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Small Particles – Big Effect?
A Teaching Unit to Foster Students' Risk Literacy Regarding Nanotechnology

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Abstract

Nanotechnology is a key technology of the 21st century. Due to the increasing use of nanomaterials in almost all areas of life it becomes more and more important to consider the risks and benefits caused by these nanomaterials regarding to oneself, the society and the environment. However, the risk-research is lagging behind the production and marketing of nanotechnology. One precondition for a responsible acting regarding nanotechnology is the 'risk literacy'. To promote students' risk literacy, the six-hours lasting teaching unit Small particles – Big effect? is developed, conducted and evaluated in the outreach lab Backstage Science (BaSci Lab) at the University of Bremen. Target groups are 10th to 12th graders (N=57) of six school classes. The learning effectiveness of the teaching unit regarding the prerequisites of risk literacy (attitudes, subject knowledge, willingness of reflection, orientation knowledge) is measured by a questionnaire in pre-post-design. Furthermore, the students write risk judgements, which are evaluated based on the Risk Literacy Model (RLM) [1]. The findings demonstrate particularly an increase of subject knowledge regarding nanotechnology. The attitudes are on a relatively high level (interest: average 3.40; motivation: average 3.87; 5pt-Likert-Scale). Orientation knowledge (own values and norms: average 4.06; orientation on others: average 2.87; 5pt-Likert-Scale) and the willingness of reflection (self-assessment of own risk judgment competence: average 3.96; quality and credibility of sources: average 3.30; 5pt-Likert-Scale) are on a relatively high level too. Regarding the risk judgements, the students especially pursue the Peripheral Route of the RLM, the risk literacy of the students therefore tends to be low and should be further trained.

Keywords: *nanotechnology, risk literacy, risk judgement, outreach lab, biology education;*

1. Introduction

Due to the rapid development of nanotechnology the use of nanoparticles for consumer products is increasing. Especially silver-nanoparticles are used frequently due to their antimicrobial properties. Nanoparticles can be significantly more reactive in comparison to the bulk material because of a greater surface to volume ratio [2; 3]. Because of their small size nanoparticles even can enter cells and may cause effects within these cells [3]. However, the possible effects of nanoparticles have not been sufficiently researched yet. Therefore, they constitute a potential risk to oneself, the society and the environment, which is difficult to assess by laypersons. One precondition to deal responsibly with new technologies is the 'risk literacy'. Risk literacy is the ability to understand, evaluate and reflect about a possible risk. It enables laypersons to make a well-founded decision.

2. Theoretical Background

The quality of students' risk judgement and the degree of students' risk literacy can be described by the Risk Literacy Model (RLM, figure 1) [1]. The RLM is based on the social psychological Elaboration Likelihood Model and concepts from risk research [4; cf. 5]. The RLM analyses the cognitive processing regarding a risk-dilemma and describes two ways, which lead to a risk judgement. The *Central Route* shows a high level of cognitive processing, which leads to a high-quality risk judgement. Within the *Peripheral Route* the cognitive processing is low and leads to a temporary or unstable risk judgement, which cannot be well-weighed or even to no risk judgement. Which route is chosen depends on the students' *Prerequisites of Risk Literacy* (attitudes, subject knowledge, willingness of reflection, and orientation knowledge). If the prerequisites of risk literacy are high developed the likelihood increases that students pursue the Central Route. Whereas it is more likely that students choose the Peripheral Route if the prerequisites are on a relatively low level or elements are missing.

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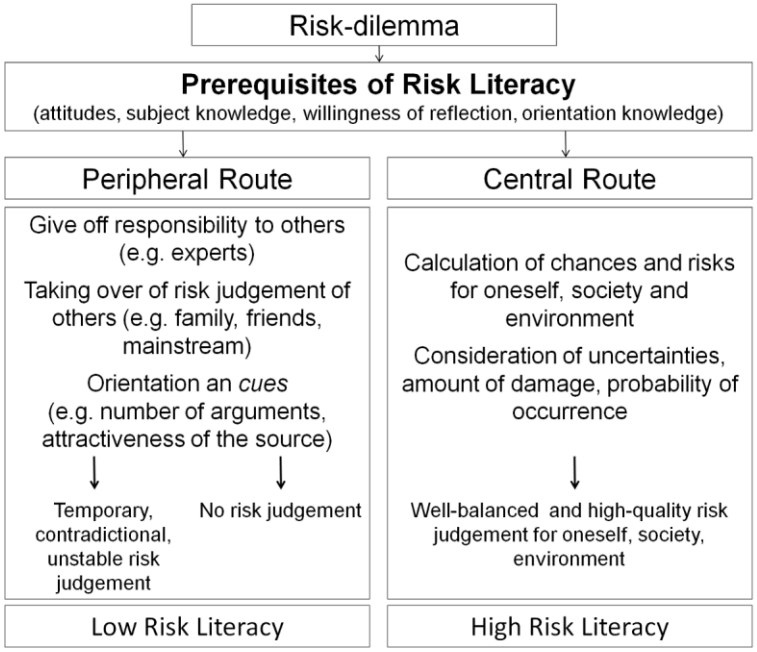

Figure 1: Risk Literacy Model [based on 1].

3. Teaching Unit and Research Questions

The objectives of this study are the development, conduct and evaluation of the six-hours-lasting teaching unit *Small particles – Big effect?.* The goal is the promotion of students' risk literacy regarding silver-nanoparticles in consumer products. The students are confronted with the nanotechnological risk-dilemma: *Silver-nanoparticles in sport shirts – Curse or blessing?*. They conduct experiments in connection with size, properties, reactivity of nanoparticles, synthesis of silver-nanoparticles, effects of silver-nanoparticles on fermentation process of yeast. In addition, training materials regarding orientation knowledge and reflection are provided. Furthermore, the students get a guideline for judging risks. The questions of research refer 1) to the different emphasis of prerequisites of risk literacy and 2) to cognitive processing of the risk-dilemma, and whether the students pursue the Central or the Peripheral Route.

4. Design of Research

Target groups are 10^{th} to 12^{th} graders (N=57, male=33, female=24; age: average 16,5) of six school classes. To measure the different emphasis of prerequisites of risk literacy a questionnaire in pre-post-design is used. The questionnaire contains mostly closed items (answer format: 5pt-Likert-Scale), which refer to the prerequisites [1. attitudes (scale *interest*, 10 items α=.885; scale *motivation*, 5 items, α=.901), 2. willingness of reflection (scale *quality and credibility of sources*, 4 items, α=.876; scale *self-assessment of own risk judgement competence*, 4 items, α=.720), 3. orientation knowledge (scale *orientation on others*, 4 items, α=.778; scale *values and norms*, 6 items, α=.815)]. Closed questions are analysed by using the software SPSS (means, SD, t-tests). Answers to open questions relating to students' subject knowledge (4. *subject knowledge*, 3 open questions) are coded according to the paradigm of Qualitative Content Analysis [6]. The reliability is provided by the Cohen's kappa coefficient [7].

Furthermore, the students have to write risk judgements in respect to the nanotechnological risk-dilemma and to justify their decision. To measure the degree of students' risk literacy the risk judgements are analysed based on the RLM [1] using Qualitative Content Analysis [6]. The risk judgements are analysed by using the software MAXQDA. The reliability is provided by the Cohen's kappa coefficient [7].

5. Findings and Discussion

5.1 Prerequisites of Risk Literacy

The findings demonstrate particularly a significantly increase of *subject knowledge* regarding nanotechnology (table 1). Based on the results we indicate that the students had very little previous knowledge (score 0.96/highscore 9). This is not surprising considering that this topic is not integrated in the educational standards of biology [8]. Further on, 24.56 % of the students state that they never heard before about nanotechnology. During the teaching unit the students gained a detailed view on this topic as the analysis of the data revealed (score 5.96/highscore 9).

Table 1: Results of the prerequisite subject knowledge (pre-post). Scores (highscore 9), standard deviations and significances are presented. Cohen´s kappa coefficient: 0.91.

scale	**score** (pre)	**SD** (pre)	**score** (post)	**SD** (post)	***p***
subject knowledge	0.96	0.78	5.96	2.01	0.000

We identified only a little increase of the other three prerequisites of risk literacy (table 2). At the end of the teaching unit the attitudes are on a relatively high level (*interest*: M 3.40; *motivation*: M 3.87). The willingness of reflection (*quality and credibility of sources*: M 3.30; *self-assessment of own risk judgment competence*: M 3.96) and the orientation knowledge (*own values and norms*: M 4.06; *orientation on others*: M 2.87) are on a relatively high level, too. Looking at the items of the scale *self-assessment of own risk judgment competence* individually, the findings indicate a significantly increase regarding the competence of risk judging (item *'I find it easy to judge about a risk.'*). Thus, after participation in the teaching unit the students feel more comfortable to judge about a risk (pretest: M 3.39/SD 1.00; posttest: M 3.84/SD 0.80; *p* 0.000). The combination of improved subject knowledge and the given guideline for judging risks might have a positive effect on the students' self-assessment of risk judgment.

Assuming that own values and norms are relatively stable attributes, no influence of the teaching unit was expected regarding the scale *values and norms*. However, the findings demonstrate a significantly increase (pre-post). Taking a closer look at the items individually, it becomes apparent that items which pick up the topic nanotechnology (e.g. *'The topic nanotechnology concerns me personally'.* pretest: M 3.11/SD 1.06; posttest: M 3.74/SD 1.22; *p* 0.000) lead to an increase of this scale. This increase can be explained by the fact that the students had little prior knowledge. During the teaching unit the students could gain a detailed view about the relevance for their own person.

Table 2: Results of the prerequisites attitudes, willingness of reflection and orientation knowledge (pre-post). Means, standard deviations and significances are presented.

scale	**M** (pre)	**SD** (pre)	**M** (post)	**SD** (post)	***p***
attitudes					
interest	3.27	0.70	3.40	0.72	0.088
motivation	3.75	0.68	3.87	0.79	0.134
willingness of reflection					
quality and credibility of sources	3.29	0.88	3.30	0.90	0.846
self-assessment of own risk judgement competence	3.89	0.54	3.95	0.60	0.455
orientation knowledge					
orientation on others	3.01	0.52	2.87	0.76	0.105
values and norms	3.84	0.40	4.06	0.68	0.003

5.2 Students' Risk Judgements

The number of mentioned categories proves that the students serve more often categories of the Central Route (N=82, table 3) compared to the Peripheral Route (N=11, table 4). Nevertheless, at the end of the teaching unit none of the students can be assigned to the Central Route. Because according to the RLM, the students have to mention ALL deductive categories of the Central Route to be assigned to this route. Therefore, the cognitive processing of the risk-dilemma and thus the students' risk literacy is too low to be assigned to the Central Route.

Table 3: Numbers of mentioned categories of the central route in students' risk judgments. Cohen´s kappa coefficient: 0.70.

categories of the central route	derivation	number
chances & risk for oneself	deductive	1
chances & risk for the society	deductive	0
risks for the environment	deductive	27
amount of damage & probability	deductive	20
consideration of uncertainties	deductive	25
suggestions for improvement	inductive	6
information	inductive	1
self-assessment	inductive	2
total nominations		**82**

Table 4: Numbers of mentioned categories of the peripheral route in students' risk judgments. Cohen´s kappa coefficient: 0.70.

categories of the peripheral route	derivation	number
give off responsibility	deductive	0
taking over of a risk judgement	deductive	1
contradiction	deductive	2
avoidance of risk	inductive	8
total nominations		**11**

Within the Central Route the students mostly address the categories **consideration of uncertainties** (*'You cannot fully assess the risk, because there are still many ambiguities.'* student_19) and **risks for the environment** (*'For the most part the use of silver-nanoparticles has negative consequences like […] killing bacteria and thus the restriction of plant growth.'* student_28). The uncertainties and the need for further research especially regarding the long-term consequences in the field of nanotechnology were addressed very precisely in the teaching unit. It can be explained by the ecological focus of the teaching unit that the students mainly name the risks for the environment.
Within the Peripheral Route the most mentioned category is **avoidance of risk** (*'In conclusion, I would say that the uncertainty, until proved otherwise, prevents me from using products containing silver-nanoparticles.'* student_18). In case of personal uncertainty, the students prefer the choice of 'zero-risk' rather than dealing cognitively with the risks and benefits.

6. Conclusions

The findings of this study prove that the students' prerequisites of risk literacy can be increased by participating the teaching unit *Small particles – Big effect?*. However, the analysis of the risk judgements demonstrates that none of the students can pursue the Central Route completely. It follows that the students' risk literacy is low. Overall, only a few categories of the Peripheral Route are served by the students. The number of served categories of the Central Route is much higher. Nevertheless, all students are assigned to the Peripheral Route as long as they do not take all deductive categories of the Central Route into account in their risk judgements.
To analyse the degree of risk literacy more in detail, the RLM has to be revised by formulating different levels within the Peripheral and the Central Route. These complexity levels will be tested empirically within a future research project.

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