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On the Risk Literacy of Young People in the Context of Nanotechnology

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Abstract
This study is concerned with the risk literacy of young people in the context of nanoparticles in everyday products. A model is developed for use in evaluating the competence of school pupils in risk assessment: the Risk Literacy Model (RLM). Building on the findings from risk research and the social psychological Elaboration Likelihood Model (ELM) by Petty and Cacioppo [1], 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). The RLM assumes that sufficient knowledge and motivation (like the ELM) and reflection ability represents the prerequisite for information processing via the central route. Using a sample of N = 132 school pupils from upper secondary level the prerequisites of central information processing, risk propensity and risk literacy were measured using a questionnaire with closed and open response formats. Risk propensity was measured before and after presentation of a short scientific text and several evaluative statements by institutions or fictitious individuals on nanoparticles in everyday products. With the help of the RLM, the risk-related judgements of the pupils were then categorised as to whether they are based on central or peripheral information processing.The results show that none of those questioned fulfil the prerequisites for central processing of information about nanoparticle-containing everyday products. Accordingly, the analysis of the quality of risk judgements on the basis of the RLM also showed that in all cases, the peripheral route was used to make risk judgements. The degree of risk literacy was thus very low. However, the risk propensity of those questioned decreased considerably through the reception of the information presented. It is recommended that risk literacy – as an aspect of assessment competence – be more strongly promoted in natural science lessons. In order to do so, it is necessary to develop tasks regarding risk assessment as well as procedures pupils can use to find solutions.

1. Introduction
Nowadays nanomaterials are used in almost all areas of life. Caused by the greatly enlarged surface of nanomaterials they are significantly more reactive than elements on micro- or macroscopic level. The risk-research is lagging behind the production and marketing of nanotechnology [2]. The risk of toxicity as well as the exposure is still difficult to assess or to prove [3]. Therefore it is even more important that consumers be informed of this circumstance of uncertainty, so that they can come to an informed personal decision on how to deal with unknown risks. In this study deodorants and shower gels are examined as an example of nanoparticle-containing ingredients. The main nanoparticulate ingredients of these products are aluminium chloride/aluminium chlorohydrate and nanosilver. In recent years both nanomaterials fell into disrepute for being triggers of Alzheimer's disease, breast cancer and antimicrobial resistance. Despite relevant studies, the evidence for a comprehensive risk assessment is unclear. In addition, thresholds or dose-response relationships are known insufficiently [4]. Nanotechnology is an example of a controversial issue, at which controversies also young people should be able to participate in. The aims and objectives of the educational standards in biology and chemistry describe, that the advance scientific and technical knowledge, as well as their risks and threats are to be identified, assessed and controlled by the pupils. Different perspectives should be involved (family, friends, individual groups of society, a different culture, the legislation, or the dimension of nature). Independent, critical behaviour, with respect of controversial issues, should be encouraged without blindly adopting expert opinions. Systematic reviews of options for action will

continue to be related to ethical values. Finally, pupils should be able to justify their own judgment, in order to represent their own point of view, taking into account individual and socially negotiable values [5]. The focus of this study is precisely on this very quality of justifications of risk-related judgments. Risk-literacy provides pupils the prerequisites for a well-weighed and well-founded risk judgment with the goal to act as responsible citizens [6]. Risk-literate is someone who has the motivation to integrate knowledge with values to get to a well-weighed risk judgment for themselves, the society and the environment. From a scientific perspective risks can be understood better. The scientific perspective combined with values and opinions creates the basis of an informed risk-decision [7].

2. Theoretical frame

The Risk-Literacy-Model (RLM) allows the assessment of pupils´ risk-judgments and therefore their degree of risk-literacy. The RLM describes two ways of cognitive risk-related information processing: the *Central Route* shows a high level of information processing, which leads to a well-weighed and well-founded high quality risk-judgement (Figure 1). Within the *Peripheral Route,* the degree of cognitive information processing is low and leads to a temporary and peripheral risk-judgment, which cannot be well-weighed and well-founded.

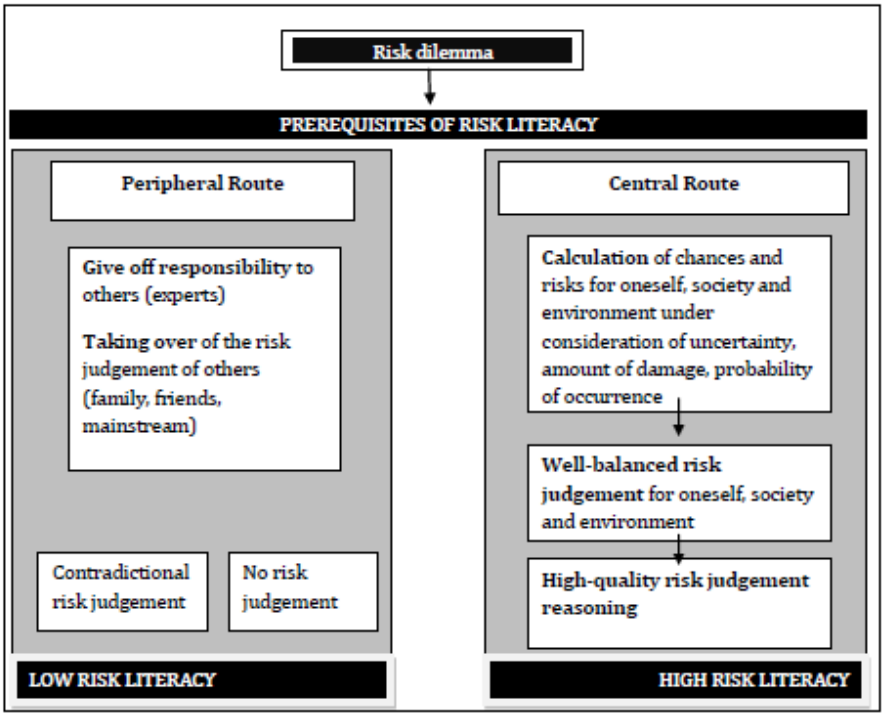

Figure 1: Risk-Literacy-Model (RLM) with Central Route (CR) and Peripheral Route (PR)

The two routes are leaned on the Elaboration Likelihood Model [1]. Which of the two ways is chosen depends on the individual pupils´ *Prerequisite of the Risk-Literacy* (Figure 2). The prerequisites are specific *Attitudes* like their interest in nanotechnology and motivation to fulfil the assessment task, and their *Knowledge* about the risk subject (nanotechnology). The *Self-Assessment of Risk Judgment Competence* describes the degree of pupils´ self-reflection-skills. They have to ask themselves, if they own enough quality information to render a judgment. Furthermore, it is indispensable that the available information is questioned on quality and seriousness. The last perception of risk-literacy is the *Orientation* and Contextual Knowledge into the risk-judgment. Pupils should take into account their personal values and morals.

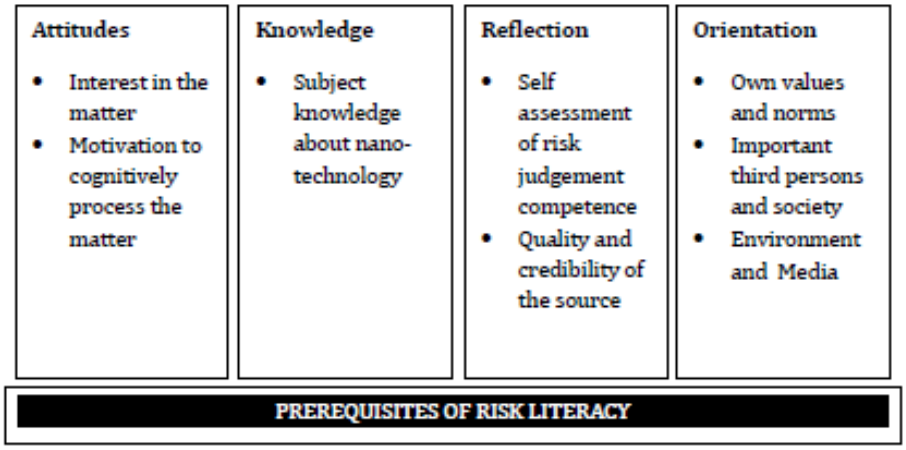

Figure2. Prerequisites of Risk literacy

If motivation, subject knowledge, contextual knowledge and the self-assessment of risk-judgment competence are high developed, the prerequisites are given to follow the *Way of the Central Route*. If the prerequisites of the risk-literacy are low developed, or components are missing, the *Way of the Peripheral Route* will be more likely. A non-interested, non-motivated person will not be willing to deal with the subject cognitively. The risk-judgment will be rendered on peripheral "cues". This orientation on cues is numerous and can be of many different natures, thus there can´t be a closing list. An example for a cue is the pure number of pro and con arguments about the subject, that a person is given. The attractiveness of the source of information, for example publicity, facebook, but also the transmitter of the risk-subject can influence the risk-judgment. If subject-knowledge is missing, the risk-judgment will also be oriented and based on peripheral cues. These risk-judgments are temporary, peripheral and sometimes even contradictory.

3. Research design

The participants of the study are pupils (N=132) at schools of the Upper Secondary Level in Bremen. For data collection the participants filled in a one-off questionnaire with open and closed items to measure risk propensity, risk literacy and the prerequisites for the pupils' risk literacy. The quantitative data were collected dichotomously (yes/no) or via a four-item Likert Scale, and were analysed using frequency analysis. The open, i.e. the qualitative data were coded according to the paradigm of the Qualitative Content Analysis [8]. The reliability was provided by the Cohen's kappa coefficient [9].

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 judgement competence was identified qualitatively from the open main task. The main task of the participants used to determine the degree of risk literacy was to write down their personal risk judgement after receiving the information. By forming inductive and deductive categories [8], these data were analysed and interpreted following the RLM.

4. Findings

4.1 The participants' risk propensity

The risk propensity decreased considerably after receiving the information from the questionnaire. 74% of 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 information, only 41% of the

participants were clearly willing to take a risk. Here, the male pupils were more willing to take a risk after receiving the information (59%) than the female pupils (44%). This corresponds to the study by Kahan et al.[10]. Men judge the benefits of nanotechnology significantly higher than women. Women in turn perceive the risks more strongly.

In summary, it can be stated that the risk propensity of the participating pupils with regard to nanoparticle substances is high. Although a decrease in risk propensity was observed during the course of the questionnaire, just over half of the SP overall would continue to use nanoparticle substances in their deodorants/shower gels. This is surprising, as 97% of SP recognised a more or less high risk regarding nanotechnology. 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 raised was evidently not yet regarded as a matter requiring action by most SP in the study. According to Iden [11], 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 information introduction and the contrasting opinion impulses already led to a decrease in risk propensity in 33% of 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 judgement 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 [7], 2009). 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 participants to arrive at a quick judgement.

4.2 The participants' prerequisites of risk literacy

In summary, the prerequisites of risk literacy were not fulfilled by the participants. They had only low knowledge, interest or motivation for cognitive elaboration at the beginning of the questionnaire. The few participants who came close to fulfilling the factual knowledge criterion (5% interested and motivated participants 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.

4.3 The participants' risk judgement

According to the RLM, this lack of prerequisites of risk literacy to arrive at a risk judgement results in the Peripheral Route. The prerequisite for a well-founded risk judgement 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 participants.

In summary it can be stated that, the participants did not (could not) display risk literacy, as the topic of nanotechnology is not taught in lessons and that also only 23% of 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 participants focus on peripheral cues to arrive at a judgement. Good risk judgement reasoning is thus excluded and the process ends with a non-existent or low level of risk literacy.

5. Discussion

In order to develop and promote risk literacy the 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 SPs must be taught sound knowledge on the scientific background of the risk subject matter. 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 fulfil two essential prerequisites of the RLM. 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 multi-faceted and complex process [6], the incorporation of factual knowledge enables a more objective risk assessment [7], which is less geared towards peripheral cues. To enable pupils to assess whether their knowledge about the judgement subject matter is sufficient enough to make a well-founded risk judgement, 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.

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