The Risk of Nano-Particles in Deodorants – How Literate Are Young People?

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ABSTRACT

*In this empirical study the risk literacy of young people in the context of nanotechnology is investigated. Therefore, a Risk Literacy Model (RLM) based on the Elaboration Likelihood Model (ELM) by Petty and Cacioppo [1] is developed. The RLM differentiates between the processing of information regarding risk assessment, which is based on either a deeper cognitive analysis (*central route*), or on the use of peripheral cues (*peripheral route*). Target group are 12th Graders (N = 245) from Bremen and Lower Saxony. The prerequisites of central information processing, risk propensity and risk literacy are measured using a questionnaire with closed and open response formats. Risk propensity is measured before and after presentation of a short scientific text and several evaluative statements by institutions or fictitious individuals on nano-particles in everyday products. The results show that the adolescents' risk literacy is very low. However, the risk propensity of the participants decrease considerably through the reception of the information presented. It is recommended that risk literacy should be more promoted in the science curriculum.*

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Introduction

Nano-particles in everyday products – What is their risk?

Nano-sciences refer to the investigation of atomic or molecular units within a size range of 1 nm to 100 nm [2]. Nanotechnology is concerned with the composition of such units [3]. In general, nano-materials describe artificially-produced materials with a changed surface-volume ratio smaller than 100 nanometres, which frequently develop changing properties [4].

The societal benefits and economic potential of nanotechnological findings lie in their contributions to quality of life and sustainability [5]. Today, nano-materials are used in almost all areas of life. Although nanoparticles are already known elements, the behaviour of these particles cannot be compared to those at the macroscopic level. Materials at the nano level have different physical-chemical properties than their larger representatives. Due to the hugely increased surface of nanomaterials, they are considerably more reactive. This makes nanotechnology so interesting for research and development, although it is these properties themselves that also contain new risks for humans and the environment. Research into the risks is still clearly lagging behind the production and marketing of nanotechnology [6].

The risk of toxicity as well as that of exposure continues to be difficult to assess or to prove [2], which is why it is becoming all the more important to inform consumers of this uncertainty, so that they may come to an informed decision regarding how to behave in the face of unknown risks. As with many other branches, the cosmetics industry relies on developments in the area of nanotechnology [4; 7]. In this study nano-particle-containing substances in deodorants and shower gels are explored exemplarily. The main nanoparticle ingredients of these products are aluminium chloride, aluminium chlorohydrate and nano-silver.

Over the past few years, the anti-microbial acting aluminium contained in deodorants has fallen into disrepute. The nano-particle aluminium is thought to be a trigger of breast cancer and Alzheimer's. Studies found a higher concentration of aluminium in the nipple tissue of women suffering from cancer than in the nipple tissue of healthy women [8]. It has been proven that high doses of aluminium trigger neurotoxic and embryotoxic effects in animal experiments [9]. Although a number of relevant studies have been carried out, a connection between the increased absorption of aluminium from deodorants and Alzheimer's disease or breast cancer has so far not been demonstrated, which is not evidence that there is no actual connection, however [9].

The element silver has been declared a "toxic substance" by the World Health Organization [10]. Its absorption into the body is possible via the lungs, digestive system (water, food) or the skin. In vitro experiments by three research groups, whose work focused on silver nanoparticles on cells of mammals, discovered cytotoxic effects, such as compound fractures of the DNA molecule and cell death [11]. Moreover, silver can promote the formation of resistant strains of harmful microorganisms due to its antimicrobial effect, which may lead to antibiotic resistance [6; 12]. There is a lack of sufficient data material for a comprehensive risk evaluation regarding nano-silver. Thresholds or dose-response relationships are not sufficiently known [11].

Why risk judgment in the classroom?

Nanotechnology is an example of a controversially discussed topic, the controversies of which young people should and can also participate in. The goal of turning our school pupils into critical, competent and responsible citizens has been taken into account and incorporated into the syllabus development. The tasks and aims of the National Educational Standards [13; 14] in the subjects of biology and chemistry describe, among other things, the progress in many areas through the interplay between natural science findings and the technical application on the one hand, and the risks and dangers that should be recognised, evaluated and understood by the pupils on the other. Among other things, nanotechnology is listed here as an example.

The judgment competence in the National Educational Standards of biology [13] and chemistry [14] states that pupils should be able to recognize and evaluate biological and chemical issues in a range of contexts. Before pupils carry out the actual evaluation, they should clarify facts and describe any potential problems. As part of this, different perspectives should be incorporated (family, friends, perspective of individual groups of society, that of another culture, legislation, or nature). It is important not just to assume other peoples' judgments. Independent critical thinking regarding the controversial topics should be promoted, without placing blind trust in the opinions of experts. Understanding and tolerance for people with dissenting views should also be developed and promoted. Systematic evaluations of action options continue to be associated with ethical values. Finally, the pupils should be able to justify their own (as well as any other or dissenting) judgment in order to advocate their own point of view under consideration of individually and socially negotiable values [13]. Indeed, the focus of the present study lies on this precise quality of reasoning about a judgment made by the adolescents.

Risk Literacy as part of Science Literacy

Risk literacy, as an integral part of judgment competence, provides pupils with the prerequisites for a well-balanced and well-founded risk assessment. The concept of risk literacy has been discussed for some time in social scientific risk communication research. It focuses on risk issues as the decision and responsibility of the citizen [15].

> "The term "Risk Literacy" refers to the ability to form, on the basis of knowledge of the factually verifiable consequences of risky events or activities, the remaining uncertainties and other risk-relevant factors, a personal judgment of risks, which generally represents the values for the shaping of one's own life as well as the personal criteria to judge the acceptability of these risks for society" [15:53].

An individual is considered risk literate if they display the *motivation* to integrate their (sound) *knowledge* about the topic into their values, in order to arrive at a well-balanced risk assessment for themselves, society and the environment. Risks are better understood from a scientific perspective. Together with value attitudes and opinions, a scientific perspective can become the basis of an informed risk assessment [16].

The OECD PISA Framework [17] defines scientific literacy as the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology. These are prerequisites of a risk literate person, too. Science literacy requires the competences to explain phenomena scientifically, to evaluate and to design scientific inquiry, and to interpret data and evidence scientifically. Especially the evaluation of data, claims and arguments and the drawing of appropriate scientific conclusions are issues of science literate persons as well as of risk literate persons. Therefore, a scientifically and risk literate person can understand the science relevant to environmental and social issues, communicate clearly about the science and weigh possible risks, and make informed decisions about these issues.

The Risk Literacy Model (RLM)

The Risk Literacy Model (RLM) is a model that was developed to assess the quality of risk judgment reasoning by school pupils, and thus to evaluate the level of risk literacy. The RLM describes two routes for the cognitive processing of risk factors towards risk judgment: the *Central Route* involves a high degree of cognitive processing, which leads to a well-balanced risk judgment and enables high-quality risk judgment reasoning. Within the *Peripheral Route*, the degree of cognitive processing is low, leading to a temporary, peripheral risk assessment that is not well-balanced and cannot be justified very well. The two routes are based on the Elaboration Likelihood Model by Petty and Cacioppo [1].

How do people decide which of the two routes to take?

In depends on the following individual prerequisites of risk literacy (Figure 1): On the one hand, the prerequisites consist of the participants' interest in the subject to be evaluated (e.g. nano-technology) and the motivation to cognitively process this matter. Here, a high degree of intrinsic motivation is beneficial. Furthermore, the pupils should possess knowledge in regard to the matter to be judged. The *self-assessment of risk judgment* competence describes the reflection ability. Pupils should ask themselves if they have enough knowledge and information available to make a risk judgment. In addition, it is indispensable that the sources available are critically questioned with regard to their quality and credibility. The final prerequisite of risk literacy refers to *orientation knowledge*. Pupils have developed certain values during their lifetimes. They describe how they imagine their own lives and that of their society and the environment; now and in the future. Orientation knowledge is a crucial aspect of the RLM, because pupils should not disregard their own values and morals when it comes to making judgments.

What are the differences between the Central Route or the Peripheral Route?

If motivation, expertise, orientation knowledge and self-assessment of risk judgment competence can be classified as "high", then the prerequisites exist to take the Central Route. If the prerequisites of risk literacy do not exist or if components are missing, then the Peripheral Route is chosen (Figure 2). If a person is not interested or motivated regarding the subject , he or she will not want to process the matter cognitively. Most laypeople cannot or choose not to think about every risk in a detailed manner; they want to decide quickly whether a risk is acceptable or not. Cues as quick decision aids are looked for and discovered [16]. This so-called orientation towards cues can be multi-facetted and numerous. They also vary individually, so that an exhaustive list is impossible. An example of a cue would be the pure number of "pros and cons" available to the person. The attractiveness of the source, e.g. advertising, Facebook, but also the sender of the risk information, can also influence the risk judgment. If the person is lacking the necessary knowledge to evaluate a risk judgment, he/she will also use cues for orientation.

Here, surrendering responsibility to a higher authority (e.g. scientists, politics) is characteristic of the **Peripheral Route**. There is no individual cognitive processing to weigh the pros and cons of the risk. Instead, this "work" is left to higher authorities who are "trusted blindly" to have already evaluated the risk and taken any necessary measures. A further example of the Peripheral Route is adopting the risk judgment of other people. A successful risk evaluation should take into account the opinions of others, but a judgment should not be adopted without individual cognitive processing. If the risk judgment is made on the grounds of the above mentioned criteria, then it is only *temporary, peripheral* and possibly also *contradictory*. A risk judgment made in this way will not be easily justified. A high-quality risk evaluation is not present. According to the RLM, these criteria result in a low degree of risk literacy.

If the prerequisites of risk literacy are present, then the **Central Route** (Figure 2) can be taken. The high elaboration of this route is made possible by the person showing initial interest as well as motivation to deal with the subject. In addition, he or she possesses a certain degree of knowledge regarding the topic in order to consider the risk. The person can reflect whether his or her own knowledge is sufficient for this process, or whether important information on certain aspects may be missing. Furthermore, the sources of the information are examined and reflected upon in terms of quality and credibility, whether the (sufficient available information comes from reliable sources. If these criteria are met, then the Central Route can be taken by carrying out an *integration of factual knowledge and orientation knowledge*. By using factual knowledge, pupils can evaluate the opportunities and risks of the subject under consideration of their personal values. As such, they take account of the remaining uncertainties and the level of harm and probability of a potential risk. They carry out this process for themselves as well as (in a change of perspective) for society and the environment. At this point, a future teaching model comes into play, which provides a toolset to implement the process of integration of factual knowledge and orientation knowledge under the considerations mentioned. As a result of the process, the pupils are able to arrive at a *well-balanced risk judgment* for themselves, for society and for the environment. Based on the previous steps of arriving at a judgment of risk, the pupils are enabled to

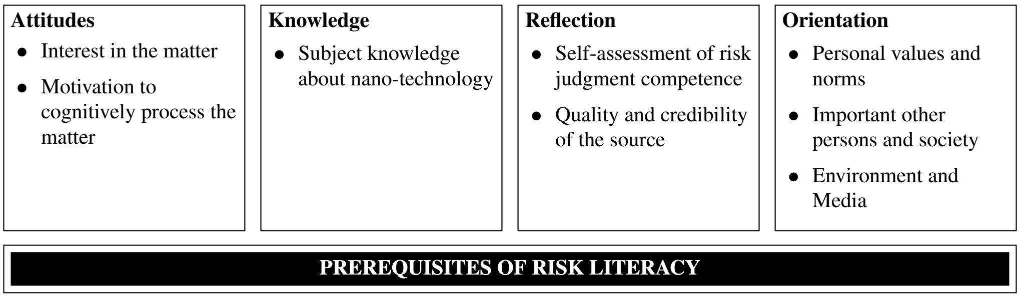

Figure 1. Prerequisites of risk literacy.

attach *high-quality risk judgment reasoning* to their judgments. This represents a high level of risk literacy.

Methods

The data are based on two surveys conducted in spring and autumn 2015. Target group are adolescents (N = 245), 152 males and 93 females visiting schools of Upper Secondary Level in Bremen (78%) and Lower Saxony (22%). The questionnaire is restricted to 12 Graders (age ranged from 16 years to 19 years, in average 17,5 years) in the natural science subjects of biology (82%) and chemistry (18%). The data collection to answer the research questions took the form of a one-off questionnaire, which was completed in writing by the pupils (time to fill in the questionnaire about 40 minutes). The questionnaire includes closed as well as open questions and is intended to measure risk propensity, risk literacy and the prerequisites for the pupils' risk literacy. The quantitative data are collected dichotomously (yes/no) or via a four-item Likert Scale, and were analyzed using frequency analysis. The open, i.e. the qualitative data are coded by means of qualitative content analysis according to Mayring [18] by two coders. The intercoder reliability is provided by the Cohen's kappa coefficient [19] and communicative validation.

Risk propensity was recorded before (closed question: "Do you take account of nanoparticle substances when buying deodorants/shower gels?") and after the information provided by the questionnaire (open question: "How will you act when next buying deodorant/shower gel?"). The prerequisites of risk literacy (interest, motivation, factual knowledge) were determined by closed questions prior to giving the information. The self-assessment of risk judgment competence was identified qualitatively from the open main task. The main task used to determine the degree of risk literacy was to write down their personal risk judgment after receiving the information about the potential risk of nanoparticles. By forming inductive and deductive categories according to Mayring [18], these data were analyzed and interpreted following the RLM [1].

Results

The participants' risk propensity

Pupils' risk propensity decreased considerably after receiving the information from the questionnaire. Seventy-four percent of the participants indicated at the beginning of the questionnaire that they do not take account of nanoparticle substances in deodorants or shower gels. After receiving the specific information about the possible risk of silver nano-particles, only forty-one percent of the pupils were clearly willing to take a risk. Here, the male pupils were more willing to take a risk after receiving the information (95%) than the female pupils (44%). This corresponds to the study by Kahan et al. [20]. Men evaluate the benefits of nanotechnology significantly higher than women. Women on the other hand perceive the risks more strongly.

In summary, it can be stated that the risk propensity of all participants with regard to nano-particle substances is high. Although a decrease in risk propensity was observed during the course of the questionnaire, just over half of the participants overall would continue to use deodorants/shower gels with nanoparticle substances. This is surprising, as more than ninety percent of the adolescents recognized a more or less high risk regarding nanotechnology (four-item Likert Scale). In relation to the strongly pronounce risk assessment, however, a high level of risk acceptance was observed. A risk that was perceived as low or slightly elevated was evidently not yet regarded as a matter requiring action by most participants in the study. According to Iden [21], with regard to cosmetic products containing nanoparticles, consumers obviously act in line with the motto: "If it's useful to me, I'm prepared to accept a risk."

On the other hand, it could be argued that the questionnaire, with its brief introduction of information and the contrasting opinion impulses already

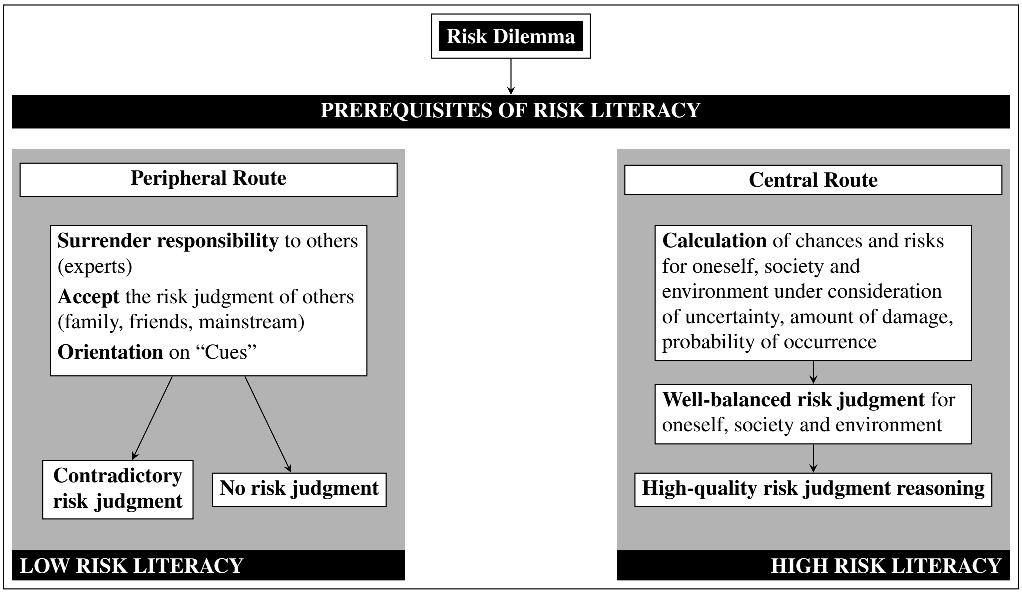

Figure 2. Risk Literacy Model (RLM) with Peripheral Route and Central Route.

led to a decrease in risk propensity in 33% of the cases. As the findings on risk literacy show, this decrease in risk propensity cannot be a product of an elaborate process. Rather, this represents a confirmation of risk judgment via the Peripheral Route. In most cases, laypeople do not wish to go through an effortful cognitive process of risk assessment. They look for efficient cues that enable them to make a quick decision regarding acceptance or aversion [16]. Parts of the questionnaire, which was specifically designed to provide a good combination of neutral, positive and negative arguments, may possibly have served as cues that were used by the pupils to arrive at a quick judgment.

The participants' risk literacy

The prerequisites of risk literacy were not fulfilled by the SPs in the study. This was to be expected, as the topic of nanotechnology and especially nanotechnology in everyday products had not been conveyed in detail to the participants of the two surveys, and therefore had no knowledge, interest or motivation available at the beginning of the questionnaire. The pupils who came close to fulfilling the factual knowledge criterion (five percent interested and motivated pupils who had at least a small amount of knowledge) were, however, not able to carry out a sufficient risk/benefit assessment, as they did not have a concept available to implement this. According to the RLM, this lack of prerequisites of risk literacy to arrive at a risk judgment results in the Peripheral Route. The prerequisite for a well-founded risk judgment is thus lacking. The results on the Central Route of the RLM show that the necessary categories ("Risks and opportunities: consideration for oneself"; "Risks and opportunities: considerations for society and the environment"; "Degree of harm and occurrence probability"; "Consideration of uncertainties") were not served, which is why the Central Route had to be rejected by all 245 participants. In principle, the categories represent the definition of risk literacy.

In summary, it can be stated that, as expected, the pupils did not (could not) display risk literacy, as the topic of nanotechnology is not taught in lessons and that also only twenty-three percent of the pupils indicated any form of everyday experience in this regard. Interest, motivation and knowledge are thus difficult to develop and maintain. The ability to reflect is also not pronounced enough, presumably because this area of competence has not (yet) been established in lessons. As a result, there is no elaboration; instead, the pupils focus on peripheral cues to arrive at a judgment. Good risk judgment reasoning is thus excluded and the process ends with a non-existent or low level of risk literacy.

Due to the frequencies of category selection resulting from contrasting statements of the participants, different concepts of the Peripheral Route of the RLM will be discussed in the following. In this study, the most common concept of the participants is the "handing over of responsibility" (29% of all pupils). They rely on the regulation of nanomaterials in everyday products by higher authorities, and arrive in most cases at the conclusion that the risk cannot be high, otherwise there would be corresponding bans. Despite this "blind trust", their risk judgments are controversial in many cases in this respect, as was previously mentioned. The participants have no knowledge regarding how risk research and risk regulation work. Specifically in regard to new technologies, not only specialist knowledge, but also this type of knowledge is important for citizens to have, as this makes it clear that definitive regulations are not yet possible and that they must therefore judge for themselves. By handing over responsibility, they avoid the desired cognitive process of making risk judgments. The following attitude is noticeable in many statements within this category: the participants do not demand evidence from research that the risk assumption is unjustified, but rather they demand evidence from research that nanotechnological substances in everyday products are harmful before they consider potential risks.

The second most common concept in the Peripheral Route of this study is the "Adoption of risk judgments by others" (22% of all participants). Although risk communication research certainly welcomes citizens orienting themselves towards their environment in terms of risk assessment, and views this as unavoidable [16], judgments should be formed individually not be adopted by others.

Discussion

In order to develop and promote risk literacy, prerequisites of risk literacy must be addressed, according to the RLM. That means that firstly the interest and motivation of young people regarding the topic of risk must be encouraged through suitable lessons. The adolescents must be taught sound knowledge on the scientific background of the risk subject. With regard to nanotechnology and the rapidly advancing research on the topic, as well as the immediate proximity to consumers, the topic should be included in the science syllabuses of schools of the Upper Secondary Level. The development and encouragement of interest and motivation as well as special subject-related knowledge fulfill two essential prerequisites of the RLM [1]. However, not only chemical or biological foundations should be created, but the transfer of knowledge about procedures and regulations of risk research and policy is also essential. In this way, the concept of "Handing over responsibility" in the Peripheral Route can be decimated when individuals understand that due to contrasting research findings, there can be no definitive regulations or "right answers". The necessity of one's own risk acceptance or aversion has to be made clear.

As the risk perception of laypeople is a multifaceted and complex process [15], the incorporation of factual knowledge enables a more objective risk assessment [16], which is less geared towards peripheral cues. To enable school pupils to assess whether their knowledge about the judgment subject matter is sufficient enough to make a well-founded risk judgment, their ability to reflect must be trained at the same time. If this prerequisite is also present, then the factual knowledge can be used, under consideration of individual values, to assess opportunities and risks.

This is where a future model comes into play. The school pupils should be given a "tool box" with which to carry out a good assessment within the meaning of the RLM. This model can represent a kind of route plan, which guides the pupils towards the Central Route of the RLM and leads them to the goal step-by-step. The goal is a well-balanced and well-founded risk judgment for the individual and for society and the environment. In addition, it should be conveyed that a change of perspective is necessary. Pupils learn what risk literacy is, why it is necessary and how they can acquire this competence.

In addition, important and in the sense of the youth relevant tasks are required. Therefore, at the Institute for Science Education, Department of Biology Education we develop such tasks and educational concepts within the project NanOpinion. Examples of such tasks are "What is the price of a good smell?" (decision making in respect to deodorants with nanoparticles) or "Small particles – big effect?" (decision making about nanoparticles in effluent sludge). In the three-years lasting project NanOpinion we hope to identify building blocks to promote risk literacy.

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