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A cross-subject content analysis of science textbooks using the understandings about scientific inquiry rubrics

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Abstract

Recent empirical research has shown that students' inquiry competence can be improved, when they are explicitly taught understandings about scientific inquiry (USI). However, there is little research on the USI content taught in high schools. Examining Science textbooks is one way of identifying what might be taught in the classroom. The aim of this paper is to analyse the content of German science textbooks regarding their USI content. To do so, the understandings about scientific inquiry rubrics (USIR) were developed, validated and applied to a sample of n = 789 texts from n = 13 German textbooks for high school science. The results show that most textbooks dedicate one specific page to USI. The breadth of statements is relatively narrow. For researchers, the USIR present an instrument for the content analysis of instruction materials and learning environments. For teachers and curriculum developers they can be used as an instrument to enrich the content of textbooks, instruction materials and presentations.

Keywords

Scientific practice; scientific inquiry; understandings about scientific inquiry; qualitative content analysis; textbooks

1 Introduction and rationale

Knowledge about scientific inquiry or scientific practices is an important part of scientific literacy (Organization for Economic Co-operation and Development [OECD], 2013; Roberts & Bybee, 2014). Science education standards and curricula all over the world, especially in developed countries, and across the various sciences acknowledge the necessity to teach and learn about scientific inquiry (Abd-El-Khalick et al., 2004; Achieve, Inc., 2013; AQA, 2014; National Research Council [NRC], 2012; Ständige Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland [KMK], 2005a, 2005b, 2005c). However, various obstacles make it difficult to implement teaching about scientific inquiry in the classroom (Crawford, 2014; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Lederman, 2006; Osborne, 2014; Strippel & Sommer, 2015). One resource that helps teachers implement scientific inquiry are science textbooks as they are important for lesson preparation. Textbook content might therefore indicate what is presented in the classroom (Beerenwinkel & Gräsel, 2005; Härtig, Kauertz, & Fischer, 2012). The aim of this paper is to analyse the content of German science textbooks regarding understandings about scientific inquiry.

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2 Literature and theoretical framework

2.1 The term "scientific inquiry" in science education

"Scientific inquiry" is used with three different meanings in science education: to refer to a) a teaching and learning strategy where the process is modelled according to the practices of scientific inquiry and which is used to deliver a variety of science content, b) the various ways in which scientists study the natural world, and c) the classroom content area of skills and knowledge necessary for inquiry (Achieve, Inc., 2013; Aepkers, 2002; Crawford, 2014; NRC, 1996, 2000, 2012). This paper deals with scientific inquiry in the latter sense of a content area. The term "doing scientific inquiry" (DSI) will be used to refer to activities or descriptions of activities such as asking questions, designing and carrying out investigations, analysing and interpreting data and developing explanations (Crawford, 2014; Lederman, 2006; NRC, 1996, 2000, KMK, 2005a, 2005b, 2005c). The term "understandings about scientific inquiry" (USI) will be used to refer to statements about the properties, functions and limiting conditions of certain aspects of scientific inquiry, e.g. what is a scientific question as opposed to a non-scientific one, or what is the function of asking a question in the inquiry process (Lederman et al., 2014; NRC, 1996, 2000; Neumann, 2011).

2.2 Teaching and learning about DSI and USI in science education

For science education purposes, the process of scientific inquiry is usually reduced in complexity. In this study, the authors use a very basic, cyclical model of scientific inquiry (see Figure 1) including questions, mentioning but not necessarily demanding hypotheses, investigation design, the actual doing of the investigation, and analysis and interpretation of the data. This is in line with other research and standards documents (e.g. Ebenezer, Kaya, & Ebenezer, 2011; Kuo, Wu, Jen, & Hsu, 2015; NRC, 1996, 2000, 2012, KMK, 2005a, 2005b, 2005c; Sommer & Pfeifer, 2018; Wellnitz et al., 2012). Within this model, progress should be possible for each aspect in terms of DSI as well as USI, i.e. learners should become able to conduct better scientific inquiries and to understand more about scientific inquiries.

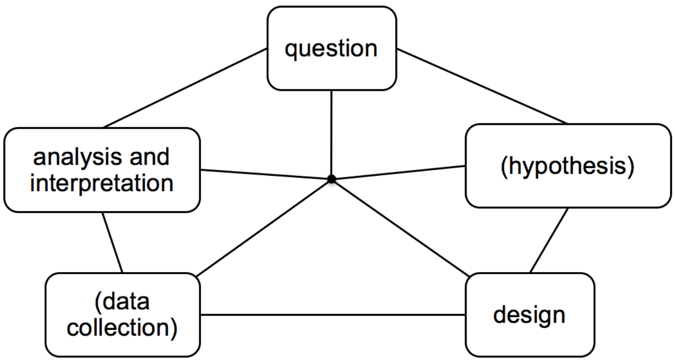

Figure 1: Basic model of a research cycle (adapted from Arnold, Kremer, & Mayer (2014))

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There is an imbalance between empirical research investigating the process[1] of scientific inquiry and understandings about scientific inquiry. Many studies have been conducted and instruments have been developed to investigate students' ability to conduct inquiries or perform parts of the inquiry process (e.g. Ebenezer, Kaya, & Ebenezer, 2011; Grube, 2010; Kuo, Wu, Jen, & Hsu, 2015; Möller, Grube, Hartmann, & Mayer, 2009; Wellnitz et al., 2016, 2012). These and similar assessment instruments have identified several issues that students struggle with in the inquiry process. For example, high school students struggle to pose investigable questions, they struggle to design investigations using appropriate variables, repetitions, conditions, and controls, and they find it difficult to interpret unexpected data or pose alternative interpretations (Arnold et al., 2014; Chin & Osborne, 2008; Chinn & Brewer, 1998; Grube, 2010; Hammann, Phan, & Bayrhuber, 2007; Hofstein et al., 2005; Wellnitz et al., 2016). Several studies note that students' ability to implement aspects of the scientific inquiry process can be improved by explicitly addressing their understandings about scientific inquiry (cf. Lederman et al., 2014; Rönnebeck et al., 2016).

However, very few studies address understandings about scientific inquiry. Some studies and standard documents specify what students should know about scientific inquiry (Lederman et al., 2014; NRC, 2000, 2012; Osborne et al., 2003). There are also some attempts to assess students' understandings about scientific inquiry (Gaigher, Lederman, & Lederman, 2014; Lederman et al., 2014; Neumann, 2011). Yet, the data analyses in these studies are tailored to the specific data collection instruments – the Views about Scientific Inquiry (VASI) questionnaire (Gaigher et al., 2014; Lederman et al., 2014) and a multiple-choice test (Neumann, 2011). Recently, the USI statements tested in the VASI have also been used to investigate a small sample of the genetics sections from seven US-American high school Biology textbooks (Campanile, Lederman, & Kampourakis, 2015). However, the study only looks at a small sample restricted to the topic of Mendelian genetics in seven Biology textbooks. They found only three explicit statements about scientific inquiry (Campanile et al., 2015, p. 219). On the one hand, this is discouraging. On the other hand, it might be necessary to investigate a larger sample. Unfortunately, the methodology is not described well enough to directly use it on a different sample.

3 Research aims

Against the background of the literature discussed above, there is a lack of research on the teaching and learning about understandings about scientific inquiry. One of the reasons might be a lack of instruments available for investigation of a variety of data. The aim of this paper is to analyse the USI content of German science textbooks across high school Biology, Chemistry, Physics and Science with specific focus on three questions:

1. Which texts contain understandings about scientific inquiry?
2. In what detail are understandings about scientific inquiry represented in these texts?
3. Which understandings about scientific inquiry are addressed in these texts?

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4 Methods

4.1 Sample

The sample consists of n = 13 current science textbooks from major German publishers. Only books published after the introduction of the latest science education reform in 2005 were included (KMK, 2005a, 2005b, 2005c). Textbooks for the 11-16 age range were examined because this is the range of compulsory secondary education in Germany. As the three major sciences (Biology, Chemistry, Physics) are taught separately as well as combined in Germany, textbooks for these courses were included in the sample. A variety of books were analysed to describe qualitative and quantitative similarities and differences. The sample comprises three Biology textbooks (Brennecke, Küster, Leienbach, & Post, 2013; Friedrich et al., 2014; Hausfeld & Schulenberg, 2008), six Chemistry textbooks (Arnold et al., 2008; Asselborn & Jäckel, 2013; Bohrmann-Linde et al., 2008a, 2008b, 2008c; Böker et al., 2013), one Physics textbook (Alboteanu-Schirner et al., 2013) and three integrated Science textbooks (Bresler et al., 2011; Cieplik et al., 2011; Sudeik & Vorwerk, 2006). Only one Physics textbook was included as only this book had been updated at the time of the study.

4.2 Data collection

Initial scanning of the books led to the decision not to examine the textbooks in total as many texts did not have any representations of scientific inquiry. It was finally decided to include all methods pages (identified by the key as "texts telling you about how science works") from all books (n = 186) and 25% of the hands-on laboratory tasks randomly selected from each book (n = 603). All texts were scanned and uploaded into QCAmap for data analysis.

4.3 Data analysis

The understandings about scientific inquiry rubrics (USIR) as an instrument for qualitative content analysis were developed in a multi-step approach (see Figure 2, Mayring (2014)). Based on the consensus about aspects of scientific inquiry in the literature discussed above, it was decided to create rubrics for understandings about three aspects of a research cycle: questions (see Table 1), investigation design (see Table 2), and analysis and interpretation of data (see Table 3). It was decided to model the USIR on a research cycle as this model is already widely used in research on doing scientific inquiry and might thus allow for comparison in the future. The three aspects were chosen as they are regarded as universal parts of scientific investigations across subjects and research approaches. An example of the application to a textbook page can be seen in Figure 3.

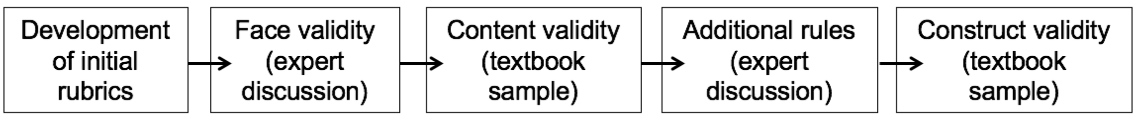

Figure 2: Process of rubric development

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Each rubric describes a four-level learning progression from 0 to 3. The authors of this study decided that four levels would allow a sufficient discrimination between texts while still making the rubrics applicable to a variety of data. The descriptions of the different levels were derived from the literature about scientific inquiry (Chinn & Malhotra, 2002; Ebenezer et al., 2011; Grube, 2010; Hammann, 2004; Kuo et al., 2015; Lederman et al., 2014; NRC, 2000, 2012; Neumann, 2011; Osborne et al., 2003; Wellnitz et al., 2016, 2012). Level 0 indicates that a certain aspect is not mentioned in the text. Level 1 is coded if a general statement is made that a certain aspect is part of the scientific inquiry process. Level 2 and 3 describe three areas: the properties of a certain aspect (e.g. what is a scientific question?), the functions of a certain aspects (e.g. what is a scientific question used for?) and further statements about a certain aspect (e.g. what else is known about scientific questions?). Level 2 is coded if one of the areas is addressed in a text. Level 3 is coded if two of the areas are addressed in a text. These distinctions are arbitrary because there is currently no empirical research on the difference in difficulty between these areas. It was decided that it will be more complex to talk about two areas within one text rather than to provide more information on one area (e.g. address one function and one property as opposed to addressing several properties). By adding one area of USI at a time, this already provides an instrument for reforming learning environments that currently only focus on DSI. In the future, it might be possible to prioritize one area or specific statements based on empirical evidence.

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Table 1: Rubric "USI-questions" (1 = one of these needs to be fulfilled; 2 = two of these need to be fulfilled)

level	definition	anchor examples
0	- no reference in the text to the role of questions in scientific inquiry	
1	- reference in the text to the role of questions scientific inquiry	Many questions about nature can only be answered through observations and experiments as well as their evaluation. (Brennecke et al., 2013, p. 78)
2	- reference in the text to the role of questions scientific inquiry a) reference to at least one property [1] (can be empirically investigated, are comprehensible, are problem-oriented) b) inquiry procedures are guided by the question asked [1] c) at least one further statement about scientific questions [1] (asking scientific questions is a cyclical process, scientific questions can ask for repeatable observations or relationships, it might be necessary to choose from a variety of scientific questions)	First, write down the question that you want to answer in your investigation. [...] Often, an investigation leads to new questions and problems that lead to further investigations. (Bresler et al., 2011, p. 130)
3	- reference in the text to the role of questions scientific inquiry a) reference to at least one property [2] (can be empirically investigated, are comprehensible, are problem-oriented) b) inquiry procedures are guided by the question asked [2] c) at least one further statement about scientific questions [2] (asking scientific questions is a cyclical process, scientific questions can ask for repeatable observations or relationships, it might be necessary to choose from a variety of scientific questions)	The experiment is the most important method to investigate an unanswered question in biology. Questions are often derived from observation. [...] You need to decide what is the likely cause of this and formulate a hypothesis accordingly. (Friedrich et al., 2014, p. 148)

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Table 2: Rubric "USI-design" (1 = one of these needs to be fulfilled; 2 = two of these need to be fulfilled)

level	definition	anchor examples
0	- no reference to scientific investigation design	
1	- reference to scientific investigation design	Experiments are one way to create scientific knowledge. (Hausfeld & Schulenberg, 2008, p. 212)
2	- reference to scientific investigation design a) reference to at least one property [1] (time span, accuracy, sample size, repetition, constant conditions, blinds, reproducibility, control of variables, controls) b) reference to at least one function [1] (finding repeatable observations, finding relationships) c) at least one further statement about scientific investigation design [1] (different procedures may be used to answer the same question, inquiry procedures can influence results)	For example, if you want to know how fast a bean stall is growing, you try to answer this question using an observation. You measure the length of the bean stall every day and write down the measurements. (Brennecke et al., 2013, p. 78) Experimental scientific problem-solving In science, you can solve many problems by cleverly choosing experiments. […] You derive a prediction how the problem could be solved. […] From that prediction, you derive further predictions that you can test in an experiment. (K. Arnold et al., 2008, p. 163)
3	- reference to scientific investigation design a) reference to at least one property [2] (time span, accuracy, sample size, repetition, constant conditions, blinds, reproducibility, control of variables, controls) b) reference to at least one function [2] (finding repeatable observations, finding relationships) c) at least one further statement about scientific investigation design [2] (different procedures may be used to answer the same question, inquiry procedures can influence results)	The science of Chemistry primarily uses experiments for a specific reason. They allow us to answer questions, gain new insights and understand relationships through observation. […] Thus, experiments fulfil an important task. They allow us to derive assumptions and predictions and test these. [...] In science, insights from experiments will only be accepted, when the experiments are reproducible, i.e. you have to make sure that other scientists can repeat your experiments and come to the same results. (Asselborn & Jäckel, 2013, p. 20) Here, you can see a fundamental principle of experimentation. Make sure that you only change one variable at a time. Otherwise, you cannot identify a clear relationship. (Alboteanu-Schirner et al., 2013, p. 117)

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Table 3: Rubric "USI-analysis and interpretation" (1 = one of these needs to be fulfilled; 2 = two of these need to be fulfilled)

level	definition	anchor examples
0	- no reference to scientific analysis and interpretation of data	
1	- reference to scientific analysis and interpretation of data - no adequate reference to properties/ functions of scientific analysis and interpretation of data	The result from a comparison is the answer to the original question and includes both similarities and differences of the two animals. (*result = end of investigation*) (Brennecke et al., 2013, p. 234) If you experiment carefully and keep a detailed protocol, your experiment will always lead to the same results under the same conditions. (*result = end of investigation, always the same*) (K. Arnold et al., 2008, p. 92)
2	- reference to scientific analysis and interpretation of data in the text a) reference to at least one property [1] (certainty, scope, generalizability, cross-referencing) b) reference to at least one function [1] (interpretation of the data, answering hypothesis/ question, generation of further questions/ hypotheses) c) at least one further statement about scientific analysis and interpretation of data [1] (different conclusions can legitimately be drawn from the same data, more than one conclusion can be drawn from the same set of data)	It is very important to observe everything and draw conclusions from this. You have to make a clear difference between observation and interpretation. (Asselborn & Jäckel, 2013, p. 20) If you can draw further conclusions from your experiments, you also have to write these down in the evaluation. (Cieplik et al., 2011, p. 80)
3	- reference to scientific analysis and interpretation of data in the text a) reference to at least one property [2] (certainty, scope, generalizability, cross-referencing) b) reference to at least one function [2] (interpretation of the data, answering hypothesis/ question, generation of further questions/ hypotheses) c) at least one further statement about scientific analysis and interpretation of data [2] (different conclusions can legitimately be drawn from the same data, more than one conclusion can be drawn from the same set of data)	Result and conclusion: At the end of an experiment, you compare your results to the original hypothesis. Sometimes an experiment will not yield a meaningful result. In this case, you should think about why this is the case. Sometimes an experiment will lead to further questions. The observations described above could suggest that soil also influences germination. You need to test this assumption with a fitting experiment. (Friedrich et al., 2014, p. 148) For example, you can conclude from experiments what substances will react with each other under which conditions. Experiments also allow you to make statements about similar experiments. [...] If possible, provide explanations for all your observations. Take into account your original question. (Asselborn & Jäckel, 2013, p. 20)

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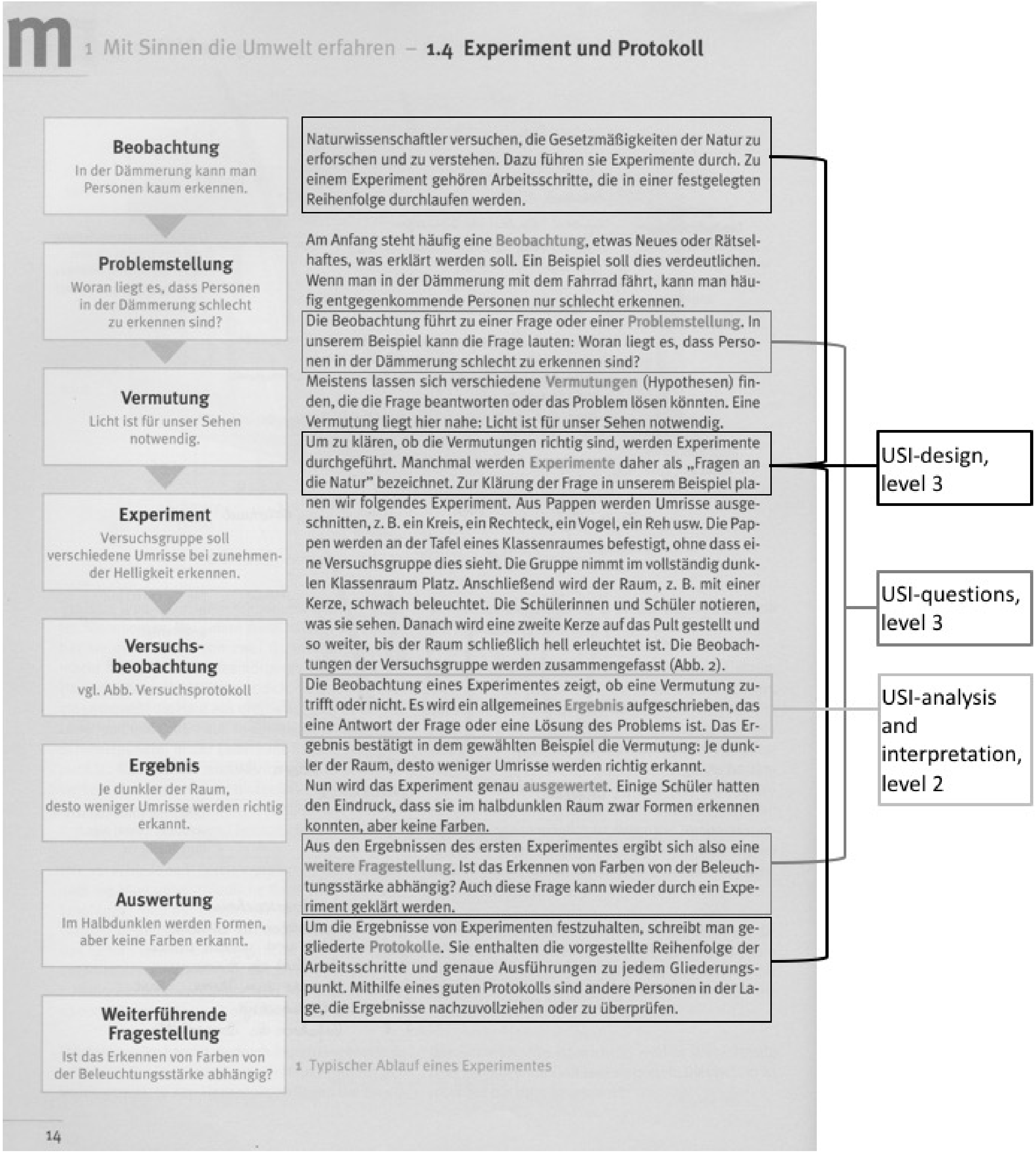
m 1 Mit Sinnen die Umwelt erfahren – 1.4 Experiment und Protokoll

Beobachtung
In der Dämmerung kann man Personen kaum erkennen.

Problemstellung
Woran liegt es, dass Personen in der Dämmerung schlecht zu erkennen sind?

Vermutung
Licht ist für unser Sehen notwendig.

Experiment
Versuchsgruppe soll verschiedene Umrisse bei zunehmender Helligkeit erkennen.

Versuchsbeobachtung
vgl. Abb. Versuchsprotokoll

Ergebnis
Je dunkler der Raum, desto weniger Umrisse werden richtig erkannt.

Auswertung
Im Halbdunklen werden Formen, aber keine Farben erkannt.

Weiterführende Fragestellung
Ist das Erkennen von Farben von der Beleuchtungsstärke abhängig?

Naturwissenschaftler versuchen, die Gesetzmäßigkeiten der Natur zu erforschen und zu verstehen. Dazu führen sie Experimente durch. Zu einem Experiment gehören Arbeitsschritte, die in einer festgelegten Reihenfolge durchlaufen werden.

Am Anfang steht häufig eine Beobachtung, etwas Neues oder Rätselhaftes, was erklärt werden soll. Ein Beispiel soll dies verdeutlichen. Wenn man in der Dämmerung mit dem Fahrrad fährt, kann man häufig entgegenkommende Personen nur schlecht erkennen.
Die Beobachtung führt zu einer Frage oder einer Problemstellung. In unserem Beispiel kann die Frage lauten: Woran liegt es, dass Personen in der Dämmerung schlecht zu erkennen sind?
Meistens lassen sich verschiedene Vermutungen (Hypothesen) finden, die die Frage beantworten oder das Problem lösen könnten. Eine Vermutung liegt hier nahe: Licht ist für unser Sehen notwendig.
Um zu klären, ob die Vermutungen richtig sind, werden Experimente durchgeführt. Manchmal werden Experimente daher als „Fragen an die Natur" bezeichnet. Zur Klärung der Frage in unserem Beispiel planen wir folgendes Experiment. Aus Pappen werden Umrisse ausgeschnitten, z. B. ein Kreis, ein Rechteck, ein Vogel, ein Reh usw. Die Pappen werden an der Tafel eines Klassenraumes befestigt, ohne dass eine Versuchsgruppe dies sieht. Die Gruppe nimmt im vollständig dunklen Klassenraum Platz. Anschließend wird der Raum, z. B. mit einer Kerze, schwach beleuchtet. Die Schülerinnen und Schüler notieren, was sie sehen. Danach wird eine zweite Kerze auf das Pult gestellt und so weiter, bis der Raum schließlich hell erleuchtet ist. Die Beobachtungen der Versuchsgruppe werden zusammengefasst (Abb. 2).
Die Beobachtung eines Experimentes zeigt, ob eine Vermutung zutrifft oder nicht. Es wird ein allgemeines Ergebnis aufgeschrieben, das eine Antwort der Frage oder eine Lösung des Problems ist. Das Ergebnis bestätigt in dem gewählten Beispiel die Vermutung: Je dunkler der Raum, desto weniger Umrisse werden richtig erkannt.
Nun wird das Experiment genau ausgewertet. Einige Schüler hatten den Eindruck, dass sie im halbdunklen Raum zwar Formen erkennen konnten, aber keine Farben.
Aus den Ergebnissen des ersten Experimentes ergibt sich also eine weitere Fragestellung. Ist das Erkennen von Farben von der Beleuchtungsstärke abhängig? Auch diese Frage kann wieder durch ein Experiment geklärt werden.
Um die Ergebnisse von Experimenten festzuhalten, schreibt man gegliederte Protokolle. Sie enthalten die vorgestellte Reihenfolge der Arbeitsschritte und genaue Ausführungen zu jedem Gliederungspunkt. Mithilfe eines guten Protokolls sind andere Personen in der Lage, die Ergebnisse nachzuvollziehen oder zu überprüfen.

1 Typischer Ablauf eines Experimentes

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Figure 3: Example of a textbook page (Sudeik & Vorwerk, 2006, p. 14) showing the application of the rubrics (text segments are combined for coding; USI-questions: dark grey, USI-design: black, USI-analysis and interpretation: light grey)

4.3.1 Face and content validity

Face validity was established in expert discussion between five science educators and researchers. These experts had not been part of the initial development process but hold expertise in science teaching, science teacher education and science education research. The experts met on several occasions to discuss each rubric individually and also the rubrics in comparison.

Content validity was established by applying the rubrics to a sample of 20% of the n = 789 textbook texts. Two independent coders not involved in the initial development were introduced to using the rubrics. Afterwards, they coded the texts applying the rules of qualitative content analysis (Mayring, 2014). All phrases or statements regarding scientific questions, scientific research design or scientific analysis and interpretation of data in the texts could be coded using the rubrics. The results from the coding process were again discussed with the expert panel to confirm coding and interpretations.

4.3.2 Reliability

The same two independent coders applied the rubrics to the full textbook sample. Inter-coder agreement (ICA) for each of the rubrics is 0.8 or higher (see Table 4) and can therefore be regarded as good (Miles & Huberman, 1994, p. 64).

Table 1: Inter-coder agreement (N = 789 texts; $\boldsymbol{ICA} = \frac{\#codings-\#disagreements}{\#codings}$)

rubric	inter-coder agreement
USI-questions	0.96
USI-design	0.97
USI-analysis and interpretation	0.98

4.3.3 Construct validity

As the textbooks are all recent, no change in the representation of scientific inquiry in the textbooks over time could be measured to establish construct validity. However, it was assumed that more representations of USI could be found in methods texts than in investigation tasks. This assumption was confirmed through data analysis. However, further testing of construct validity will be necessary in the future.

5 Results

As already described in the sampling procedure, most texts in the German science textbooks contain no representations of the scientific inquiry process at all. Among the two text types analysed, hands-on laboratory tasks do not contain explicit representations of understandings about scientific inquiry either. Thus, this results section will focus on the representations found in methods texts (n = 186).

References to at least one of the three aspects analysed can be found in about ten percent of the texts for each aspect (see Table 5). The representations are roughly evenly distributed across levels one to three. Six percent of the methods pages combine references to all three USI aspects.

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Table 5: Distribution of texts regarding different aspects of USI (n = 186)

Level	USI-questions	USI-design	USI-analysis and interpretation
0	91%	90%	90%
1	3%	4%	3%
2	3%	3%	4%
3	3%	3%	3%
∑ 1-3	9%	10%	10%

When looking more closely at the methods texts it becomes clear that eleven texts from nine books are constructed in a similar manner. They are dedicated to explaining how a scientific investigation works from beginning to end and are usually combined with an example from their respective science. Such texts can be found in all books but Bioskop and the three Chemie 2000+ books. There does not appear to be a strict pattern as to where in the book these texts appear – some are placed at the beginning, some in the middle, and some towards the end. Only three books describe scientific inquiry as a cyclical process (Markl (Biology), Fokus Chemie (Chemistry), natur bewusst (Science)). The other textbooks suggest a linear process of scientific inquiry. Strikingly, the two Biology textbooks Markl and Biosphäre use the same example of an investigation regarding the germination of cress. The Chemistry and Science textbooks use various investigations as examples.

The specific statements about scientific inquiry in the texts focus on similar details. Regarding questions, the most popular USI subarea are functions. Nine texts mention that questions guide the ensuing inquiry. Seven texts mention a property of scientific questions. They all describe a scientific question as one that can be derived from an interesting observation. Only three texts mention an additional statement about scientific questions. They talk about the idea that asking questions is a cyclical process.

Regarding investigation design, properties and functions are the most popular subareas. Seven texts mention a single property. Biology texts (n = 3) stress the role of controls in an experiment. Other texts mention variable control, reproducibility, and constant conditions. Seven texts mention a function of investigation design. Six of these state that the function is to identify relationships. Only one Biology text identifies making repeatable observations as a potential function of investigation design. Thus, there is a strong bias towards experimental investigation design. No text mentions one of the additional statements about investigation design.

For analysis and interpretation, most texts focus on the functions of the same. Twelve texts state that analysis and interpretation are necessary to evaluate the original question/ hypothesis. Two texts mention that the function of analysis and interpretation is also to create new questions. Only two texts mention properties, specifically generalisability and security. Two texts additionally mention that more than one conclusion might be drawn from a set of data.

In summary, German high school science textbooks mostly refer to understandings about scientific inquiry in a limited number of "scientific method texts", one of which can be found in nine out of thirteen books. In total, the textbooks contain relatively few explicit statements about understandings of scientific inquiry. Furthermore, the breadth of statements is very narrow.

6 Discussion and Conclusions

In this paper, the authors proposed that understandings about scientific inquiry (USI) present an important content area for school science education. It was also indicated that analysing science textbooks might be a useful way to get an insight into what understandings about scientific inquiry might be presented in the classroom. The understandings about scientific inquiry rubrics (USIR) were developed and validated as an instrument to analyse content regarding understandings about scientific questions, investigation design and analysis and interpretation of data, and then applied to a sample of German science textbooks. The overall finding of relatively few references to understandings about scientific inquiry is in line with research on USI in US Biology textbooks and research on related NOS content in German Chemistry textbooks (Campanile et al., 2015; Marniok & Reiners, 2016). However, this analysis also showed that there are some examples of texts with rich USI content across the different science textbooks. It is already known that teachers generally use textbooks for lesson preparation (Beerenwinkel & Gräsel, 2005; Härtig et al., 2012). It should now be investigated whether and how these specific methods texts are used by teachers and/or students.

The USIR might also be useful as a research instrument for other texts. In contrast to the framework presented by Gaigher, Lederman, & Lederman (2014) for the analysis of the VASI questionnaire, the USIR aim to provide a versatile instrument for analysing USI in a variety of science texts. The authors have already successfully applied the USIR to interviews about scientific inquiry (Strippel, 2017). This obviously requires new anchor examples. However, the levels and definitions remain the same.

The authors would also like to propose that the USIR can be used as a development instrument. Regarding science textbooks, they might be used to introduce statements on different levels of the three areas at different stages of the books. They might also be used to broaden the content provided in each of the three areas. Furthermore, the USIR can also be applied to develop the content of other instruction materials and learning environments. As the learning progressions have been created based on a cyclical model (see Figure 1) used in research and development on doing scientific inquiry (DSI), the USIR can be used to match existing DSI content. The authors have successfully applied the USIR to revise an existing out-of-school learning environment (Braun, Strippel, & Sommer, 2017; Strippel, Tomala, & Sommer, 2017). The USIR was used to analyse the materials (e.g. presentations, leaflets) for two school laboratory projects aimed at introducing high school students to scientific inquiry. The materials were then revised using the USIR to add more and specific understandings about scientific inquiry content.

Finally, the instrument and its development process are subject to limitations. As the different aspects of inquiry are interrelated, some statements and indicators might be subsumed under a different aspect. One might also wish to have a different number of inquiry aspects covered by the rubrics, for example including hypotheses. Furthermore, the levels cannot be regarded as equidistant. At this stage, one cannot state that the difference between level 1 and 2 is in any way the same as between level 2 and 3. Thus, statistical analysis is currently limited to descriptive operations. Furthermore, when interpreting the results from applying the USIR, one should always account for the data that was analysed. When a certain inquiry content is presented in a textbook, this guarantees by no means that it will be delivered in that way. Finally, the USIR might require future revision. As presented in this paper, the rubrics and the results from the textbook analysis are an invitation to discuss how understandings about scientific inquiry can be used in meaningful ways to improve functional scientific literacy.

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