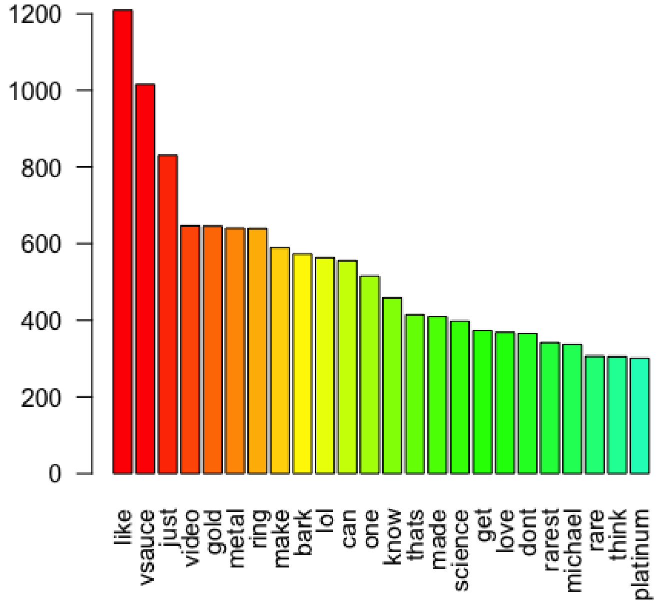
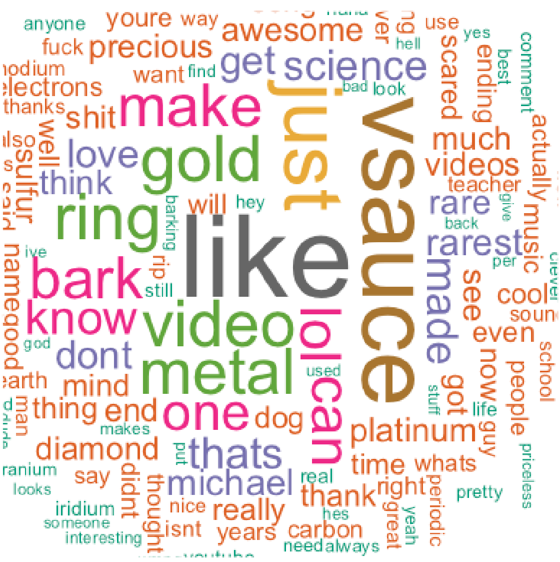


Figure 22 – Wordcloud on "What is the rarest precious metal" video, Vsauce



Again, we could not get any insight from either the Frequency Plot or the Wordcloud. The language in the comments are also here dominated by the practical comparisons that were used to describe the difficult concepts. Vulgar language made yet another appearance, indicating the irreverent nature of the conversation, as does the strong prominence of the term “lol” (laugh out loud).

In summary, we widened the search for nanotechnology to the biggest YouTube channels dedicated to science in order to see if any nanotechnology-related discussion was taking place. The channels had millions of subscribers, implying that the audience was not only people in the field of science but the general lay public; some of the channels, although science dedicated, had a channel classification Entertainment. The topic of nanotechnology, maybe surprisingly, in these channels appeared very sporadically, and we found no dedicated video with nanotechnology in its title. The scientific difficulty in explaining what nanotechnology is may perhaps be a contributing factor in the low uptake of these channels creating nanotechnology content. Nevertheless, as we could not geolocate the individual commentators, in combination with the low amount of specific nanotechnology-channels, YouTube is not a suitable option for analysis; we could not draw any relevant or valid conclusions from the data that we did find.