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Competencies: The Assessment of Scientific Thinking as Metascientific Reflection (including example items for secondary school, grade 12)
Status: 2017

Kerstin Oschatz, Jochen Kramer and Wolfgang Wagner

LIfBi
LEIBNIZ INSTITUTE FOR EDUCATIONAL TRAJECTORIES

Leibniz Institute for Educational Trajectories (LIfBi)
Wilhelmsplatz 3, 96047 Bamberg
Director: Prof. Dr. Sandra Buchholz
Executive Director of Research: Dr. Jutta von Maurice
Executive Director of Administration: Dr. Robert Polgar
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Kerstin Oschatz, Jochen Kramer, Wolfgang Wagner

e-mail address of the author:
kerstin.oschatz@uni-tuebingen.de

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The Assessment of *Scientific Thinking*

The aim of scientific thinking (*Wissenschaftspropädeutik)* is one of the three main goals of higher secondary school in Germany (KMK, 1995). The German concept *Wissenschaftspropädeutik* can be best translated as preparation for a life with and in science and comprises of a highly complex theoretical construct that is deeply rooted in German *Bildungstheorie* (systematic, scientific examination of education, its goals personal, social and economic relevance; sometimes described as *philosophy of education*) and a humanistic understanding of education. In its core the term *Wissenschaftspropädeutik* means the preparation of young individuals for a sophisticated handling of science itself as well as the preparation for a lifetime of learning and operating in a society, deeply dependent on science and its outcomes (Huber, 2000). Therefore the term *scientific thinking* was chosen as a translation of the German concept *Wissenschaftspropädeutik*. So far only few studies have attempted to examine whether the central aims of scientific thinking are achieved at the end of upper secondary school or what importance this might bear in relation to further personal and professional development like career choice or achievement (Trautwein & Lüdtke, 2004, 2007; Ramseier et al. 2005; Eberle et al., 2008; Durrer & Heine, 1995). One reason for this lack of research roots is an absence of adequate instruments to measure *Wissenschaftspropädeutik* / scientific thinking (Dettmers et al., 2010). Therefore, the assessment of scientific thinking was incorporated as one objective of the National Educational Panel Study (NEPS) for pupils in their final year at higher secondary school (*Gymnasium*). This paper presents a summary of the main framework and example items for the scientific thinking test for pupils in grade 12 of upper secondary school (*Gymnasium*).

1 Characteristics of the NEPS Framework of *Wissenschaftspropädeutik*

The German concept *Wissenschaftspropädeutik* does not only mean the preparation of pupils through the teaching of scientifically legitimate knowledge and scientifically developed techniques but incorporates the reflection of scientific ideas and the factors determining its development (Hahn, 2013; Benner, 2002). The conceptualisation of scientific thinking competence in NEPS was based on the understanding that this competence does not only serve as a preparation of future scientists for their academic experiences but also as a preparation of future laymen for life (Huber, 2005). In this modern understanding, scientific thinking pronounces the ability to orientate oneself in the system ‘science’. Here a substantial overlap with research areas like Nature of Science, Scientific Inquiry or Scientific Reasoning are visible.
Traditionally, scientific thinking (*Wissenschaftspropädeutik)* not only drew on natural sciences but on the comparison of all academic disciplines (Hahn, 2013; Hentig et al., 1971). Therefore,

it is often stressed that only through their comparison the potentials and limitations of different scientific perspectives become visible. In credit of its broad and complex nature, scientific thinking (*Wissenschaftspropädeutik)* has been described as "a concept without edges" (Griese, 1983, 257).

Due to the broadness of the concept and with regard to limited testing time, the NEPS approach concentrates on one key component of scientific thinking. Based on a popular structure implemented by Huber (2009, 1997) scientific thinking *(Wissenschaftspropädeutik)* can be divided into three subsequent tiers: "the learning and practicing of science (basic terms, methods)", the learning and practicing "through science (a habitus of questioning and reasoning)", and the learning "about science (critical reflection of the bigger picture)" (Huber, 1997, 348, *translated by the authors*). Even though these three tiers handle science from different angles, they are subsequent and interrelated. Huber located the reflection of scientific ideas regarding their genesis, limitations, and consequences on the third tier, which can be understood as the most complex level. This tier was chosen to be the centre of the NEPS assessment of scientific thinking competence as "metascientific reflection". Figure 1 gives an overview of the three tiers according to Huber (1997) modified by Müsche (2009).

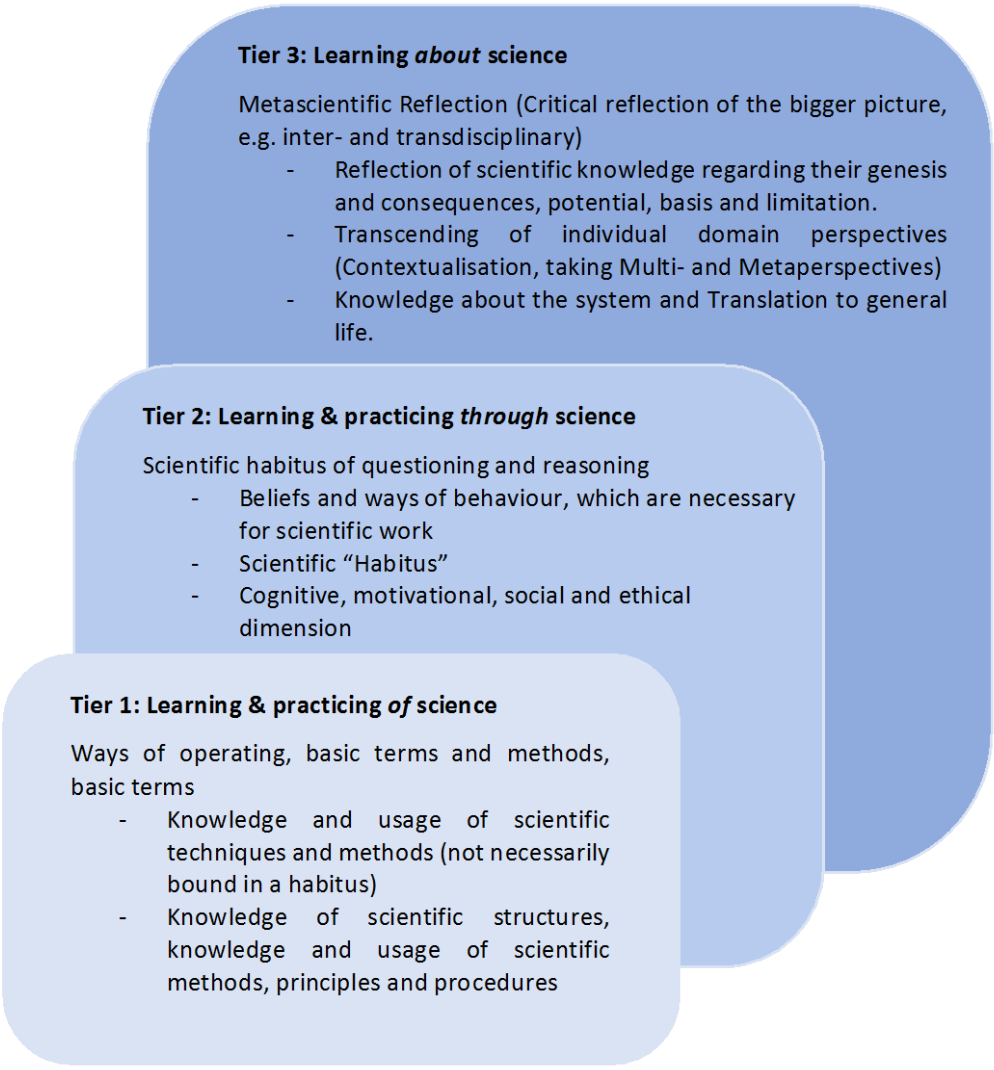

Figure 1. Tiers of scientific thinking (Wissenschaftspropädeutik), Müsche 2009, modified of Huber (1997), translated by the authors

During test development, the NEPS framework was based on a translation of the popular three tiers into a normative structural model with three dimensions by Müsche (2009). Drawing on Huber, Müsche defined the dimensions (1) metascientific knowledge, (2) understanding of methods, and (3) metascientific reflection. The third dimension is comprised of five sub competences:

1. To contextualise scientific ways of generating knowledge, scientific claims and results in a bigger picture
2. To reflect on scientific ideas regarding their foundation, potential, the circumstances of their development and consequences
3. To judge scientific processes of knowledge generation and potential using methodological knowledge
4. To question and test the validity, explanation power and limitations of scientific claims
5. To contrast inconsistent knowledge and contradictory theoretical approaches (Müsche, 2009, 78).

1.1 The NEPS Framework of Metascientific Reflection

According to NEPS, every layperson is dependent on their ability to engage in metascientific reflection to orientate herself in a world shaped by science and needs the competence to reflect on scientific ideas and the factors determining their development. This becomes particularly relevant when individuals are faced with conflicting scientific claims regarding important topics of common interest to society. Therefore, the sub competence "contrasting inconsistent knowledge and contradictory theoretical approaches" was chosen as the center point of the test construction in the NEPS framework. As this sub competence requires knowledge within the other four sub components, choosing it as the center point allowed to incorporate all sub competences comfortably. The test construction was based on five vignettes regarding scientific controversies on problems of a wider interest for society. This focus enabled NEPS to draw the understanding of scientific thinking (*Wissenschaftspropädeutik)* as preparation of future laymen for life (Huber, 2005) into the centre of the test.
Each vignette and subsequent items lie in a distinctive scientific domain and focuses on different perspectives of metascientific reflection (regarding research methods; the generation, processing or interpretation of data; historical, ethical or society-related aspects of the conflict). The scientific thinking test consists of 32 items arranged in five controversies.

1.2 Item Format

The test is composed of stimulus texts, describing the scientific controversy, and claims regarding central aspects of the controversy. Items have to be answered in a forced choice format (correct vs incorrect). All controversies focus relevant, complex, and multicausal problems of public interest. The length of the texts varies between 300 and 400 words and can incorporate graphs or tables. In the stimulus texts a short introduction into the topic is given, the controversy between two scientists is explained and the positions of the researchers are described. The texts give all necessary information for solving the items and pose a judgement on the claims made by two fictional scientists in the controversy. All five subcomponents named by Müsche (2009) are covered across the items. To be adequate for testing the abilities of future competent laypeople, the items do not require it to plan complicated scientific studies or evaluate scientific decisions, but to reflect on scientific theories and stances.

1.3 Assessment conditions and general remarks

The test takes 30 minutes. It is essentially unidimensional and does not intend to measure scores on a sub competence level. All items were carefully constructed to be solvable by competent scientific laypeople, therefore no specific scientific knowledge is necessary to solve the items.

The controversies are being described as directly discussed by scientists and are not based on the translation through a third person or the interference of media.

2 The NEPS metascientific reflection test – Item examples

The following figure shows a typical vignette with item examples.
Please note that the items presented in this report have been removed from the test for different reasons, for example, better items existed for the scientific discipline or the item discrimination was not good enough.

CONTROVERSY 1: PESTICIDES

Worldwide pesticides are used in agriculture to minimize and control pests or weeds. In a TV-show, experts discuss the future usage of pesticides regarding scope and range.

Biologist A militates against the usage of pesticides, whereas Biologist B advocates their use.

Biologist A has been a Professor for Biology in Berlin for 30 years and works for the EU-Authority for food safety. She is warning the public against the usage of pesticides. Particularly the slow and deferred effects of pesticide residues in food can be dangerous. There are assumptions, that these residues promote the onset of cancer, impair the immune system and increase the risk of an onset of Parkinson's disease. Even though numerous studies exist, there is a considerable lack of longitudinal studies and a deficit on studies regarding the interdependence of several active ingredients. Due to these reasons research projects regarding these factors were currently receiving great financial support through EU-research programs. As long as the data of these projects is not available and worries regarding long term effects of pesticides cannot be cleared, the risks of the usage of pesticides remains undeterminable and should therefore be avoided, states Biologist A.
Biologist B has been a research assistant at the Biology department of a German university for 10 years. She regards the claims of Biologist A as not justified, as pesticides have been used in Germany to control pests for more than 50 years. She suspects dangers and risks through the reduction of pesticides, and claims these risks have not been accounted for so far. Thereby currently controlled pests could multiply unimpededly and cause new problems. As an example, she refers to the intense increase of the bank vole – a specific kind of mouse – and the interrelated increase in hantavirus infections in the South of Germany. This dangerous viral disease is transmitted from mice to humans and can be lethal. According to Biologist B, the study of one of her PhD-students shows that the intensive increase of bank vole is based on the decreasing usage of pesticides against rodents. Unfortunately, this branch of research would, according to Scientist B, not receive sufficient funding.

CONTROVERSY 1: PESTICIDES

The scientists represent conflicting claims regarding the usage of pesticides. To evaluate, how well the positions are justified, it is important to analyze each position precisely. Below you will find several statements regarding central aspects of the controversy, which you should review. The statements can regard possible sources of the controversy, the different research methods used, or explanations and interpretations of the scientists.

Below you will find several statements regarding central aspects of the controversy pesticides. Please decide, whether the statements regarding the controversy are correct or incorrect.

*Please make **one cross per row**.*

	correct	incorrect
a) One reason for the controversy is that Biologist A is ignoring the problems that are induced through the dismissal of pesticides.		X
b) The position of Biologist B should be regarded more highly, as she grounds her position on data, while Biologist A only emphasises the lack of data.		X
c) The controversy would not exist, if Biologist A would have known the new study regarding the increase of bank vole that Biologist B refers to.		X
d) The controversy would even still exist, if Biologist B would have ascribed more importance to the problems attached to the usage of pesticides.	X	
e) One reason for the controversy is based on the fact that Biologist A refers in her statements to all of Europe, whereas Biologist B refers to the usage of pesticides in Germany.		X
f) It is unlikely that Biologist A would revise her opinion, if she would read the new study regarding the increase of bank vole,	X	
g) It is relevant for the controversy that both Biologists look at the usage of pesticides from different angles.	X	
h) To support the position of Biologist B substantially, it is not enough to only refer to one study.	X	

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