



Textual Representation and Intertextuality of Graphene in Swedish Newspapers

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Abstract Textual representation of graphene in Sweden’s most circulated newspapers is analyzed in 229 articles from 2004 to 2018. What is and is not said about graphene is explored through systematically identifying the lexical and grammatical patterns of sentences using the word “graphene.” Graphene is said to be a super material with certain properties, to be an object of research, commercialization, and application, and to have societal significance. Given frequent classifications of graphene as a nanomaterial in scientific discourse, there is notably limited reference to graphene as “nano” in the newspapers and only marginal reference to risk. This paper discusses the findings regarding this Swedish newspaper discourse on graphene in relation to its intertextuality, i.e., how texts draw upon and recontextualize other texts: the Swedish newspaper discourse on graphene echoes discourses of promise formulated elsewhere in society; it is not very diversified in terms of themes; it is dominated by positive and neutral representations rather than by risk; and it makes limited reference to the nano-discourse, even though, according to most definitions, graphene is a nanomaterial.

Keywords Language · Nanotechnology · Intertextuality · Discourse · Risk

Introduction

Graphene, i.e., a material comprising a single layer of carbon atoms, has become an object of public attention in recent years. In October 2010, Andre Geim and Konstantin Novoselov were awarded the Nobel Prize in physics for their experiments on this “two-dimensional” material [1]. Graphene is said to be immensely useful for society, with great potential for use in applications ranging from electronics to medicine, sanitation, energy, coatings, and enhanced materials [2–4]. The wide applicability of graphene derives from its unique combination of properties; for example, graphene is extremely thin, strong, and stiff (but in some variants bendable), as well as light, highly conductive, and impermeable [4, 5]. To ensure successful development and maximal benefit to society, graphene has become a top priority in strategic research initiatives. The Graphene Flagship of the European Union (EU) is a case in point. The Flagship is “Europe’s biggest ever research initiative,” coordinating 150 research groups in 23 countries with a budget of EUR 1 billion [6]. The Flagship is coordinated from Chalmers University of Technology in Gothenburg, Sweden.

Although most of the attention directed toward graphene focus on its prospects and potential benefits to society, studies have shown that graphene-based materials have harmful effects on organisms, although the wider implications of these findings are inconclusive and uncertain [7–9]. Like many other technological innovations, graphene is potentially hazardous to

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humans and the environment and therefore a possible cause for public concern over risk and regulation.

This paper explores how the acclaimed “wonder material” of graphene is represented in public discourse, more precisely Swedish newspapers. This aim is pursued using a textual and linguistic approach addressing the following research questions (RQs): (RQ1) What is said (or more precisely written) about graphene in Swedish newspapers? (RQ2) What is graphene said not to be? Following previous discourse analyses, expectations and presuppositions in the discourse are addressed by paying special attention to the absence of certain concepts, exploring what is *unsaid* (see, e.g., [10–12]). Thus, a third question addressed in this study is as follows: (RQ3) What is *not* said of graphene? As this third question, out of context, has an indefinite set of answers, further contextualization and specification are provided below, after a brief review of previous work on how technology is depicted in the press. By answering these questions, this study identifies what core ideas are and are not explicitly associated with graphene in newspaper discourse.

Technology in the Press: Good or Bad News?

Representations of technology in the press are mixed. On one hand, newspaper representations of technology are often positive in tone, expressing, for example, benefits, promise, social progress, business opportunities, and fascination [13–17]. Reporting is sometimes futuristic, portraying the cutting edge of human progress, identifying the next socio-technological revolution. Through reports on the most recent discoveries in energy production, information technology, space travel, medical treatment, bio- and gene technology, and the increasingly small-scale manipulation of matter at the micro- and nanoscales, newspaper readers get a glimpse of the scientific frontiers [14, 16–18].

On the other hand, newspaper representations of technology have sometimes been found to have a negative tone. Technology is commonly addressed, including by the media (e.g., [13, 20–23]), as a paradigmatic case of “risk” in modern society [19]. In negative portrayals, technologies are associated with effects ranging from the side effects of medical treatments (e.g., [24]) to irreversible catastrophe, sometimes described with reference to the mythological opening of Pandora’s box [25–27].

Besides an evaluative dimension, the concepts of promise and risk share a future orientation [28]. Consequently, like other actors of society, the news media express expectations about technologies [29], though caution is needed in order not to over-simplify such expectations as either “positive” or “negative” [30]. For example, while a promise has positive connotations, exaggerated promises, i.e., hype, have more negative associations [31]. Moreover, risk is something unwanted, but anticipation of risk, as well as the ethical, legal, and social implications of technologies, has become imperative for discourses of “responsible” research and innovation [32, 33].

A mixed representation of technology is not necessarily inconsistent, as technological innovations often are both beneficial and hazardous. From the viewpoint of journalism, both promise and risk have news value [28, 34]. The concept of technology covers many different phenomena, some more beneficial (or hazardous) than others. Technologies have many aspects. For example, representations of nuclear technology likely differ depending on whether the focus is on the basic physical principle (i.e., fission), its application (i.e., civil vs. military), or its side effects (e.g., nuclear waste and potential meltdowns). Also, knowledge and interest change over time. In different periods, one and the same technology can be represented in quite different ways [16, 17, 35].

Representations of Technology in the Swedish Press

Unlike overviews for other countries [15, 17], no study directly examines how Swedish newspapers cover technology in general. However, two areas of studies are relevant to this study of newspaper reporting on graphene in Sweden: how newspapers represent research, not technology, strictly speaking, and how some specific technologies are represented.

In Sweden, public trust in research is high [36]. Research areas that are most trusted by the public are medicine, technology, and natural science, while social science, educational science, and the humanities are less trusted. Newspaper coverage of research is overwhelmingly positive or neutral in tone, with only 3% of the coverage having a negative tone [37]. The research areas most trusted by the public are also those most covered in a positive tone (i.e., medicine, technology, and natural sciences).

The coverage of some specific technologies offers a more mixed picture. The coverage of nanotechnology in the Swedish press mostly echoes international patterns, with the tone of coverage being mostly positive with a focus on future applications [38]. Reporting on risk focuses mainly on the potential harm caused by nanotechnology and nanomaterials (e.g., the asbestos-like properties of nanoparticles), but also, though less frequently, on the risk of nanorobots [39]. The combination of more or less speculative and precise risk issues parallels findings regarding news coverage internationally [40].

Although mostly positive, the press is more critical of nanotechnology in Sweden than in other countries [38]. Representations of biotechnology in Swedish newspapers are similarly more critical than in newspapers in other countries [41, 42]. Taken together, these findings suggest a more critical stance toward technology in Swedish newspapers than in their international counterparts, at least regarding nano- and biotechnology. In support of this conclusion, a study of newspaper coverage of risks in the UK and Sweden found a “drastically higher quantity” of hazard reports in the Swedish than the UK sample (more than four times as many) [43]; the authors tentatively explained this difference with reference to the “safety culture” prevalent in Sweden, with its extensive welfare state.

What Is Said About x ?

The discursive construction of technology (as good, bad, or otherwise) has been addressed in many ways. The approach taken here considers the explicit linguistic representation of something, x (e.g., graphene), as the basis of analysis.

By means of a series of lexical and grammatical choices, a discourse is built representing a particular situation [44–47]. Predications of discourse referents (e.g., “graphene is strong”), as well as modifications (e.g., “strong graphene”) and complementations (e.g., “the strength of graphene”), are fundamental to this situation or discourse. To *deconstruct* the information given about a particular referent x (e.g., graphene) in a particular discourse, the predications, modifications, and complementations of x can be identified (cf. [10, 48–52]). In this study, our interest is in the discourse referent “graphene” and what is said of it in Swedish newspaper discourse (see RQ1). For example, is graphene said to be

“risky,” “beneficial,” or “revolutionary”? Moreover, is the situation represented as factual (e.g., “graphene *has* benefits”) or in hypothetical terms (e.g., “graphene *will have* benefits”)”? A special case of the question “What is said about graphene?” (i.e., RQ1) is the question “What is graphene said not to be?” (i.e., RQ2). For example, is graphene said *not* to be risky, beneficial, or revolutionary?

Both RQ1 and RQ2 are answered by identifying lexical and grammatical patterns of how the word “graphene” is used in Swedish newspaper articles (more details of the analysis are described in the “**Method**” section). This deconstruction of what is said of graphene will reveal the core ideas explicitly associated with graphene in news discourse. Such associations with graphene in public discourse are likely to influence how it is understood and managed in society, the extent to which graphene does or does not become controversial, and whether it is believed to be beneficial and important.

Intertextuality and What Is *Not* Said About x ?

In contrast to what *is* said about x (including what *is* said that x is *not*), what is *not* said is another important factor shaping attitudes likely to form toward x . In the absence of negative portrayals, positive attitudes toward x can form without competition. Discourse analysis has therefore taken an interest in what is *not* said (or is *unsaid*) about x in discourse [10–12, 53]. As a rhetorical strategy, *not* saying certain things about x avoids dispreferred associations with certain ideas. For example, in promoting x , *not* stating that x is “safe” can be preferable, even though safety is a desirable state, because any association with safety will evoke a frame of reference involving negative consequences.

As any idea x has an indefinite number of non-associations, studying what is not said entails theoretical and methodological challenges [54]. Asking what is not said about x does not make much sense without relating x to certain background knowledge, assumptions, and presuppositions [10, 55]. Background expectations must therefore be considered. The notion of intertextuality [10, 56] is introduced as it enables further specification of the question of what is *not* said (and, more generally, questions of what *is* said in discourse).

Intertextuality is about “how texts draw upon, incorporate, recontextualize, and dialogue with other texts”

[10]. Questions of what is and is not said about x can be reinterpreted by asking whether the things said about x in a particular text or discourse under analysis, call it d , draw on (or even reproduce verbatim) elements of what is said about x in some other text or discourse, call it d^* . The question “What is not said about x in d ?” presupposes an expectation that something, call it p , could have been said about x in d . A reason to expect this is that p is something said about x in some other text or discourse d^* . If p then is *not* realized in d , it can be identified as something that is not said about x .

Following this reasoning, RQ3 is a question of whether newspaper discourse on graphene does *not* refer to ideas present in some other discourse about graphene, call it g^* . The two ideas of interest here are those of nanomaterials and risk, soon to be explored. The variable g^* remains a fuzzier entity, but will soon be exemplified. Moreover, the possibility of considering what is not said about graphene as *a matter of degree* should be acknowledged, i.e., by measuring the *proportion* of articles of a sample that do not refer to “nano” and “risk.”

A few years back, nanomaterials were wonders of technological innovation that were about to change the world as we knew it [57]. Nanomaterials are often defined as materials having one or more of their dimensions in the nanoscale, often defined as 100 nm or less [58]. Following such mainstream definitions, graphene is a type of nanomaterial. Indeed, in scientific discourse, graphene is often recognized as such and the association between graphene and “nano” is therefore strong (see, e.g., [59]). However, is this association also part of the public discourse in newspapers? If so, to what extent? In specifying RQ3, the following question is therefore raised: (RQ3.1) To what extent is graphene associated with “nano”?

There is a substantial risk perception literature showing that technology in certain contexts is associated with risk [60]. As we have seen, the same association between technology and risk is found in newspaper reporting. Moreover, some studies specifically address the toxic effects of graphene, as it can be harmful to cells, although substantial uncertainty must be acknowledged [7–9]. The present study addresses to what extent such concerns over risk are represented in Swedish newspaper discourse on graphene. Another specification of RQ3 is thus addressed: (RQ3.2) To what extent is graphene associated with risk?

Method

Newspaper Material

Eight Swedish newspapers have been included in the sample. Four of these are major respected daily morning papers (sorted in descending order of daily circulation): *Dagens Nyheter*, *Göteborgs Posten*, *Sydsvenskan*, and *Svenska Dagbladet*. *Dagens Nyheter* and *Svenska Dagbladet* are national papers having their editorial offices in Stockholm. *Göteborgs Posten* and *Sydsvenskan* are regional papers having their editorial offices in Gothenburg and Malmö, respectively, and their main circulation in southwestern and southern Sweden. Sweden’s two main evening papers are also part of the sample, i.e., *Aftonbladet* and *Expressen*, both of which have their editorial offices in Stockholm. In addition to these daily morning and evening papers, two specialized papers are included in the sample: *Dagens industri*, a morning paper with a financial focus published 6 days a week, and *Ny Teknik*, a weekly paper with a focus on technology and innovation.

Articles on graphene were identified through the online database Mediarkivet Retriever Research (<https://www.retriever.se/product/mediarkivet/>) using the Swedish word *grafen* (graphene), including inflected forms *grafenet* (the graphene), *grafens* (graphene’s), and *grafenets* (the graphene’s). Like many other substances and materials (mass nouns), there is no plural form to consider. Note that the written word *grafen* coincides with the word for “graph” in the definite inflection. In spoken language, there is no such ambiguity due to a prosodic difference. Such false positives were manually excluded from the dataset.

In total, 229 relevant articles were identified up to December 2018. More than half of the articles were published in *Ny Teknik* (Table 1). Given this newspaper’s focus on technology and innovation, numerous articles from *Ny Teknik* were expected; while it is a weekly paper, and the others are published once a day or 6 days a week (*Dagens industri*), it is still the newspaper that most frequently mentions graphene.

Considering the other newspapers in the sample, graphene was of very limited interest in the evening tabloids *Aftonbladet* and *Expressen* (Table 1). This observation confirms previous research findings that interest in science and technology is mostly reserved for the elite press [17]. The rather high interest in graphene in

Table 1 Numbers of articles on graphene in Swedish newspapers, 2004–2018

Newspaper	Frequency
<i>Ny Teknik</i>	127 (55%)
<i>Dagens Nyheter</i>	32 (14%)
<i>Göteborgs Posten</i>	30 (13%)
<i>Dagens industri</i>	11 (5%)
<i>Sydsvenskan</i>	10 (4%)
<i>Svenska Dagbladet</i>	9 (4%)
<i>Aftonbladet</i>	5 (2%)
<i>Expressen</i>	5 (2%)
Total	229 (100%)

Göteborgs Posten can be seen in light of this being the local paper of the region around Gothenburg, the city where Chalmers University of Technology is located. As mentioned above, this university is the coordinator of the EU's Graphene Flagship initiative.

The first reference to graphene in the Swedish newspaper sample appears in 2004, but only 17 articles (7%) mentioning graphene were published before the announcement of the 2010 Nobel Prize in physics (on 5 October). There are two salient peaks in the empirical material (see Fig. 1): one in 2010, the year of the Nobel Prize, and another in 2013, the year when the Graphene Flagship was established. Since 2013, interest in graphene has steadily declined.

Analysis of What Is Said About Graphene (RQ1 and RQ2)

A Note on Examples

To avoid excessive word count, English translations of the Swedish originals are used for illustration. However, in cases in which translation is especially tricky, the original Swedish words are specified. Moreover, examples are not always quoted verbatim, but sometimes stripped of irrelevant words in the original to save space and clarify crucial aspects of the construction exemplified.

Sentences and γ -Terms

The questions about what is said about graphene (RQ1) and what graphene is said not to be (RQ2) are answered by analyzing explicit linguistic patterns in sentences that

contain (i) the Swedish word *grafen* (graphene) or (ii) an anaphoric or cataphoric reference to graphene. Here, two terminological conventions will be used. First, the α -term (i.e., alpha-term, from *anaphor*) is used for an anaphoric or cataphoric expression that co-refers to *grafen*. There are three types of α -terms: noun phrases, for example, “the material”; pronouns, for example, “it”; and zero anaphora, in which the subject is omitted but graphene is presupposed to be the subject, for example, “Why is graphene so great? Conducts electricity as well as copper. Strong, 100 times stronger than steel.” Second, the γ -term (gamma-term, from *graphene*) is used to collectively refer to the Swedish word *grafen* or an α -term.

A “sentence” is here defined as a string of words delimited by terminal punctuation (i.e., a period, question mark, or exclamation mark) or a new line. It therefore includes headlines, which often are not proper clauses in a strict sense, since they often lack a subject and finite verb. In the 229 articles of the sample, there are in total 1519 sentences with γ -terms: 1259 sentences that contain the noun *grafen* and 260 sentences with α -terms.

A Two-Step Procedure

The questions “What is said about graphene?” (RQ1) and “What is graphene said not to be?” (RQ2) are analyzed in two steps by identifying the predications and modifications of γ -terms, as well as the complements in which γ -terms occur (for similar approaches, see [10, 48–52, 61]). In the first step, every sentence has been coded for the following characteristics (see Table 2, for details and examples): the syntactic function of the γ -term; modifiers and complements of the γ -term; the verb and complementary argument of the verb-argument structure in which the γ -term participates; negation; and expressions of expectations, in contrast to representations of past and present factuality [62–64].

The second step of the analysis takes the coding in the first step as input for identifying recurrent *themes* of what is said about graphene (i.e., semantic similarities in predication, modification, and complementation). For example, one theme of what is said about graphene is that graphene is the output of manufacturing, which is realized through various constructions such as “graphene producer” (compound referring to an agent), “graphene production” (compound referring to a process), “the company produces graphene” (verb of clause), “graphene that is produced from graphite” (verb of relative clause), and “production of graphene” (head

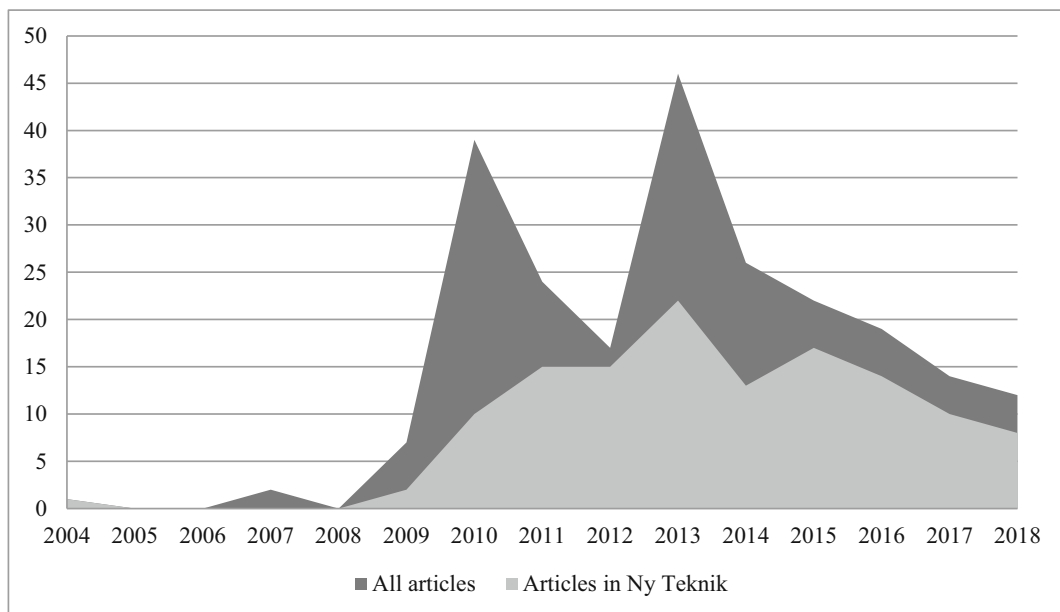


Fig. 1 Number of articles containing the word *grafen* (graphene), 2004–2018

of noun phrase). A consequence of this procedure is that every theme of what is said (see below) is anchored in a set of attested constructions (like those just mentioned) in which a γ -term participates in a particular way (as part of a compound, etc.). In total, 67 themes and subthemes have been identified in more than one article, but only those ones occurring in at least 5% of the articles are considered significant enough to be presented below. Note that the frequencies of themes are given relative to their presence in articles, not sentences, although sentences are ultimately the unit of analysis. Reporting the frequencies of themes relative to sentences is possibly misleading, as a theme can occur in many sentences, although these sentences may be restricted to only a small number of articles.

Analysis of the Extent to Which Graphene Is Associated with “Nano” (RQ3.1) and “Risk” (RQ3.2)

The extent to which “nano” and “risk” are *not* part of what is said about graphene (RQ3) is indirectly identified by the analysis described in the previous section: the proportion of articles in which “nano” and “risk” are *not* part of what is said about graphene is simply the complement of the articles in which graphene *is* associated with “nano” and “risk.” In addition to this measure, graphene’s (non)association with nano and risk is also identified at a more general level: graphene can be

associated with nano and risk in articles, although neither concept is something *said of* graphene. Besides something said about graphene, two additional scopes of analysis are considered: the scope of sentences (Does “nano” or “risk” occur in the same sentences as γ -terms?) and the scope of articles (Does “nano” or “risk” occur in the same articles as γ -terms?). Note that “nano” and “risk” can occur in the same sentences as γ -terms without being part of what is said about graphene. Also note that “nano” and “risk” can occur in the same articles as γ -terms without being in the same sentences as γ -terms. The inclusion of these wider scopes in the analysis is more informative regarding the extent to which graphene is associated with nano and risk, than is considering only the information explicitly given *about* graphene. However, such associations are more subtle and less clear in their significance.

Two more things need clarification before turning to the results. First, as discussed elsewhere, the morpheme “nano” occurs in several different words [65, 66], for example, “nanotechnology,” “nanomaterial,” “nanometer,” and “nanorobot.” Here, there is no restriction to any particular “nano-words.” Second, the concept of risk is located in a semantic field with related concepts that, besides the noun risk in Swedish, include other words with the same root, such as the verb *riskera* (to risk) and the adjective *riskabel* (risky). In addition, the semantic field of risk [67, 68] includes synonyms and antonyms of risk (of

Table 2 Linguistic categories

Category	Example
A. Syntactic function of γ -term	
Subject of (active) clause	<i>graphene</i> is a material with super properties
Subject of passive clause	<i>graphene</i> was discovered
Object of clause	everyone wants to use <i>graphene</i>
Predicative complement	this is <i>graphene</i>
Complement of a preposition in prepositional phrase (PP), in turn being...	
Complement in noun phrase	research on <i>graphene</i>
Complement in adjective phrase	fluorographene is as strong as <i>graphene</i>
Object	researchers work with <i>graphene</i>
Adjunct	in <i>graphene</i> , carbon atoms are arranged in a net
Pre-head modifier	
Compound	<i>graphene</i> research
Genitive	<i>graphene</i> 's properties
No syntactic function (over and above being the head of its phrase)	The super material <i>graphene</i> in Sweden [headline]
B. Verb of verb-argument structure in which the γ -term participates	<i>graphene</i> will <i>revolutionize</i> European industry
C. Complementary argument of the verb-argument structure in which the γ -term participates	<i>graphene</i> will revolutionize <i>European industry</i>
D. Modifiers and complements	
Epithet	the <i>material</i> <i>graphene</i>
PP complement	<i>graphene</i> in <i>golf clubs</i>
Relative clause	<i>graphene</i> that was awarded the Nobel Prize in 2010
Peripheral dependent	<i>graphene</i> , a completely new material
Adjective	<i>high-quality</i> <i>graphene</i>
E. Negation	
Regular	<i>graphene</i> is <i>not</i> thicker than a carbon atom
Quantifier	<i>graphene</i> causes <i>no</i> problems
Affixes	<i>graphene</i> is <i>impenetrable</i>
Verbs	<i>graphene</i> <i>lacks</i> bandgap [a technical term explaining <i>graphene</i> 's high conductivity]
G. Expressions of expectations	
Future tense	<i>graphene</i> will <i>make</i> Swedish industry world-leading
Modal auxiliaries and adverbials	<i>graphene</i> <i>could</i> replace rare metals
Attitudes of expectation	the industry has <i>hopes</i> for <i>graphene</i>
Other	<i>graphene</i> is considered the super material of the future

different word classes). Here, the synonymous root *fara* (danger or hazard) is considered in addition to words with the root *risk* (the English distinction between “danger” and “hazard” is not lexically encoded in Swedish). Here, these words sharing the root *risk* or *fara* are collectively referred to as ρ -terms (rho-terms, from *risk*), for example, *risk* (a noun), *fara* (danger), and *farlig* (dangerous).

Results

What Is Said About Graphene?

In sentences in the articles of the sample, γ -terms are found in a number of different syntactic positions. For the noun *graphen*, the most common ones are as follows:

Table 3 Themes of what was said about graphene in at least 5% of articles ($N = 229$)

Theme	<i>n</i>	%	Example
Material	162	71	the material graphene; graphene is a material
Super material	94	41	the super material graphene
Carbon	58	25	the carbon material graphene; graphene consists of carbon atoms
Nano	23	10	graphene is a nanomaterial; the nanometer-thin material graphene
Thickness	55	24	graphene is a very thin material
Strength	63	28	graphene is stronger than steel
Conductivity	55	24	graphene conducts electricity and heat
Transparency	33	14	graphene is transparent
Flexibility	35	15	graphene is bendable
Weight	30	13	graphene is light
Properties (nonspecific)	31	14	properties of graphene; graphene's properties
Physical arrangement (form)	93	41	graphene consists of carbon atoms arranged in a chicken-wire pattern
Two-dimensionality	23	10	graphene is considered two-dimensional; the two-dimensional material graphene
Compound	24	10	graphene on silicon carbide; graphene oxide
Research	80	35	graphene research; research on graphene; researchers manufacture graphene
Other science relation	42	18	study of graphene; at the University of Linköping [Sweden] they produce graphene
Scientific organization	32	15	graphene project; graphene center; conference on graphene
Scientific manipulation and testing	35	15	researchers test graphene; measures have been made of graphene; experiments on graphene
Discovery	32	14	graphene is a discovery; A. Geim and K. Novoselov discovered graphene
Nobel Prize	58	25	A. Geim and K. Novoselov got the Nobel Prize for discovering graphene; graphene, a Nobel-Prize-winning material
Manufacturing: output	56	24	a company that manufactures graphene; graphene production; graphene producer
Manufacturing: building block	36	16	solar cells are produced with graphene; you can build a bullet-proof vest with graphene
Quality	16	7	graphene of high quality; high-quality graphene
Use	49	21	the use of graphene; everyone wants to use graphene
Application and products (general)	42	18	graphene product; products with graphene; application of graphene
Specific applications and products	106	46	graphene in transistors; graphene in speaker membranes; graphene car; the [shoe] soles contain graphene
Substitution	17	7	graphene can replace rare metals; graphene can replace silica
Commercialization	49	21	the company is trying to commercialize graphene; graphene will revolutionize industry; the company's graphene production; it is possible to buy different types of graphene
Benefits	55	24	the benefits of graphene; graphene's possibilities
Revolution	24	10	graphene can revolutionize European industry
Hope and fascination	39	17	graphene raises the hopes of industry; researchers are fascinated by graphene
Beneficiary	21	9	EU invests in graphene
Novelty	32	14	the new material graphene
Sweden	22	10	graphene in Sweden; Swedish graphene
Uniqueness	14	6	graphene has unique properties

Indentation of a category indicates subcategorization of the antecedent (non-indented) category. One article can instantiate more than one theme

complement of preposition in prepositional phrase (31% of sentences), subject of (active) clause (22% of sentences), pre-head modifier (19% of sentences), and object of clause (15% of sentences) (see Table 1 for examples of these categories). Additional, less common categories of syntactic functions of *grafen* are subject of passive clause (5% of sentences) and predicative complement (1% of sentences). Finally, not all uses of *grafen* can be ascribed a syntactic function (3% of sentences), as in headlines.

In 22% of sentences, *grafen* has modifiers and complements. The main ones are epithets (13% of sentences), prepositional phrase complements (4% of sentences), relative clauses (2% of sentences), peripheral dependents (2% of sentences), and adjectives (2% of sentences).

Considering α -terms, most of them consist of the nominal anaphora “the material” (43% of α -terms) and “the super material” (11% of α -terms) or the pronoun “it” (33% of α -terms). Other α -terms include zero anaphora (10% of α -terms) and other nominal or pronominal anaphora (3% of α -terms), such as “the substance” and “this.” Unlike explicit references to graphene (with the noun *grafen*), the most common syntactic function of an α -term is that of being the subject of active clause (57%), followed by complement of preposition in prepositional phrase (13%), object of clause (12%), and subject of passive clause (11%). Compared with the explicit noun (*grafen*), proportionally, more α -terms function as subjects while proportionally fewer function as complements of prepositions in prepositional phrases and pre-head modifiers (only 5% of the α -terms). Like *grafen*, some α -terms cannot be ascribed a syntactic function (2%).

These syntactic patterns of γ -terms, together with the specific words that instantiate each structure, form the basis for identifying themes of what is said about graphene. The themes are presented in a conceptual order, rather than in one based on frequency. Note that only themes present in at least 5% of the articles are presented. Nor are the themes mutually exclusive, in that one sentence (and article) with a γ -term can instantiate more than one of these themes and subthemes. Table 3 provides an overview of the themes.

Physio-chemical Characterization

Graphene is ascribed a number of physical and chemical properties. First, graphene is frequently classified as a

“material” (71% of articles), for example, “the material graphene” and “graphene is a material.” In many of these cases, graphene as a “material” is more enthusiastically specified as a “super material” (41%). Another common classification of graphene is as “carbon” (25%), often in combination with “material,” for example, “the carbon material graphene” and “graphene is a layer of carbon atoms.” In 10% of the articles, what is said about graphene relates to nano, for example, graphene is said to be “nano,” as in “the nanomaterial graphene,” “graphene is a nanomaterial,” “the nanometer-thin material graphene,” “graphene is a nanometer-thin super material,” “graphene is a single layer of carbon atoms with an approximate width of 0.4 nanometer,” and “graphene is 0.4-nanometer-thick carbon.” Below, graphene’s association with “nano” is revisited.

Other physical properties ascribed to graphene are high strength (28%), minimal thickness (24%), high conductivity (24%), transparency (14%), bendability (15%), and low weight (13%). Often several of these properties are listed in combination, for example, “graphene is a thin, super-strong, bendable, transparent, conductive material that consists of carbon molecules.” Sometimes generic non-specified reference is made to graphene’s “properties” (14%).

The shape or physical arrangement of graphene is frequently referred to (41%). For example, graphene is said to be a “layer of carbon atoms” (as quoted above) and “graphene consists of only one layer of carbon atoms arranged in a chicken-wire pattern.” Other examples include compounds such as “graphene layer,” “graphene sheet,” and “graphene flake.” In the articles referring to its shape, graphene is sometimes said to be “two-dimensional” (10%). Finally, a physical feature ascribed to graphene is that it is said to be compounded with other substances (10%), for example, “graphene oxide” and “graphene on silicon carbide.”

Research and Science

In 35% of the articles, graphene is represented as an object of “research,” for example, “graphene research,” “graphene researcher,” “research on graphene,” and “researchers work on graphene.” Relatedly, but not explicitly referring to “research,” graphene is represented as an object of scientific attention in other ways (18%), for example, “article on graphene,” “thesis on graphene,” and “studies of graphene.” Other examples of this

category include reference to universities and scientific titles, for example, “*Chalmers* [University] uses this technology to manufacture graphene” and “the Russian professors Andre Geim and Konstantin Novoselov produced graphene from a piece of graphite.” Another category consists of science and research organizations and collaborations (15%), namely, “programs,” “projects,” and “conferences,” for example, “graphene program,” “graphene project,” and “conference on graphene.”

Related to these themes of research and science, graphene is represented as an object of specific forms of manipulation in research and engineering (15%), for example, “researchers test graphene,” “graphene is being developed,” “graphene is mixed with rubber,” “graphene is bombarded with gallium ions,” “measurements are made of graphene,” and “experiments with graphene.” Another research and science process is that of discovery. In 14% of the articles, the “discovery” of graphene is explicitly referred to. Finally, in 25% of the articles, graphene is said to have prompted the awarding of “the Nobel Prize,” as in “the discoverers of the super material graphene got this year’s Nobel Prize in physics” and “the Nobel Prize-awarded material graphene.”

Manufacturing

Graphene is said to be associated with manufacturing in two ways: (i) graphene is itself “produced” and “manufactured” (24%)¹ and (ii) rather than being the outcome of manufacturing, graphene is represented as a building block for manufacturing other things (16%). Examples of the former are as follows: “at the University of Linköping, they produce graphene” and “the researchers manufacture thin layers of graphene.” Examples of the latter are the following: “light panels and solar cells could also be constructed with graphene” and “Korean researchers have manufactured light speakers with the super material graphene.” The producers, if specified, include researchers and industry, so this category overlaps with the previous one, as well as with the next one, depending on whether the subject/producer is a researcher or a company (more details about products incorporating graphene are presented in the next

section). In the context of manufacturing, the graphene produced is sometimes said to be of “high quality” (7%).

Application and Use

Quite often, graphene is said to be “used” (21%), for example, “graphene is used,” “we can use graphene,” and “the use of graphene.” Relatedly, “applications” and “products” of graphene are referred to (18%), for example, “graphene application,” “application of graphene,” and “graphene product.” In addition to these general descriptions, reference is made to more specific graphene applications and products (46%), for example, in “transistors,” “batteries,” “circuits,” “computers,” “displays,” and “sensors.” In addition to these objects, there are sometimes references to process-oriented forms of application. One such process is the possibility of using graphene as a substitute for other materials (7%), for example, “medical researchers and engineers try to replace damaged retinas with graphene” and “graphene is often pointed out as a replacement for silica in electronic circuits.”

Commercialization

In 21% of the articles, what is said about graphene reflects its role in commercialization. In close association with words such as “company” and “industry,” it is said, for example, that graphene will “become a new Swedish industry” and (as noted above) is manufactured by companies (e.g., “a small number of companies manufactures graphene”). Also, graphene is said to be something “sold” and “bought,” for example, “Graphensic in Linköping sells graphene” and graphene is said to be both “expensive” and “cheap.”

Societal Significance and Benefit

Graphene is said to be beneficial in various ways (24%), for example, “now come the benefits of graphene,” “human imagination is the (only) limitation to where and how graphene can be beneficial,” and “graphene is on its way to change the world.” In these positive representations, graphene is said to be “revolutionary” (10%), for example, “graphene is a material that will revolutionize our everyday lives” and “graphene can revolutionize energy production in the future.”

Relatedly, graphene is said to be the focus of hopes and fascination (17%), for example, “now researchers

¹ In Swedish, these verbs are *tillverka* (manufacture), *framställa* (produce), *göra* (make), *producera* (produce), *få fram* (produce), and *ta fram* (produce).

set their hopes on graphene,” “the super material graphene raises the hopes of industry,” and “since its discovery in 2004, researchers have been fascinated by graphene.” Relatedly, graphene is represented as a beneficiary of some action (9%), for example, “the EU makes large investments in graphene.”

Other

Three remaining themes reach frequencies of at least 5%. First, in 14% of the articles, graphene is said to be something novel, for example, “the new material graphene.” Second, in 10% of articles, graphene is geographically anchored in Sweden, for example, “Swedish graphene is ready for production.” Third, in 6% of the articles, graphene is said to be “unique.”

Non-factuality and Expectations in Representations of Graphene

A dimension that cuts across these representations of graphene is the difference between what graphene *is* (or *was*) and what it *can* (or *will*) *be*. Typically, the unmarked (indicative) form in a language (e.g., “graphene *is* a layer of carbon atoms”) represents a situation as factual, while the non-factual representation of a situation is marked using a variety of linguistic devices [64, 69]. For example, situations that *could* or *will be* are represented by tense systems and the grammatical category of future tense; modal systems, including modal auxiliaries (e.g., *can* and *could*) and adverbs (e.g., *maybe*); and verbs of propositional attitudes (e.g., *hope that*, *expect that*, and *wish that*). Although past tense, like future tense, is marked in languages like Swedish and English, the past is very different from the future. While the past (that which *has been*) is grouped together with the present (that which *is*) to form the factual, the future is not [63, 64, 70]. Following this distinction between factual and hypothetical, expectation is a species of the former.

Of the themes listed above, some of them mostly combine with expressions of factuality (e.g., representations of physio-chemical characterization, such as thickness, strength, and conductivity; manufacturing; discovery; and the Nobel Prize), while others tend to combine with expressions of expectations (e.g., use, application, commercialization, benefits, and hope and fascination). Of the 1519 sentences analyzed, expectations about graphene are expressed in 28%. Examples of

such sentences are as follows: “graphene *will change* the world” (future tense); “graphene *will be* a new Swedish industry” (future tense); “the goal is Swedish graphene products on the market *within two years*” (future adverbial); “graphene *may* revolutionize IT and communication technologies” (modal verb); and “The EU *hopes* that the supermaterial [i.e., graphene] *will help to accelerate* growth in Europe” (the verb *hope* and future tense). Overall, 54% of the articles ($n = 229$) contain at least one sentence that expresses an expectation about graphene.

What Graphene Is Not

In a few articles, graphene is denied properties (11%). Some of these dissociations contribute to the representation of graphene as an exceptional material, i.e., graphene is said *not* to be thicker than a carbon atom (one article), *not* to be soft (one article), and *not* to be visible (two articles). Moreover, graphene is said *not* to let gases and liquids through or to be *impenetrable* (three articles) and to lack a band gap (four articles), i.e., a concept in physics that, for example, explains the conductivity of a material. In two articles, products with graphene (i.e., computers and motorcycle helmets) are said *not* to be as easily heated.

Other cases in which graphene is denied properties concern the manufacturing of graphene and its being part of products. There are claims that *not* many can produce graphene (one article), but also that the mass production of graphene is *not* more difficult than small-scale production (one article). In contrast to ascribing high quality to graphene (see above), there are claims that it is *not* possible to manufacture high-quality graphene (one article) and that almost no graphene on the market is of high quality (one article). There are claims that bridges cannot be built of graphene alone (one article), that equally efficient changeover switches (*omkopplare*) cannot be made of graphene as opposed to silicon (one article), and that “we have not found any new home interior that contains graphene” (one article). There is the claim that “there are many who cannot buy graphene” (one article). Also, there is the conditional statement that, if graphene is not produced in perfect layers, it will become weak (one article).

Four articles articulate skeptical claims regarding the hopes ascribed to graphene: that it “has *not* worked as well as many had hoped” (one article); that it “has *not* succeeded at industrial scale” (one article); that “*no*

graphene revolution has happened” (one article); and that “there is *no* chance that graphene will replace steel,” which can be compared with what is affirmatively said about graphene (see above). Also, in contrast to claims of the novelty of graphene (see above), one article claims that “making filters of graphene is *nothing* new.”

Another article asks “Is graphene harmless?” (*ofarlig*) and continues by discussing the potential risks of graphene (see next section). Three other articles *deny* that graphene has negative physical effects on humans, saying that, in contrast to nanotubes, it does not penetrate the lungs and cause inflammation; it does not irritate human tissue; and it is “just carbon” and “does not cause any problems” (cf. [71]). In two other articles claiming that “graphene kills bacteria” and that “graphene is an efficient antibacterial agent,” graphene is said to be “harmless to bacteria” in particular forms and that graphene is not, in general, an “antibacterial agent” (*bakteridödare*).

To What Extent Is Graphene Associated with Nano and Risk?

Considering the complete sample, “nano” and “risk” (i.e., ρ -terms) *are* elements of what is said about graphene; neither “nano” nor “risk” is absent from what is said about graphene in Swedish newspaper reporting.

Nano

In 23 articles (10% of the articles), “nano” is an element of what is said about graphene (Fig. 2(C)), and in 19 of these (i.e., 8% of articles), graphene is said to *be* “nano” (Fig. 2(D); for examples, see above). An example in which “nano” is part of what is said about graphene (Fig. 2(C)), but graphene is not said to be nano (Fig. 2(D)), is “graphene is complemented by nanometer-thin structures of metal.”

Changing the perspective, these findings imply that in 90% of the articles, “nano” is *not* something linked to graphene. In an overwhelming majority of cases, graphene is not classified as a nanomaterial, although more general classifications of graphene as a “material” or “super material” are very frequent (see section above). Graphene is more frequently classified as carbon than as a nanomaterial.

Although “nano” is rarely an element of what is said about graphene, in 29% of the articles containing *grafen*, there are also instances of “nano” (Fig. 2(A)),

and in 15% of the articles, “nano” occurs in the same sentence as a γ -term (Fig. 2(B)). To conclude, there is a more frequent association between graphene and nano than is covered by the “what is said” relationship. However, despite the inclusion of associations over and above what is said, “nano” is still not discerned in 71% of the articles, and in 85% of the articles, γ -terms never occur in the same sentences as “nano.”

What then can be said about those articles that contain “nano” (Fig. 2(A, B)), but not as something said of graphene (Fig. 2(C))? In many such cases, there is no clear link between the γ -terms and nano besides co-occurrence in the same text. In other cases, an inferential link between nano and graphene is possible, with graphene not said to be nano, but (possibly) implied to be (see Fig. 2(E)) (cf. [55, 72]). (The plausibility of making such inferences is discussed here; whether newspaper readers in fact make these inferences is another matter not explored.) For example, consider the following sentence in which graphene is said to be hard to see, and then this claim is ascribed to an interviewee who, in turn, is ascribed a professorship in nanoscience: “Graphene is hard to see ... says Mikael Fogelström, professor in microtechnology and nanoscience.” In this example, nano is not part of what is explicitly said about graphene (Fig. 2(C)) and graphene is not explicitly said to be nano (Fig. 2(D)). However, certain information conveyed by the sentence invites its readers to infer that graphene is nano, reasoning roughly as follows: the cited source has expertise in graphene (that is why he is interviewed); he also possesses expertise in nano (he is a professor of nanoscience); so graphene is reasonably assumed to be a nanomaterial. In 12% of the articles, such implicit links exist between graphene and nano, with graphene not being said to be nano, but plausibly being implied to be (Fig. 2(E)).

Risk

Similar findings hold for risk, although associations are even weaker in this case. In only six articles (3%) are ρ -terms found in what is said about graphene (Fig. 2(C)). There are five articles in which graphene is said to be a risk (Fig. 2(D)), for example, “another health risk might be graphene” and “researchers warn of the risks of graphene,” and one article in which graphene is said to reduce risk (i.e., a case of (C), but not (D), in Fig. 2). However, as with nano, there are more extensive textual associations between graphene and ρ -terms: in 17% of

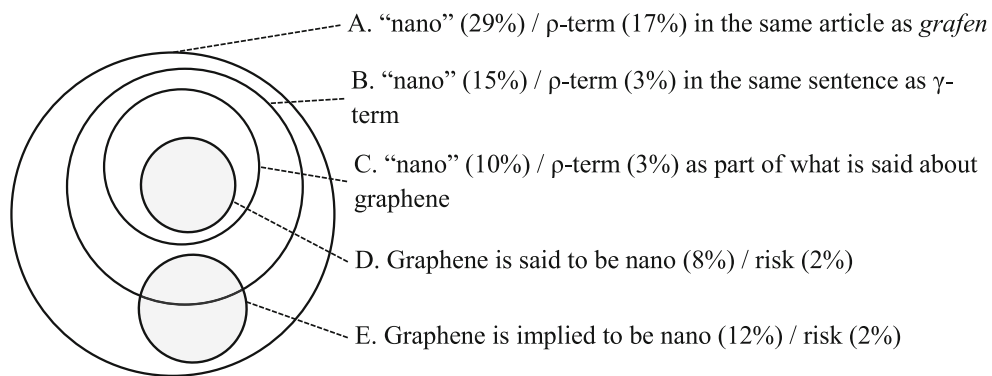


Fig. 2 Graphene’s associations with nano and risk (percent of articles, $N=229$). A ρ -term is a word which has *risk* or *fara* (danger/hazard) as roots. A γ -term collectively refers to the word *grafen* (graphene) and anaphoric or cataphoric reference to *grafen*

the articles, there are ρ -terms (Fig. 2(A)); in eight of these, a γ -term and a ρ -term are part of the same sentence (Fig. 2(B)). As in the case of nano, the reverse negative conclusion dominates for risk: in 83% of the articles, ρ -terms are absent; and in 97% of the articles, there is no sentence containing a γ -term and a ρ -term. However, as in the case of nano, but less commonly (only 2% of articles), there is sometimes an inferential link between graphene and risk, with graphene not said to be a risk, but (possibly) implied to be (Fig. 2(E)). Examples include articles that first discuss the risks of nanomaterials and second say that graphene is nano, suggesting that graphene might pose a risk.

Discussion

Most of what is said about graphene in Swedish newspapers can be summarized in the following condensed characterization based on the empirical findings (considering themes present in at least 5% of the articles):

Graphene is a material, even a super material. It is a form of carbon arranged in a particular way, having a particular shape (or form). Graphene is a nanomaterial, but it is a new thing, and it is unique, since it combines a large number of special properties: it is thin, light, strong, highly conductive, transparent, and bendable. Graphene belongs to the world of research and science. Its discoverers have even been awarded the Nobel Prize. Graphene is also part of the world of business and commercialization: it is manufactured, sold, and bought. Graphene has (or will/can have)

positive implications for society, and might revolutionize certain domains of society. It has (or will/can have) a number of more or less specific applications. Development of graphene is (or will/can be) taking place in Sweden.

These discourse patterns in what is (and is not) said about graphene in Swedish newspapers can be reinterpreted by considering their intertextuality [10, 56] at different levels. First, the newspaper discourse on graphene contains both descriptions of what graphene actually is and what is expected of it.² The latter type of representation can be linked to *expectations* articulated about graphene elsewhere in society [73], other than in media discourse. Second, the articles of the sample frequently reuse a rather limited number of conceptual resources and themes, with the result that the newspaper discourse on graphene is not very diverse; rather, what is presented is a coherent story about graphene and its promises (cf. [73], also see [74]). For example, exact formulations and explicit associations with, for example, “super material,” “use,” “application,” “manufacture,” “research,” “discovery,” “Nobel Prize,” and “revolution” reappear in one article after another. Third, the newspaper discourse on graphene is a continuation of newspaper reporting on technology more generally. As such, an emphasis on technology as promise (i.e., positive expectation) rather than risk (i.e., negative expectations) can be noted. Finally, despite a possible link to the nano-discourse, this

² Both factual descriptions and expressions of expectations serve important roles for the journalist in producing a newsworthy, yet coherent, story. Expectations of great societal impact are newsworthy. However, for a truly novel technological innovation, descriptions and characterizations of it are required to make readers familiar with it.

possibility is not frequently realized, and when it is, the link between nano and graphene is often indirect and quite vague. Consequently, graphene is represented as a technology in its own right (cf. [74]), not drawing on the previous hype surrounding nanotechnology [57]. Each of these intertextual links of the newspaper discourse on graphene is revisited in more detail below.

Graphene and the “Circulation of Promises”

In recent years, scholars of science and technology studies have clarified the role of expectations in innovation processes and the development of science and technology [29, 74–76]. The main observation from this field of work on “the sociology of expectations” is that expectations are constitutive and performative. Discursive and rhetorical acts expressing expectations do have actual effects on socio-technical arrangements. Studies show that expectations about the future shape actions in the present. Expectations set up objectives toward which actors can coordinate their attention and resources. As such, studies have explained how expectations and promises have played a formative role in the establishment of various technological fields, such as membrane technology [74], nanotechnology [30, 77–79], and graphene technology [73, 80]. More concretely, expectations (promises as well as concerns) become reasons for engaging in action, such as networking and forming alliances, as well as for funding and planning future action. Once expectations and promises are (collectively) accepted and inscribed in agendas and roadmaps, expectations suggest, or even require, future action [81–83]. Thus, expectations are performative, since the *expression* and *acceptance* of an expectation that proposition *p* will realize can be responsible for the *realization* of *p*, at least, in part [29, 84].

Given the constitutive and performative role of expectations, actors in innovation processes and the development of technology realize the importance of governing them [85]. Thus, besides governance *by* expectations (i.e., their potential to shape innovation processes), we should recognize governance *of* expectations, i.e., coordinated, sometimes strategic, activities to influence expectations to fit a desired content and form [74, 80]. The interaction of these processes is an important part of explaining hype in technology: the recognition of governance *by* expectations motivates governance *of* expectations, which in turn can explain the exaggeration of promises, i.e., hype, which in turn has effects on the innovation process.

Alvial-Palavicino and Konrad [73, 80, 86] have explored “anticipatory practices” (a term originating from Anderson [77]) related to the socio-technical field of graphene, studying how the promises of graphene are produced and become “circulated” among actors in different arenas of the innovative sphere: science, research policy, and the market. As a first crucial step in shaping expectations of graphene (in turn shaping the development of the graphene field), Alvial-Palavicino and Konrad have identified visions of graphene articulated in the high-impact journals *Science* and *Nature*. For example, the massively cited paper “The rise of graphene” from 2007 by Geim and Novolelov in *Nature* is full of expectations [87]. It refers to the economic and innovative prospects of graphene and its wide-ranging applications. Second, Alvial-Palavicino and Konrad have explored the formation of the Graphene Flagship, in which previously produced expectations were absorbed and additional expectations were produced. Tightly integrated in the application process for the Flagship was the production of a roadmap. As an instrument for governing expectations, the roadmap came to coordinate the scientific community working on graphene in Europe. A version of the roadmap was published in *Nature* [88] and it “spares no expectations” [86], suggesting that graphene is the next disruptive technology and has the potential to “revolutionize many aspects of our life.” The roadmap presents a diverse set of applications of graphene, the possibility that it could replace existing materials, and how it can be produced. In 2013, the decision was made to grant graphene research one billion Euros in a flagship program. This decision can be seen both as a result of anticipatory practices and as a promise itself [73]. In the third and final “arena” explored by Alvial-Palavicino and Konrad [73], i.e., the market, investments have been made and new companies started within a “network of expectations,” where key actors must balance promise, hype, and disappointment.

We can now reflect on the representation of graphene in newspaper reporting in relation to the “circulation of promises” of graphene reviewed above. What becomes clear is that the story told about graphene largely echoes anticipatory practices and expectations produced about graphene in other arenas [73, 80]. Strong associations with science and research, wide-ranging applications, the possibility of manufacturing, societal impact, commercialization, business opportunities, and radical change and revolution are core representations of

graphene in the media material as well as in the anticipatory practices discussed by Alvial-Palavicino and Konrad [73] and Konrad and Alvial-Palavicino [80].

The intertextual links between the arenas explored by Alvial-Palavicino and Konrad [73] and Konrad and Alvial-Palavicino [80] and in news discourse raise a question about the extent to which the media play an instrumental and strategic role in spreading expectations in the case of graphene. If so, the governance of media relations would constitute yet another anticipatory practice in the techno-scientific field of graphene. This question cannot be answered definitively here. It requires an investigation of its own and is thus a possible topic for future research. However, studies of the relationship between science and journalism suggest that strategic media relations for the dissemination and communication of science have grown, explained partly by transformations of science, including policies for funding and the increased emphasis of social impact [89–91]. We can note that scientists are frequently cited sources in the media material (although this aspect of the reporting is not part of this analysis), suggesting an opportunity for voicing preferred representations of graphene.

Before turning to the next section, a note is required. The spreading of promises about graphene through the media by its promoters (its “promise champions” [74]) might be instrumental and strategic, aiming at increasing attention and enthusiasm on the part of the public, policymakers, and investors. However, the science-media relationship is probably best understood as one of mutual benefit. Expectations of a better or worse future articulated by legitimate sources, such as professors, have news value. As scientific “breakthroughs” suggest disruptive societal change, stories about cutting-edge technological development are fascinating (or scary) and newsworthy.

Limited Diversity

The reporting on graphene contains little controversy or inconsistency, although some weak polemic patterns must be acknowledged, as seen from what graphene is said not to be (e.g., high quality or not, revolutionary or not). A salient observation is that certain explicit formulations about graphene, for example, that it is a “super material,” echo throughout the newspaper articles. Particular phrases and linguistic elements are reused, contributing to a rather homogenous story about what

graphene is. This highly intertextual feature of the sample reflects a discourse that expresses a rather limited set of highly consonant and interdependent ideas.

Revisiting the discussion in the previous section, the formation of a socio-technical field is partly achieved through selection and exclusion [86]. As some expectations in particular are agreed on, they form collective expectations or an agenda for further coordination and action. Insofar as the media discourse on graphene is influenced by the anticipatory practices elsewhere (as discussed above), the media discourse is predicted to reflect the unification of the field achieved in other arenas. The efforts made in other arenas to produce a coherent discourse on what graphene is and what is expected of it thus have re-emerged in the news media discourse.

A Story of Promise, Rather Than Risk

The newspaper discourse on graphene is a continuation of previous representations of technology in newspapers; as such, this discourse is neutral or emphasizes the positive side of technology, downplaying risks. The news discourse on graphene is one of research, applicability, discovery, revolution, and commercialization [14, 15, 17]. Intertextual links to previous negative portrayals of technology in the news [21–23] are weak, even though graphene has been associated with safety concerns in scientific discourse [7–9]. This available discursive linkage between graphene and risk is largely ignored. In relation to previous findings regarding Swedish newspapers, the present findings regarding graphene are aligned with findings on the positive tone of reporting on research [37]. Moreover, the reporting on graphene is more similar to that on nanotechnology, which has been found to be mostly positive [38], than to that on biotechnology, which is more critical [41, 42]. However, in comparison with the reporting on nanotechnology, which indeed has been *mostly* positive, but where concerns over risks have nevertheless been raised [39, 40], such concerns are almost absent in the case of graphene. There is no “safety culture” [43] in evidence.

Swedish newspaper reporting on graphene is overwhelmingly more positive than negative. This finding is based on the linguistic patterns identified, where graphene is rarely said or implied to be a risk. On the contrary, graphene is understood to have applications

and social benefits and to be an object of commercialization, hope, fascination, and even revolutionary expectations. That said, we should note that negative representations of graphene are *not completely* absent. As shown above, there are references to risk, although very rarely. Also, there are a few representations of what graphene is not, indicating some preliminary signs of disappointment (see section “[What Graphene Is Not](#)”). Despite such findings, the Swedish news discourse on graphene is overwhelmingly a positive story of emerging technology, not one evoking discourses of risk and disappointment. This positive representation of graphene recalls previous findings that, for example, the news discourse on nanotechnology is dominated by themes of science, research, discovery, applications, business, funding, and innovation [18, 92–94]. However, despite these similarities between reporting on graphene and on nano, graphene’s association with “nano” is surprisingly often absent, downplaying yet another available discursive linking, which is the topic of the next section.

Leaving Nano Behind?

In contrast to this study’s findings regarding graphene, previous studies of nanotechnology have found that nanotechnology and nanomaterials now give rise to a slightly more heterogeneous news discourse [18, 95]. Besides associations with science, research, discovery, applications, business, funding, and innovation [18, 38, 92–94], similar to the associations with graphene, the nano-discourse contains more associations with risk, doomsday scenarios, and disappointment due to the enormous expectations of nanotechnology that have not yet been realized [39, 40, 96]. The representations of nanotechnology and nanomaterials in newspaper reporting are ambiguous in a way as yet unparalleled in the case of graphene.

As discussed above, but not fully explored here, graphene’s weak association with nano in Swedish newspaper discourse could be partly strategic. The limited intertextuality between graphene and nano might be the result of an intentional strategy by key sources to avoid the (problematic) ambiguity of nano, or it might be a journalistic strategy to produce newsworthy stories about “the next big thing,” rather than covering “old news” about nanomaterials. If so, one reason for avoiding the classification of graphene as nano is that nanotechnology has to some extent fallen

out of fashion. The “nano-hype” [57] observed some years back seems to have lost some of its former glitter. The many and diverse associations of nano that have emerged in public discourse might have become somewhat of a burden in attempts to promote the technology. The ambiguity of nano, which incorporates a wide range of ideas, including futuristic and unrealistic depictions in science fiction and a heterogeneous set of application areas [18, 57], may be considered an unwelcome association in the formation of technological optimism regarding novel innovations [85]. Moreover, nanotechnology and nanomaterials have been subjects of concern regarding safety and risk regulation, as there have been (albeit limited) associations with risk, including allusions to both “nanorobots” and asbestos-like properties [18, 39, 40]. This wide range of associations constitutes potentially unwanted baggage when presenting graphene as the “next big thing” in technological innovation. Basically, the promotion of graphene is perhaps better off without any associations with the declining fascination with nanotechnology [35, 97]. As such, the newspaper reporting on graphene contributes to the formation of graphene as a scientific-technical field of its own (cf. [74]). In this sense, graphene illustrates an opposite discursive process to that observed for the molecule cyclodextrin, which can encapsulate other molecules and therefore has applications in relation to, for example, drug delivery, food, and cosmetics [98]. In the case of cyclodextrin, key actors (a “cyclodextrin lobby”) were able to shift a toxicity framing of the molecule to a framing of positive expectations. This reconfiguration was, in part, achieved by a “nano-turn” in which cyclodextrin became associated with the hype and promise of nanomedicine [98].

Finally, the intertextual links between the graphene and nano-discourses can be addressed by counterfactual reasoning, starting with the premise that graphene is a nanomaterial (an uncontroversial assumption). Moreover, given a desire to present graphene positively and as newsworthy, its classification as “nano” would have been more strongly emphasized if nano had positive connotations and was still considered “news.” Since graphene is explicitly classified as nano in only one out of ten articles, the conclusion is that nano’s connotations are currently not positive. The link between graphene and nano *could* have been both

uncontroversial and relevant (from another perspective, e.g., the scientific classification of materials), but since this “opportunity” has largely been ignored, it is probably not desired. As such, the graphene discourse explored here also says something about the current state of the nano-discourse.

Conclusion

The representation of graphene in Swedish newspapers can be summarized by a rather limited set of propositions that resonate throughout the sample. In some cases, exact formulations are reused: graphene is a super material that is strong, light, thin, and highly conductive; it is an object of research and science and its discoverers were awarded the Nobel Prize; and it can be used for various purposes, having societal benefits and possibly even revolutionizing industry. What is said about graphene in Swedish newspapers is positive or neutral, with very limited competition from negative portrayals, including risks and hazards. This controversy-free discourse likely resulted from anticipatory practices and the circulation of expectations in the graphene field [73, 80], and it can be assumed to have implications for graphene policy and management. First, without negative portrayals, mostly positive attitudes are likely to be construed from the public discourse. Second, these findings can be related to a recent emphasis on the ethical, legal, and social impacts of technology, or on responsible innovation [32, 33]. Part of this paradigm is the inclusion of stakeholders as well as topics concerning the management of research and innovation. Exemplifying the latter, these processes should anticipate not only the benefits of innovation, but also its negative impacts, i.e., its risks to society, health, and the environment. Given the limited critical reflection evident in the positive story told about graphene, this media discourse does not contribute to a “responsible” discourse on graphene [71]. Third, we can note that the media discourse on graphene reinforces practices in place elsewhere in society concerning the formation of high expectations of graphene, for example, in research, management, and the private sector [73, 80]. In striving to produce science as “news,” newspaper reporting applies schemata of cutting-edge and socially important technological promises, or of controversy, technological misuse, and risk. Currently, Swedish newspaper reporting on graphene is clearly dominated by the former.

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Compliance with Ethical Standards

Conflict of Interest The author declares that he has no conflict of interest.

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