INCLUSIVE SCIENCE EDUCATION

VALIDATION AND REVISION OF THE FRAMEWORK FOR INCLUSIVE SCIENCE EDUCATION

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VALIDIERUNG UND ÜBERARBEITUNG DES KATEGORIENSYSTEMS INKLUSIVER NATURWISSEN-SCHAFTLICHER UNTERRICHT (KinU)

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Sarah Brauns, Simone Abels

ABSTRACT

All students have the right to participate in science education. For this to be achieved, not only research in the inclusive context needs to be further developed, but teachers also require guidance on how to implement inclusive science education in practice. To meet this demand, the Framework for Inclusive Science Education was developed in the federally funded project "Teaching Science Education Inclusively" (Nawi-In). Since the Framework was previously systematically derived from the literature (Brauns & Abels, 2020), only a smaller part of which came from empirical work, the Framework was verified in practice in a validation process. This means that in several steps the Framework was applied to different data of the Nawi-In project (classroom videos and audio-recorded lesson reflections of student teachers). In the case of the classroom videos, it was analysed which inclusive science aspects from the Framework the student teachers had implemented in practice. In the lesson reflections, it was analysed which inclusive science aspects the student teachers had noticed in their own and another teacher's classroom videos. By applying the Framework to the data as means of validation, it was analysed, for example, how disjunctive the categories are. The Framework was extended by inductive categories, i.e., it is showing even more or more concrete inclusive approaches to science education now. In addition, further quality criteria were reviewed. Implications have led to the revision of the Framework. The new Framework for Inclusive Science Education 2.0 consists of a total of n=2117 categories. Of these, there are 15 main categories, each of which has 12 subcategories. The subcategories are each divided into codes and more concrete subcodes. The recurring structure of the subcategories and codes has made the application of the Framework simpler and more comprehensible. Nevertheless, the Framework 2.0 still only shows different approaches to inclusive science teaching, but cannot conclude whether all students could actually participate in the class. The implications show that the Framework 2.0 has the potential to continue to be used in science teacher education, to be applied to further data in science education research and possibly to be transferred to other subjects.

CONTENT

FIGURES

TABLES

1. INTRODUCTION

'Education for all' is how Booth et al. (2006) interpret one of the concepts of inclusive education. This understanding of inclusion is about enabling all students to participate in education (Black-Hawkins, 2010). "As we have come to understand it, inclusive pedagogy is an approach to teaching and learning that supports teachers to respond to individual differences between learners, but avoids the marginalisation that can occur when some students are treated differently" (Florian, 2014, p. 289). The understanding of 'education for all' aims to reduce individual barriers for students and to promote the individual potential of students without attribution as in special education nor the belief that the ability to learn is fixed (Griful-Freixenet et al., 2020). However, inclusive education is not only about broadening the view on the students' potentials, but also breaking down fixed structures and understanding that different students can take and need different approaches in class.

While 'education for all' refers to teaching in general, this understanding of inclusive education needs to be specified for the different school subjects. "The notion of 'science for all' suggests that all students – irrespective of achievement and ability – should engage in opportunities to understand the practice and discourse of science" (Villanueva & Hand, 2011, p. 233). Villanueva and Hand (2011) thus specify the concept of inclusion for science education, but what inclusive science education is, does not become concrete in this quote. In order for all students to participate in science education, it is necessary that students are enabled to access science in different ways (Baumann et al., 2018). There are already indications in the literature on how these can be implemented in science education (Brauns & Abels, 2020). Experimental phases, for example, are an essential component of science education (Brauns & Abels, 2021a). In order to make experimental phases inclusive, it is the teacher's task to enable different approaches to them (Brauns & Abels, 2020). For example, approaches to experiments can be enabled through addressing different senses. Students can use smell as an indicator (Teke & Sozbilir, 2019). In addition, experiments can involve feeling objects and their positions as they float and sink (Kahn et al., 2017). This also includes adapting devices for experimentation so that, for example, tactile markings are used on graduated cylinders, flasks or scales (Watson & Johnston, 2007). Devices for measuring can also have acoustic or vibrating functions (Koehler & Wild, 2019; Vitoriano et al., 2016). It is also possible to differentiate experimentation phases by the number of experiments (Schmitt-Sody et al., 2015), by the social forms in groups or individual work (McGrath & Hughes, 2018) and to support students acting as learning guides (Bodzin et al., 2007).

Inquiry-based learning also lends to the implementation of scientific practices in inclusive science education (Abels et al., 2020; Hofer et al., 2018; McGrath & Hughes, 2018; Mulvey et al., 2016). Through the phenomena-based engagement and inquiry stance that students adopt, interest is aroused (Bodzin et al., 2007; Maroney et al., 2003). Inquiry-based learning is particularly appropriate as it can be created with varying degrees of openness adapted to the students' needs, for example, by making the research questions, methods and data analysis of the investigations more or less structured, guided or even left open (Abels, 2015; Blanchard et al., 2010; Mulvey et al., 2016; Watt et al., 2013).

However, science education does not only consist of inquiry-based learning and experimentation phases. The specific technical language, scientific concepts, models, phenomena and other elements are also characteristics of science education (Brauns & Abels, 2020). For the development of technical language, for example, glossaries or technical vocabulary tables (Affeldt et al., 2018; Huber, 2017; Schmitt-Sody & Kometz, 2014), visualisations in the form of figures, symbols or pictograms can be used in a supportive manner (Adesokan & Reiners, 2015; Markic & Bruns, 2013), or multilingual approaches can be created (Collier et al., 2016). For developing science concepts, for example, digital access can be created via apps, computer programmes or simulations (Schmitt-Sody & Kometz, 2011; Stinken-Rösner, 2020; Teke & Sozbilir, 2019), or science concepts can be taught with a connection to everyday life or based on a specific context (Menthe et al., 2015). Just as there are other different characteristics of science education, there are also countless other approaches to these characteristics that can be created in order to create inclusive science education. Although various publications have already provided guidance on the inclusive implementation of science education, these have never been fully mapped, clearly structured and finalised before the Framework for Inclusive Science Education (Brauns & Abels, 2020).

2. THE FRAMEWORK FOR INCLUSIVE SCIENCE EDUCATION 1.0

In order to map the connection between science and inclusive education in one framework, the Framework for Inclusive Science Education was established in the federally funded project "Teaching Science Education Inclusively"[1] (Nawi-In; Brauns & Abels, 2020). In a systematic literature review, a total of n=297 titles with reference to inclusive science education were identified (Brauns & Abels, 2020). The categories of the Framework were derived from the literature using inductive category deriving (Kuckartz, 2018). A total of n=935 categories were systematised, each representing a science characteristic (e.g., scientific research methods, scientific concepts, technical language, phenomena, etc.) combined with a way of inclusive implementation (e.g. material-guided support, enabling … on the basis of linguistic support, enabling … at different degrees of openness). The categories were systematised in the Framework at four different levels of abstraction from the main category level (abstract) to the subcode level (concrete). N=16 categories constitute the main categories (fig. 1) and were defined in

[1] Funded by the German Federal Ministry of Education and Research (2018-2021, no 01NV1731)

Brauns and Abels (2020). Accordingly, 16 science characteristics (fig. 1, green) were derived from the literature and linked to the idea of inclusive pedagogy[2] (fig. 1, red).

1. Developing inclusive science learning environments	2. Adapting security for inclusive education	3. Developing (inclusive) diagnostics for scientific specifics	4. Teaching scientific concepts inclusively	5. Creating inclusive scientific contexts
16. Teaching the understanding of nature of science inclusively				6. Teaching scientific terminology inclusively
15. Creating inclusive data evaluation and result presentation		**THE FRAMEWORK FOR INCLUSIVE SCIENCE EDUCATION**		7. Creating inclusive inquiry-based learning
14. Developing students' science conceptions inclusively				8. Teaching scientific phenomena inclusively
13. Creating inclusive application of scientific research methods	12. Creating inclusive scientific documentation	11. Developing inclusive scientific information media	10. Creating inclusive generation of hypotheses and research questions	9. Teaching scientific models inclusively

Fig. 1. The Framework for Inclusive Science Education 1.0 (Brauns & Abels, 2020, p. 21)

In the Nawi-In project, different data were analysed with the Framework for Inclusive Science Education (Brauns et al., 2020). In this way, two goals were pursued: On the one hand, the professional competencies regarding inclusive science education of student teachers were analysed and, on the other hand, the Framework was validated and further developed (Brauns & Abels, 2021b). The consolidation of the results from the individual validations of an entire process takes place in this paper (Brauns & Abels, submitted a, submitted b, in prep., 2021). For this purpose, the methodological procedure for validation, the implications from the empirical application of the Framework and the new, revised Framework for Inclusive Science Education 2.0 are presented. In addition, the quality criteria of the Framework are reviewed and implications for the further application of the Framework are provided.

The descriptive statistics of the sample and the Framework showed that a large number of the categories were derived from theoretical-conceptual literature. For this reason, the demand for empirical application and further development of the Framework was obvious. The analyses revealed even more gaps. For example, the focus of the literature was rarely on teachers, who are responsible for teaching (Brauns & Abels, 2020). Therefore, applying the Framework to data from student teachers addressed a gap in research. Furthermore, the analysis of the Framework showed how extensive it was, which could make it difficult to apply (Brauns & Abels, 2020). Until then, the Framework gave hints for inclusive science education that needed to be tested in practice.

[2] The Framework in its original form can be downloaded here: www.leuphana.de/inclusive-science-education (1/2020)

Overall, the Framework was to be understood as dynamic from the beginning, so that its development will always be ongoing depending on the developments in the field.

3. RESEARCH FOCUS AND AIMS

Although the Nawi-In project uses the Framework for Inclusive Science Education to analyse the professional competencies of student teachers, the focus of this paper is on the triangulation of the different validation steps and revision of the Framework itself. Since the Framework for Inclusive Science Education was derived in a systematic review from the literature, in which mainly theoretical-conceptual and normative references were provided, deficiencies already became apparent during the creation of the Framework, which needed to be revised through its application in research (Brauns & Abels, 2020). For this reason, this paper brings together all the implications for revising and extending the Framework. In summary, this paper pursues the following aims of the validation and revision of the Framework:

- Triangulating the validation steps of the Framework
- Reviewing the quality criteria with regard to the qualitative content analysis
- Revising the structure of the Framework
- Further developing the categories of the Framework

In this sense, the revision of the Framework is not only discussed and justified in this paper, but also the new, revised Framework for Inclusive Science Education 2.0 with its revised definitions is made freely available. As one of the quality criteria, the methodological procedure for the validation of the Framework is made transparent in detail below.

4. VALIDATION PROCEDURE OF THE FRAMEWORK

The validation process for the revision of the Framework for Inclusive Science Education was created along the project logic of Nawi-In (fig. 2, p. 5, Brauns & Abels, 2021b; Flick, 2019). After individual steps of the validation on practice have been conducted (Brauns & Abels, submitted a, submitted b, in prep., 2021), the results of these steps are triangulated in this paper. Validity as a process has the goal of trustworthiness (Lamnek & Krell, 2010). In qualitative research, such individual procedures are common, because conventional criteria from quantitative research usually cannot be transferred (Mayring, 2014; Stasik & Gendzwitt, 2018; Tjora, 2018). There are no universal rules that can be applied; rather, the methods need to be adapted to the problem (Broad, 2017; Stasik & Gendzwitt, 2018). In qualitative research, the measurement character changes to the interpretative-communicative character (Lamnek &

Krell, 2010). In the literature, various techniques are recommended for validation in qualitative research (e.g., triangulation, peer debriefing, member checks, communicative validation, etc.) and criteria are established, such as credibility, transferability, dependability, confirmability, stability, reproducibility, accuracy (Lincoln & Guba, 1985; Mayring, 2014). The validation techniques and quality criteria were individually compiled for the Framework for Inclusive Science Education and are described in more detail below.

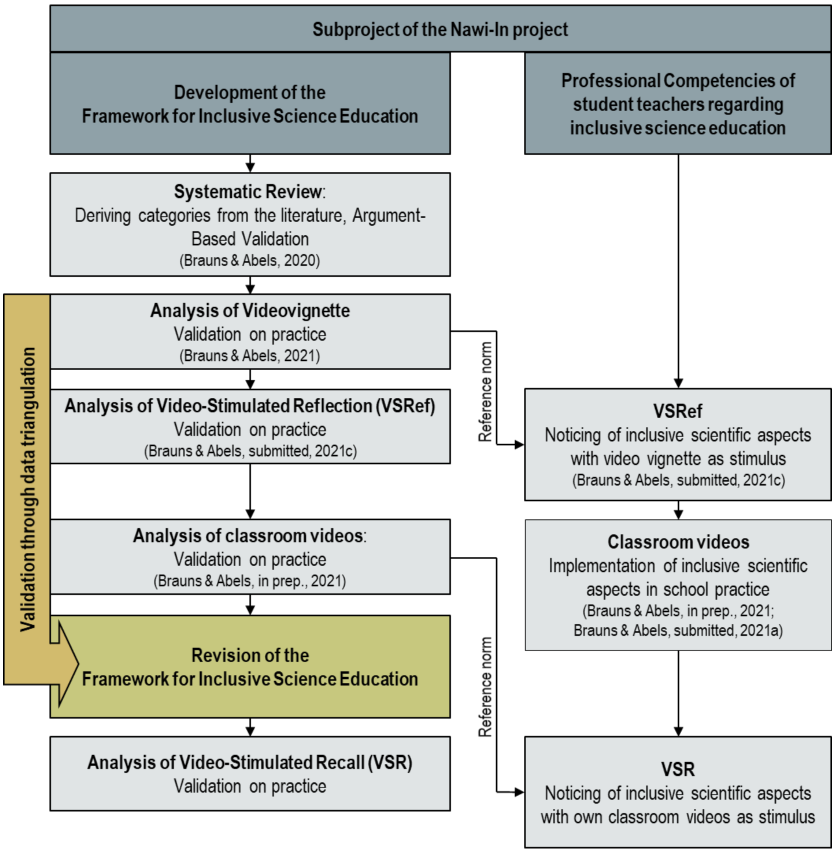

Fig. 2. Project logic and validation process of the Framework for Inclusive Science Education (adapted after Brauns & Abels, 2021b, p. 72).

4.1 VALIDATION TECHNIQUES

“Validation is a social discourse” (translated after Lamnek & Krell, 2010, p. 148). One of the validation steps already took place during the derivation of the categories from the literature in the systematic review (Brauns & Abels, 2020). In recurrent cycles, the categories were repeatedly discussed and revised in research groups in the sense of an argument-based validation (Döring & Bortz, 2016). Every step from coding text passages, paraphrasing the codings (formulating them in one’s own words), clustering paraphrases with the same content statements, formulating the categories, structuring the categories in the Framework, etc. was repeatedly reviewed and revised using the argument-based approach (Brauns & Abels, 2020). In argument-based validation, the researchers disclose their preliminary assumptions and interpretations are then jointly reviewed (Lamnek & Krell, 2010). This approach is so called, because arguments are exchanged and discussions are held for the assumptions and interpretations (Döring & Bortz, 2016). In this way, not only is intersubjectivity guaranteed, but decisions are directly justified (Lamnek & Krell, 2010). All data analysed with the Framework for Inclusive Science Education – more precisely the data of the video vignette, the video-stimulated reflections (VSRef) and the classroom videos – were first validated each time in an argument-based approach together with at least one other researcher Brauns & Abels, submitted a, submitted b, in prep., 2021). The results are always referred back to the state of the research and discussed together, so that extensions and modifications take place again and again (Mayring, 2019). The constant feedback and revision is reminiscent of the procedure in qualitative content analysis, in which categories and concepts are continuously developed (Kuckartz & Rädiker, 2019). Following this procedure can indeed increase validity in qualitative content analysis (Broad, 2017). In this way, it was first ensured that the data were adequately analysed with the Framework and that the results were of high quality. This is because the results of the analyses served as a basis, and as a starting point for expanding the Framework and for formulating implications for changing the Framework.

By analysing the video vignette, the VSRef and the classroom videos with the Framework for Inclusive Science Education, the Framework was verified in the sense of a validation on practice (Lamnek & Krell, 2010). This is because the argumentative approach could not verify the theoretical-conceptual categories from the Framework, the gaps could not be closed and the applicability in research could not be tested. The path from theory to practice is also described as the transformation of scientific knowledge into practice (Lamnek & Krell, 2010). Each validation on practice was carried out one after the other Brauns & Abels, submitted a, submitted b, in prep., 2021). However, the Framework was always applied in its latest state and thus developed cumulatively. This means that the Framework, including the categories derived from the analysis of the video vignette, was used for the analysis of the VSRef. In the analysis of the classroom videos, all categories of the Framework were used with the inductive categories from the analysis of the video vignette and the VSRef. In this way, the extension of the Framework for Inclusive Science Education through the derivation of inductive categories took place through the validation on practice and in the adding process.

Essentially, the validation through data triangulation presented in this paper led to the revision of the Framework (Flick, 2019, 2020; Lamnek & Krell, 2010). “Triangulation of data combines data drawn from different sources and at different times, in different places or from different people” (Flick, 2010, n.p.). As mentioned above, the video vignette, the VSRef and the classroom videos were used as different data at different times. In addition, different student teachers at primary and secondary level were researched, and in the video vignette the teaching of an experienced teacher was analysed. All data were independent of each other.

> "This is the adequate variant of integration when data from studies with two independent samples are analysed in the context of a triangulation design. In this case, the comparison of the findings can achieve the objective of increased validity because it only takes place after those findings have been made" (Kuckartz & Rädiker, 2019, p. 175).

It is common in qualitative research that visual and auditory data are also triangulated (Flick, 2010). In addition, it is important to distinguish the data of the dual focus of the project at this point. The methodological research questions were always related to the development and revision of the Framework (Brauns & Abels, submitted a, submitted b, in prep., 2021).

After the techniques of validation have already been applied Brauns & Abels, submitted a, submitted b, in prep., 2021), the criteria for validating the Framework for Inclusive Science Education will be implemented and reviewed in the further course of this paper.

4.2 QUALITY CRITERIA

In order to assess whether the Framework for Inclusive Science Education is valid, the mere extension of the categories by applying them to practice and the triangulation of the results are not sufficient. Döring and Bortz (2016), for example, list criteria such as intersubjective comprehensibility, indication, empirical anchoring, limitation, reflected subjectivity, coherence and relevance, on which they describe indications for implementation. Steinke (2010) lists inter-subject comprehensibility, indication of the research process, empirical foundation, coherence, relevance and Tracy (2010) lists worthy topic, rich rigor, sincerity, credibility, resonance, significant contribution, ethical, meaningful coherence. These different quality criteria need to be modified with regard to the research project and objectives (Mayring, 2014). For this reason, for the validation of the Framework for Inclusive Science Education, the quality criteria presented in the following from the literature were concretised through the specific implementation in the Nawi-In project.

Empirical foundation

Empirical foundation as a quality criterion describes the theoretical foundation of the Framework, the extent to which the results are justified on the basis of theoretical data and the methods used were selected on a theoretically sound basis (Döring & Bortz, 2016; Tracy, 2010). Since the categories of the Framework were originally derived systematically from the literature, the basic Framework was theoretically grounded. Both in the derivation of the Framework and in the application of the Framework to the data of the Nawi-In project, well-founded methods of qualitative research and for systematising the methodological approach were selected and applied (e.g., Fink, 2009; Kuckartz, 2018; Mayring, 2014). The results of the application of the Framework were continuously discussed on the basis of related research and theories (Brauns & Abels, submitted a, submitted b, in prep., 2021).

Reproducibility

Reproducibility includes the credibility and transparency of the research (Döring & Bortz, 2016; Mayring, 2014; Tracy, 2010). It requires that a research process is comprehensively documented so that external parties can understand and evaluate the entire process (Döring & Bortz, 2016; Steinke, 2010). This involves transparently presenting all methodological steps, (interim) results and challenges (Tracy, 2010). Moreover, the steps are not only presented, but the methodological decisions are also justified in terms of the concept of indication (Döring & Bortz, 2016). In deriving the categories, Brauns and Abels (2020) first present in full transparency the search strategy with the search terms, which results in specific databases and the selection process of the literature. This procedure was carried out systematically following Fink (2009) and documented and published in detail (Brauns & Abels, 2020). The rules of qualitative content analysis according to Kuckartz (2018) were applied in the data evaluation. In addition, the revision processes in deriving the categories from the literature were discussed. In the Framework 1.0 by Brauns and Abels (2020), all source references of the individual categories were also listed in order to make it comprehensible from which literature the individual categories were derived. Overall, both the comprehensive documentation of the derivation of the Framework and the Framework itself with its source references are available to the public as an open access contribution. The application of the Framework was also documented in detail, whereby at least one independent article was (or will be) formulated for each validation step of the Framework and also published in open access (Brauns & Abels, submitted a, submitted b, in prep., 2021). The data analyses took place in each case with careful application of the rules of qualitative content analysis according to Mayring (2014).

Reliability

Reliability includes confirmability, accuracy, reproducibility and rich rigor (Mayring, 2014; Tracy, 2010). For example, to increase the reliability of the results, the size of the sample or data is important and that data collection and analysis are carried out appropriately (Tracy, 2010). In addition, reliability can be achieved through intercoder reliability, where two coders, who have been sufficiently trained to use the Framework, code the same material with the Framework, and through accuracy (Mayring, 2014). In deriving the Framework, double coding with trained coders took place, which was compared, discussed and verified in an argumentative validation (Döring & Bortz, 2016). In addition, Brauns and Abels (2020) published guidance on the application of the Framework so that other researchers can also use it. This also includes that the main categories of the Framework were defined in the same paper and also coding rules to delimit the main categories. When applying the Framework, a defined part of the data was always coded by a second researcher to ensure intercoder reliability (Mayring, 2014). Subsequently, the results were validated using argumentative methods (Döring & Bortz, 2016). The cycle of review and discussion as well as the revision of the results took place in several loops, as presented in the respective articles (Brauns & Abels, submitted a, submitted b, in prep., 2021). In this way, the results become more and more reliable and accurate.

Coherence and limitations
Coherence describes how consistent and free of contradictions the results are (Steinke, 2010). In addition, it verifies whether the methods fit the objectives, research questions and results of the study and whether these have been meaningfully linked to the literature (Tracy, 2010). In addition, the limitations describe under which conditions the results can be generalised and to what extent the generalisation is limited (Döring & Bortz, 2016). It can be helpful to contrast cases or present extreme cases (Steinke, 2010). In deriving the categories, the coherence of the categories of the Framework, whereby the categories should be disjunctive, was provisionally justified in an argumentative process (Brauns & Abels, 2020). In the same process, it was pointed out that through application to practice (Lamnek & Krell, 2010), further action was needed to verify how disjunctive the categories actually were. The application to practice then resulted in further implications, which are implemented in this paper with the revision of the Framework. In this way, coherence is created in the Framework 2.0. Both in the creation and the application of the Framework, the limitations were listed that with the Framework, the inclusive approaches of science education can be identified. Nevertheless, the Framework cannot confirm whether a science lesson is actually inclusive in the sense that we would know if all students participated (Brauns & Abels, 2020).

Transferability
Transferability answers the question of the extent to which the findings can be generalised to other theories or fields (Tracy, 2010). Because the Framework is a link between science characteristics and inclusive implementation, it shows that some inclusive approaches that are not science specific (e.g., supporting the application of scientific research methods through group work) are potentially transferable to other subjects. Nevertheless, the Framework was developed specifically for inclusive science education and is therefore most suitable for this subject area.

In addition, the Framework can be used in both pre- and in-service education. Furthermore, the Framework can be used to plan, reflect and analyse inclusive science teaching. The application of the Framework in the Nawi-In project has shown that the Framework can be used to analyse different data (e.g., transcribed audiographies, videographies) based on different goals (e.g., lesson perception, planning competence, action competence).

Relevance
Does the research achieve practical relevance and thus make a significant contribution (Döring & Bortz, 2016; Mayring, 2014)? This includes that the contributions are contemporary and interesting (Tracy, 2010) or also that problems are solved (Mayring, 2014). The derivation of the Framework is justified by the inclusion claim for its implementation in education (van Mieghem et al., 2020). In Brauns and Abels (2020), it is also explained in a well-founded man-

ner why the connection between science teaching and inclusion was initially conceived theoretically and then filled with content and concretised through the Framework. With the derivation of the inclusive science categories and the systematisation in the Framework, a desideratum was closed with the work in Brauns and Abels (2020). In addition, the derivation of the Framework from the literature showed where there were research gaps that could be increasingly limited through the application and further development of the Framework. The relevance of the Framework is demonstrated by the applicability in inclusive science education research, but also by creating means to enable all students to participate more likely in science education. In order to achieve this goal, the Framework is therefore an essential contribution to the education and professional development of (becoming) teachers. In this context, the Framework is the basis for a handbook for designing and reflecting on inclusive science lessons.

Reflective subjectivity

Self-reflexivity refers to the awareness of subjective “values, biases, and inclinations of the researcher(s)” (Tracy, 2010, p. 840). In this process, the analysis process is accompanied by self-observation and the researcher’s own position is repeatedly questioned (Döring & Bortz, 2016; Mayring, 2014). When the Framework was derived from the literature, the researchers’ expertise in inclusive science education was not as developed as it is now. For this reason, for example, important search terms were not used in an initial search. For the work in Brauns and Abels (2020), the original search was therefore revised and re-conducted to derive the Framework. Reflective subjectivity is particularly relevant in the application of the Framework, as the researchers who created the Framework have extensive knowledge of the categories as opposed to external or other researchers who intend to use the Framework. Due to different levels of knowledge, which can only be adjusted with a high effort, intercoder approaches for verifying quality can be difficult.

Ethics

“The research considers Procedural ethics (such as human subjects), Situational and culturally specific ethics, Relational ethics, Exiting ethics (leaving the scene and sharing the research)” (Tracy, 2010, p. 840). In order to legitimise the ethical soundness of the Nawi-In project and the development and application of the Framework, the research of the Nawi-In project was approved by the Ethics Committee of the Leuphana University, which follows the *Guidelines for Safeguarding Good Research Practice* of the German Research Foundation (DFG, 2019). In addition, the Nawi-In project was approved by the relevant school authority for data collection in schools. The school management, teachers, student teachers, guardians and students were comprehensively informed about the use of the data and their rights, and with the written declaration of consent they voluntarily agreed to make the data available confidentially and anonymised for research and teacher education.

5. RESULTS

In order to ensure the quality criteria for the Framework 2.0, the revision process of the Framework when applied to practice (Brauns & Abels, submitted a, submitted b, in prep., 2021) is presented further on. For this purpose, the inductively derived categories of the different data analyses are presented, as these give a substantial insight into the further development of the Framework 1.0. In addition, the implications that were gathered during the application to the data in the Nawi-In project are listed. These implications led to the increase of the quality of the Framework. Finally after the specification of the validation process, the revised Framework 2.0 is described and discussed.

5.1 DEVELOPMENT OF THE INDUCTIVELY DERIVED CATEGORIES

Originally, a total of n=935 categories were derived from the literature, of which n=16 formed the main categories (Brauns & Abels, 2020). Each time the Framework 1.0 was applied to practice, additional categories were derived from the data, which led to the expansion of the Framework (fig. 3). Altogether, 399 categories were added to the original Framework for Inclusive Science Education.

In addition, as different data and different sample sizes were present in the individual analyses, the proportions of inductive and deductive categories are compared in figure 2. The largest proportion of inductive categories, 40 %, was coded from the video vignette. 11 % of the coded categories in the VSRef were inductive categories and 23 % were inductive categories in the classroom videos.

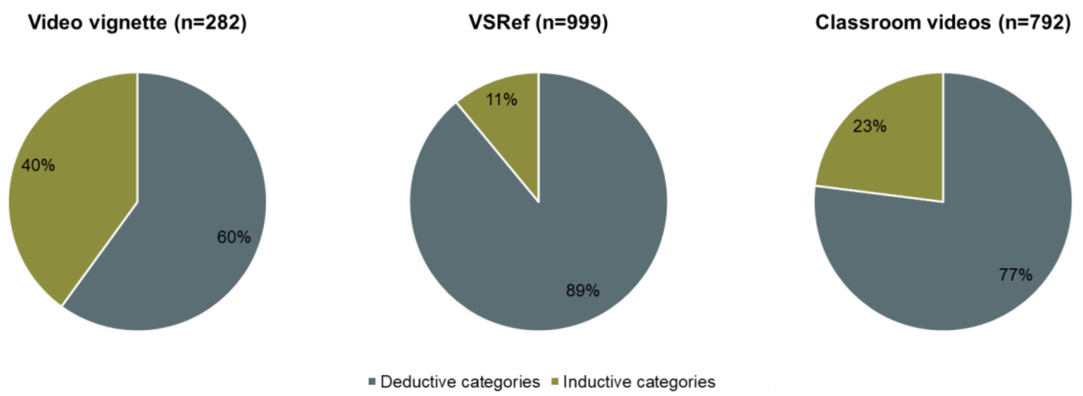

Fig. 3. Proportions of the inductive categories after the validation steps on practice

There were no changes in the main categories when applied to practice. Mainly codes and most often subcodes were inductively derived from the different data (fig. 4.). For the comparability of the inductive categories at the levels of the Framework, the proportions of the coded categories are listed again.

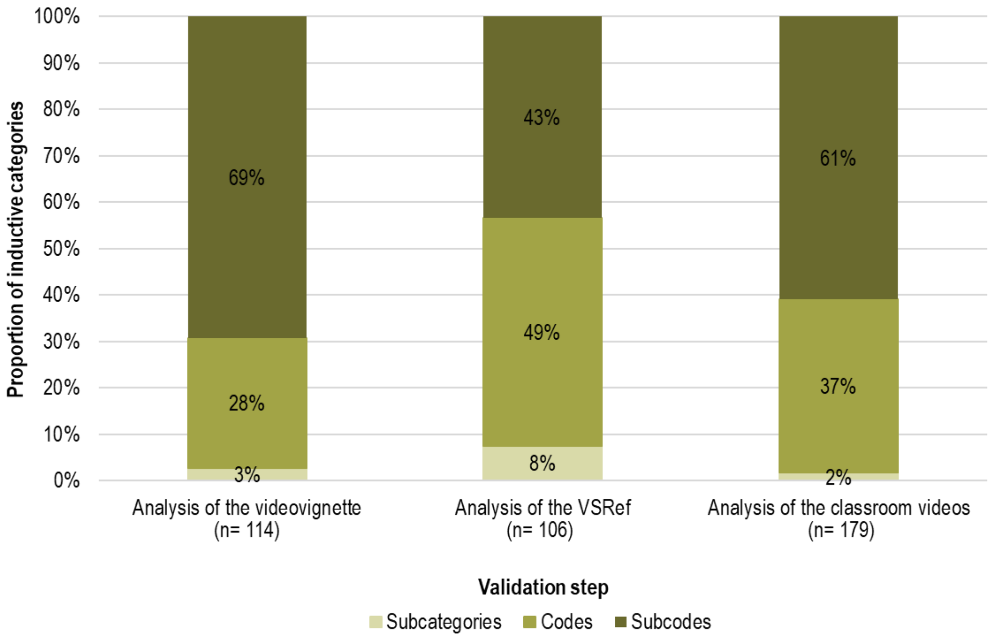

Fig. 4. Distribution of inductive subcategories, codes and subcodes at the different analysis times and data materials (Brauns & Abels, submitted a, submitted b, in prep., 2021)

The distribution of the inductive categories among the main categories of the Framework 1.0 shows which inclusive design of scientific characteristics was mainly addressed in the VSRef and classroom videos. Furthermore, it demonstrates which categories were particularly refined. The four main categories with the most inductively derived categories are *(10.) Creating inclusive generation of hypotheses and research questions* with n=65 categories, *(13.) Creating inclusive application of scientific research methods* with n=62 categories, *(15.) Creating inclusive data evaluation and result presentation* with n=57 categories and *(5.) Creating inclusive scientific contexts* with n=45 categories (fig. 5, p. 13). The 13th category already was one of the categories with a lot of codings derived from the literature (fig. 5, p. 13) (Brauns & Abels, 2020). These were mainly addressed in the VSRef and classroom videos, which increases the likelihood that more inductive categories are derived Brauns & Abels, submitted a, submitted b, in prep., 2021). In the other three categories with the most inductively derived categories there were rather fewer indications given in the literature for the inclusive design of these scientific characteristics. Through the application of the Framework these categories could be considerably expanded. Especially the main category on the inclusive design of scientific contexts, which was very rarely addressed in the literature and research, could now be considerably extended.

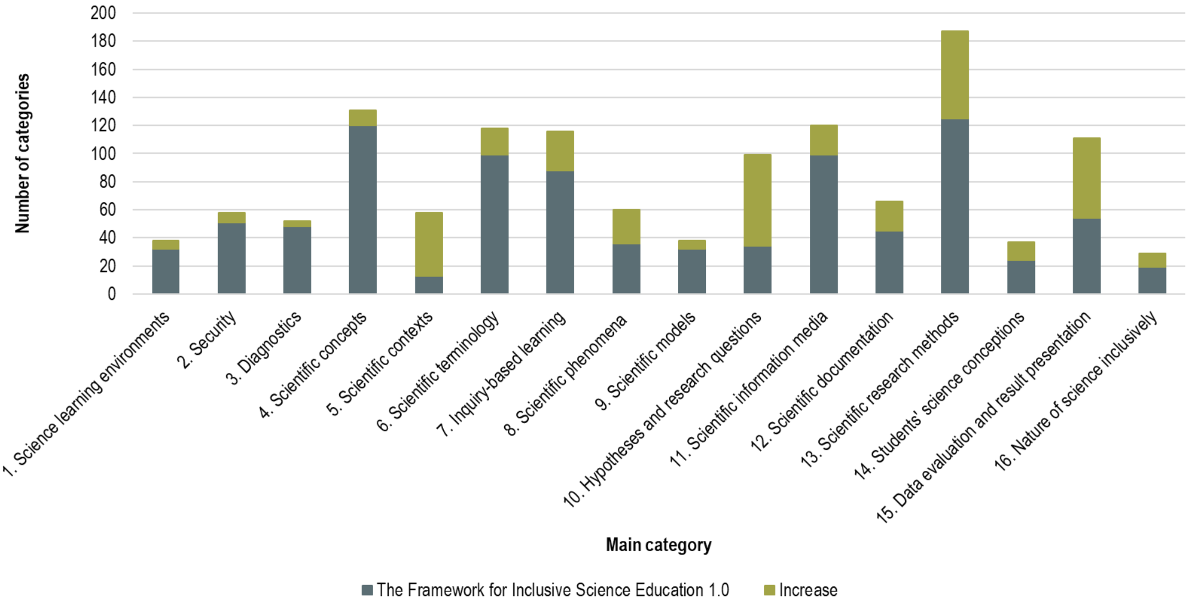

Fig. 5. Addition of inductive categories per main category of the Framework 1.0 (expanded from Brauns & Abels, 2020)

Overall, the application of the Framework 1.0 to practice has considerably extended the categories of the Framework, and it is evident that at the subcode level in particular, the categories have been inductively enhanced. These results are used to revise the Framework 1.0, which leads to the Framework 2.0 presented below.

5.2 IMPLICATIONS FOR CHANGE

The implications for revising and redesigning the Framework for Inclusive Science Education 1.0 were compiled from the application of the Framework to practice by the researchers of the Nawi-In project, as well as from final theses and discussions of student teachers who have also applied the Framework. In each case, the implications justify changes for the redesign of the Framework.

Simplifying the structure

Due to the large scope of the original Framework, it was challenging for researchers not involved in the Nawi-In project to apply the Framework. Consequently, training with the Framework 1.0 was time-consuming. For this reason, the structure of the Framework 1.0 was to be simplified. This was implemented by unifying the structure. This means that subcategories and codes per main category were mainly unified through the Framework 2.0.

Creating an overview

In order to better navigate the extensive Framework 2.0 and to better provide training to others on the Framework, student teachers have requested a simplified overview in addition to the Framework. This overview is provided in the course of the revision of the Framework. It shows the scientific characteristics of the main categories and the recurrent inclusive approaches at the subcategory and code level (tab. 1, p. 20).

Review and extension of the code level

Through the inductive extension of the Framework 1.0 when applied to the data of the Nawi-In project, it has become apparent at the code level that some inclusive approaches were to be found under several science characteristics (e.g., *Enabling … with visual support, Enabling … with experiments, …*). For this reason, the structure could be standardised for the same codes, which has led to simplification. In addition, inclusive approaches were added as potential codes for further science characteristics in order to make the code level more uniform among all main categories. Thus, a great benefit of the Framework 2.0 is its predictive nature on inclusive approaches that were not thought of yet.

Removal of the subcategories on different levels of requirements

The subcategory on different levels of requirements under each main category showed that the codes and subcodes were not disjunctive to other categories of the Framework, e.g., *Enabling learning with scientific information media on an easy level ... (11.7.1)* (Brauns & Abels, 2020, p. 69-72):

... by visualisations (11.7.1.1)	vs.	*Developing visual scientific information media (11.1.11)*
... by structuring aids (11.7.1.2)	vs.	*Supporting learning with scientific information media by structuring (11.1.11)*
... by avoiding scientific terminology (11.7.1.3)	vs.	*... by avoiding unnecessary scientific terms (11.3.1.1)*
... by simple speech (11.7.1.4)	vs.	*Supporting learning with scientific information media with linguistic simplification (11.3.6)*

For this reason, all categories for the different requirement levels were deleted.

Removal of the main and subcategories addressing the science learning environment

The analyses have shown that the science learning environment should be superior to the Framework. Teachers usually have no direct influence on the nature of the science learning location, i.e., a classroom or a laboratory. In addition, the science learning location as a main category does not change over a complete lesson and as a subcategory does not change in relation to certain science characteristics. This was shown, for example, in the analysis of the video vignette in the Nawi-In project, where the main category of the learning location was coded over the entire vignette (Brauns & Abels, 2021b). These reasons led to the removal of the main category 'science learning environment' (fig. 6, p. 15).

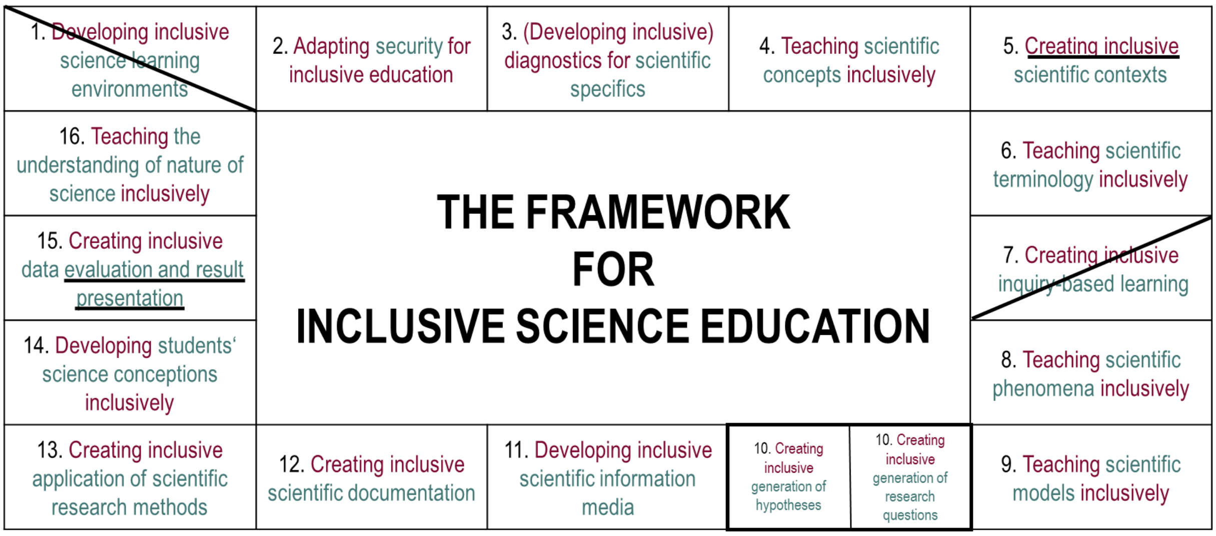

Fig. 6. The Framework for Inclusive Science Education adaptions

Removal of the main category addressing inquiry-based learning

For the main category of inquiry-based learning, it has been shown that a science lesson can only be classified as inquiry-based learning in a superordinate way (fig. 6). In order to identify inquiry-based learning, many aspects of the lesson have to be taken into account, for example, the phases of the 5E-model according to Bybee et al. (2006) (Engagement, Exploration, Explanation, Elaboration, Evaluation), which can extend over a complete lesson. For this reason, the categories for inquiry-based learning could only ever be applied to whole lesson videos. Therefore, it turned out that the categories were not always disjunctive, for example (Brauns & Abels, 2020, p. 62):

Creating inquiry-based learning inclusively ... by help cards for the experimental setup (7.1.1.1)	vs.	*Creating application of scientific research methods ... by help cards with sketches of the structure of the experiment (13.1.10.4)*

Separation of scientific questions and hypotheses as a main category

When applying the Framework 1.0 to the classroom videos as well as to the VSRef, it became clear that scientific questions and hypotheses are often addressed one after the other as separate or single steps. Therefore, this main category was divided into two for the Framework 2.0 (fig. 6).

Further implications

Moreover, the application of the Framework 1.0 drew attention to further individual categories that were not disjunctive (fig. 6). For example, *oral accesses* were to be combined with approaches *in dialogue* and *independent elaboration* was to be integrated as an approach to the *open design of a science characteristic*. In addition, it became clear during the application of the Framework 1.0 that there are generally inclusive approaches (e.g., *enabling via linguistic simplification, supporting as a learning guide*, etc.) and science-typical inclusive approaches (e.g., *enabling model-based, enabling experimentally*) in the Framework. In order to clarify the science-characteristic nature of the Framework once again, science-typical inclusive approaches are highlighted in the overview by underlining (tab. 1, p. 20).

Implications we decided against

Implications we decided against included, for example, the separation of science characteristics and inclusive approaches. This has only been adopted for the simplified overview in this paper. For Framework 2.0, it was important for us to clarify the connection of the scientific with the inclusive implementation as the goal of the creation of the Framework.

In addition, it was suggested to remove the subcode level in order to reduce the scope of the Framework. However, we see the subcode level in particular as important, because this level is often missing in the literature although it no longer leaves open questions of concrete implementation. For this reason, the subcode level was retained and simplifications were implemented through an overview and a unified structure.

5.3 THE FRAMEWORK FOR INCLUSIVE SCIENCE EDUCATION 2.0

The new and revised Framework for Inclusive Science Education 2.0 has a total of n=2117 categories, which, as in the first version of the Framework, are distributed from the main category level, through the subcategories, codes to the subcodes on a total of four levels of abstraction. This means that 1182 categories were added to the Framework during the validation process. These categories were derived inductively and added by expanding the subcategory with possible categories.

There are n=15 main categories (fig. 7, p. 17). Due to the adaptations described in the previous section 4.2, there is one main category less in Framework 2.0 in terms of total number. No further categories have been added for the science learning environment and inquiry-based learning as these categories are no longer present in Framework 2.0.

<table>
<tr><td>1. Adapting security for inclusive education</td><td>2. Developing (inclusive) diagnostics for scientific specifics</td><td>3. Teaching scientific concepts inclusively</td><td>4. Creating inclusive scientific contexts</td><td>5. Enabling the development of scientific terminology inclusively</td></tr>
<tr><td>...</td><td rowspan="3" colspan="3">THE FRAMEWORK
FOR
INCLUSIVE SCIENCE EDUCATION
2.0</td><td>6. Teaching scientific phenomena inclusively</td></tr>
<tr><td>15. Teaching the understanding of nature of science inclusively</td><td>7. Teaching scientific models inclusively</td></tr>
<tr><td>14. Creating inclusive data analysis and presentation of results</td><td>8. Creating inclusive generation of research questions</td></tr>
<tr><td>13. Developing students‘ science conceptions inclusively</td><td>12. Creating inclusive application of scientific research methods</td><td>11. Creating inclusive scientific documentation</td><td>10. Developing inclusive scientific information media</td><td>9. Creating inclusive generation of hypotheses</td></tr>
</table>

Fig. 7. The Framework for Inclusive Science Education 2.0

Each main category has a total of n=12 subcategories (fig. 8, p. 18). In Framework 1.0, the number of subcategories was different in each main category. The number of codes around n=90 in every main category of the Framework 2.0[3]. The same number of categories for these levels – subcategories and codes – is due to the fact that these levels were theoretically further developed and systematised with potential categories. This means that approaches that have proven successful in the application of the Framework to different scientific characteristics were initially assumed to be theoretically applicable to other scientific characteristics. Therefore, the numbers of codes in the main categories are now the same (despite one exception), whereas previously there were large differences in the numbers of codes. Overall, there is a considerable increase in the number of codes.

[3] Only category 12 (Creating inclusive application of scientific research methods) has n=100 codes, as more codes could be derived from the data.

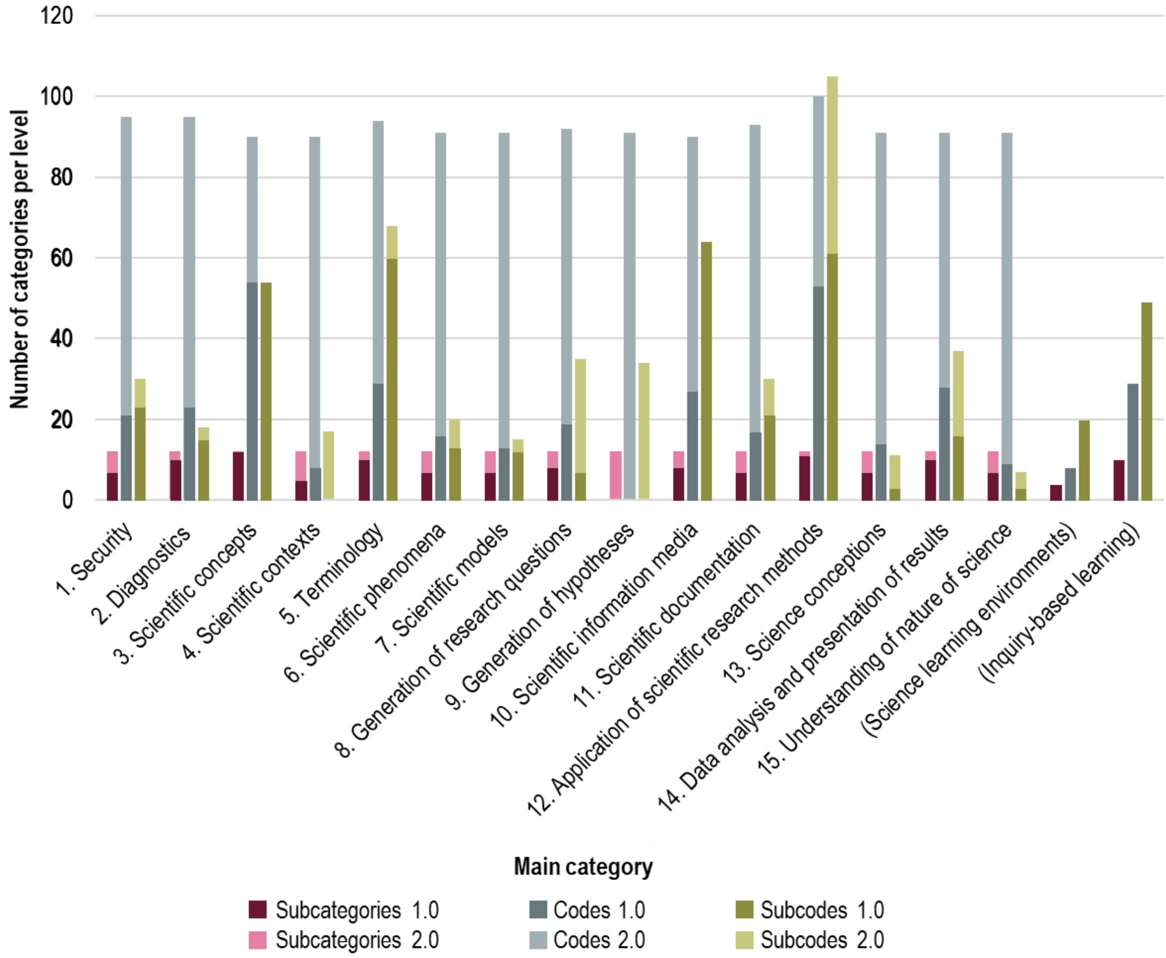

Fig. 8. Distribution of the categories of the Framework 2.0

At the subcode level, the concreteness of the implementation notes meant that only categories derived from either the literature or the data from the Nawi-In project were listed. For this reason, there is a wide range in the number of categories at this level. *Category 15. Teaching the understanding of nature of science inclusively* has the fewest subcodes with n=7. Main categories with the most subcodes include *(12.) Creating inclusive application of scientific research methods* with n=105 subcodes, *(5.) Enabling the development of scientific terminology inclusively* with n=68 subcodes and *(10.) Developing inclusive scientific information media* with n=64 subcodes. Especially categories on *(8.) the generation of research questions, (9.) the generation of hypotheses*, *(12.) research methods* and *(14.) data analysis* gained high number of subcodes. The adaptation of a general structure that extends through the entire Framework 2.0 can be seen in the descriptive statistics (fig. 8), at the subcategory and code level, because of the fact that the numbers of categories at these levels are approximately equal. To unify the structure, the inclusive approaches of the science characteristics were compared and summarised at these levels.

In this way, the recurring structure emerged, which is presented in the overview table of the Framework 2.0 (tab. 1, p. 20). In the first row, the scientific characteristics (e.g., technical language, hypotheses, scientific student conceptions, etc.) are presented. The first column shows the inclusive approaches at the subcategory level (e.g., material-guided, addressing different senses, etc.). The more concrete approaches of the code level (e.g., visual, phenomena-based, etc.) are shown in the connection between the scientific characteristics and the inclusive implementation. This structure has been presented in a minimalist way in order to make the overview as simple as possible and to be able to search or look up the more precise formulations with the help of the keywords in Framework 2.0.

Tab. 1. Overview of the Framework 2.0 (underlined Codes=scientific)

Main Category Level	Subcategory Level	Code Level
1. Adapting security … 2. Developing (inclusive) diagnostics for scientific characteristics … 3. Teaching scientific concepts … 4. Creating scientific contexts … 5. Enabling the development of scientific terminology … 6. Teaching scientific phenomena … 7. Teaching scientific models … 8.Creating inclusive generation of research questions … 9. Creating scientific hypotheses … 10. Developing scientific information media … 11. Creating scientific documentation … 12. Creating the application of scientific research methods … 13. Developing students‘ scientific conceptions … 14. Creating data evaluation and presentation of results … 15. Teaching the understanding of Nature of Science …	… materially guided	… through figures
		… through (tip) cards, templates, etc.
		… through protocols etc.
		… through tables
		… through graphic organisers
		… text-based
		… model-based
		… through enlargements or enlarged materials
		… through material tables etc.
		… on whiteboards etc.
		… through real objects
	… by addressing different senses	… visually
		… olfactorically
		… gustatorilly
		… tactilely, vibrating, tangible, Braille, etc.
		… acoustically
	… action-oriented	… through modelling
		… through play
		… through building, construction, etc.
		… through experimentation, trial and error, observation, etc.
		… through collecting
		… through station work
		… through demonstrating activities, showing off, etc.
	… based on cognitive support	… through comparing, contrasting, sorting, ordering, etc.
		… through mnemonic strategies
		… through examples, analogies, references, etc.
		… in relation to everyday life, etc.
		… context-based
		… problem-based
		… phenomenon-based
		… concept oriented
		… in a pre-knowledge/conception-based way
		… rule-based
		… through justification through relevance
		… through Nature of Science
		… through control strategies
		… through reading strategies
	… based on linguistic support	… multilingually
		… through everyday language
		… through technical language
		… through sign language
		… through linguistic simplifications
		… through content support
		… through grammatical support
		… through word memory

Main Category Level	Subcategory Level	Code Level
1. Adapting security … 2. Developing (inclusive) diagnostics for scientific characteristics … 3. Teaching scientific concepts … 4. Creating scientific contexts … 5. Enabling the development of scientific terminology … 6. Teaching scientific phenomena … 7. Teaching scientific models … 8.Creating inclusive generation of research questions … 9. Creating scientific hypotheses … 10. Developing scientific information media … 11. Creating scientific documentation … 12. Creating the application of scientific research methods … 13. Developing students‘ scientific conceptions … 14. Creating data evaluation and presentation of results … 15. Teaching the understanding of Nature of Science …	… digitally	… through videography
		… through films, programmes, etc.
		… through audio books
		… through PCs, smartphones, tablets, cameras, etc.
		… through apps, computer programmes, etc.
		… through the Internet
		… through simulations, animations, etc.
		… by using beamers, LCD projectors, etc
	… communicatively	… orally, in dialogue, etc.
		… in individual work
		… in partner work
		… in group work
		… in plenary
		… as a learning support
		… as a (multi-professional) team
	… through different degrees of openness	… in a closed, confirming way, etc.
		… in a semi-open, structured, accompanying way, etc.
		… in an open, independent way, etc
		… by creating transitions
	… at different levels of abstraction	… on an elementary, material, naive-concrete, etc. level
		… on a symbolic level
		… on an abstract, sub-microscopic level
		… by creating transitions
	… in a reflective way	… through discussion
		… through individual world views, constructions, beliefs
		… by recognising limits
		… by confronting with a professional perspective
		… through awareness
		… through verifying
	… in a constructive learning atmosphere	… multiculturally
		… through inquiry-based learning
		… through classroom management strategies
		… in a gender-neutral way
		… in a student-centred way, starting from the students, etc.
		… in a motivating way
		… in an appreciative manner
		… with enough time
		… with patience
		… with flexibility
		… with a positive error culture
		… with a sense of community
		… with fear reduction
		… with consideration

In order to present the Framework 2.0 in the best possible way, this time the Framework is provided as an extra Excel file for download (www.leuphana.de/inclusive-science-education). In this file, the Framework 2.0 is shown in both English and German. In order to clarify which categories were already present in the original Framework, which categories were developed through the application to practice in the Nawi-In project and which categories were anticipated for the inclusive design of the science characteristics, we applied different markings (see Excel appendix).

6. DISCUSSION

Are the validation techniques legit?

The validation on practice through data triangulation (Flick, 2019; Lamnek & Krell, 2010) has shown to be useful to relate the validation process to the goals and data of the Nawi-In project as recommended in the literature (Stasik & Gendzwitt, 2018). In this way, the Framework could be economically validated and further revised, while the Framework itself could be used to analyse the professional competencies related to inclusive science education. By anchoring both strands (fig. 2, p. 5), no additional data had to be collected and analysed for the revision of the Framework.

It is striking that in the analysis of the VSRef, a larger proportion of inductive categories was derived at the code level than at the subcode level (Brauns & Abels, submitted c). This illustrates that either the degree of abstraction of the connection between science and the inclusive implementation in the VSRef was presented less concretely or the student teachers mainly expressed aspects in the VSRef that were already derived and intended through the literature review and the application of the Framework to the video vignette. In addition, the considerable proportions of the categories at the subcode level of each video analysis show how rich in content videos are and how concrete actions can be derived from them. Since practice is individual and diverse, almost endless subcategories can be derived from classroom videos.

Thus, the development of the inductive categories shows that videos are particularly suitable for expanding the categories. As different data and different sample sizes were present in the individual analyses, the proportions of inductive and deductive categories are compared in figure 2 (p. 5). The largest proportion of inductive categories, 40%, was coded from the video vignette. This result can be explained by the fact that in each subsequent analysis the Framework had already been expanded, so that fewer new categories were added. However, it is striking that the proportion of inductive categories is greater in the analysis of the classroom videos than in the analysis of the VSRef. The advantage of videos is their richness of information (Tuma et al., 2013).

To what extent has the quality of the Framework increased?

In general, the review of the quality criteria shows that they were met in the application and revision of the Framework. The reproducibility for verifying the quality is enhanced by the fact that both the derivation of the Framework from the literature and all validations on practice were presented in detail and published open access. In terms of reliability, the data in a research project has to be allowed to be used by a second person, for example, to obtain double coding for intercoder reliability (Döring & Bortz, 2016; Mayring, 2014). Despite the fact that the Framework 2.0 has an even larger scope than the original Framework 1.0, changes have been made (e.g., the overview table, uniform structure) to make it easier to apply. The subcodes already provide extensive concrete guidance for the implementation of inclusive science education, while there are still large gaps, especially in the categories with fewer subcodes. The fact that in fourteen main categories the number of subcodes is lower than the number of codes also shows that especially on the most concrete level there are gaps. These can be successively closed by analysing classroom videos with different focuses, i.e., different main categories need to be addressed. The extent to which this has been achieved will become apparent in the further application of Framework 2.0 through further data analysis. By incorporating the implications for categories that were not previously definable, the results of Framework 2.0 became free of contradictions (Steinke, 2010). This was achieved as a consequence of the unified structure which made it possible to verify precisely up to the code level whether the categories were disjunctive from each other. Further confirmation of the coherence will also be provided by continued application of the Framework 2.0.

To what extent are the inclusive approaches also evident in other frameworks?

In addition, the Framework 2.0 continues to make a relevant contribution to research on inclusive science education. There is still no comparable framework that summarises the connection between the characteristics of science and inclusive pedagogy and yet depicts it in a concrete and systematised way. Moreover, frameworks for the implementation of inclusive teaching (e.g. Florian, 2014; Soukakou et al., 2014) only cover a part of the inclusive approaches of the comprehensive Framework 2.0. For example, the European Agency for Special Needs and Inclusive Education (2017, p. 7) lists the following categories:

- Overall welcoming atmosphere
- Inclusive social environment
- Child-centred approaches
- Child-friendly physical environment
- Materials for all children
- Opportunities for communication for all
- Inclusive teaching and learning environment
- Family friendly environment

These categories are an example of how most frameworks always leave questions open as to what teachers can specifically do to create an inclusive lesson. For example, what are 'Materials for all children'? The Framework 2.0 provides a complete main category that describes how science information media can be designed inclusively. In addition, the Framework 2.0 does not only deal with materials, phenomena or models etc., but also with actions (e.g., phrasing hypotheses, applying scientific research methods) and describes concretely how these can be implemented inclusively.

Why is the subcode level legit?

Nevertheless, the concreteness of Framework 2.0 results in an enormous volume of categories, which is why it should be discussed to what extent a reduced Framework would operationally make sense. According to Mayring (2015), saturation should occur after 10-50 % of the data to be analysed. However, the descriptive statistics show that saturation has still not been reached at the subcode level. While the aim of inductive generation in qualitative research is usually to find generally valid categories, the Framework 2.0 fulfils other aims. "It has to be checked [...] whether the level of abstraction is adequate to the subject matter and aims of analysis" (Mayring, 2015, p. 375). As before, the summarising categories at the main and subcategory level leave questions open as to how science education can be implemented inclusively (Brauns & Abels, 2020). Only with the help of the concrete (sub-)codes, the Framework 2.0 can advance the conceptual and operational understanding of the connection between science and inclusive implementation in a comprehensible and transparent way for others. In addition, only in this way, the Framework 2.0 can function as a guide for student teachers and teachers, so that they receive examples, which they can directly implement in practice.

To what extent does the Framework 2.0 reflect the connection between science characteristics and inclusive pedagogy?

Overall, it appears that the connection of science characteristics with inclusive pedagogy would be interchangeable with the characteristics of other subjects in some places. This is evident in those approaches that are generally inclusive, as described earlier in the findings. This could lead to the assumption that the Framework 2.0, like other frameworks of inclusive education (e.g. Florian, 2014; Soukakou et al., 2014), would be separable from the science characteristics and could be formulated as a general, subject-unspecific Framework. This is where we see the risk in using the Framework 2.0 for both planning and researching inclusive science education. The fact that the inclusive approaches are each assigned to a characteristic science subject is an added value for structuring lesson planning and research. For example, if teachers use experiments in their lessons, they can use the Framework 2.0 to specifically plan the inclusive implementation of the experiments. In research, focussing is possible in a similar way.

7. IMPLICATIONS AND LIMITATIONS

The revised and extended structure of Framework 2.0 has created more possibilities for integrating the Framework into teacher education and research. First of all, the overview table can be used. At first glance, the main inclusive approaches to the different science characteristics can be identified. The overview can be used, for example, as an introduction in teacher education, in short professional development courses with rather little time and as an introduction to the education of other researchers. After the introduction via the overview table, it is possible to go deeper into the Framework 2.0 with the Excel file. In this file, further approaches on the code level are listed and the subcode level is also shown. With the complete Framework 2.0, it is possible, as with the previous version, to view or apply the Framework either in fragments or as a whole. This means that, for example, only a certain main category can be considered. In this way, the focus is placed on a certain scientific characteristic and the categories of the other levels are optionally included for this feature. In addition, it is possible to use all scientific characteristics, i.e., all main categories. Optionally, other levels (subcategory level, code level, subcode level) can be included. Overall, the Framework for Inclusive Science Education 2.0 makes it possible to plan, reflect and research inclusive science education intensively.

The original Framework displayed the desiderata of the research in inclusive science education, which was at the same time, because of the gaps, a limitation of the Framework. The revision of the Framework has now reduced the limitations in describing, how inclusive science education can be implemented through greater saturation. However, it is still not possible with Framework 2.0 to make a final judgment as to whether a lesson with a variation of inclusive science characteristics implemented actually leads to participation of all students. With the Framework 2.0, it is rather the aim to systematically map the inclusive approaches to science education. Normative assumptions must still be made or data on student participation has to be added and investigated.

8. OUTLOOK

In the further course of the validation process, the Framework 2.0 is next applied to the analysis of the Video Stimulated Recalls (VSR). In the VSRs, the student teachers reflect on their own classroom videos with regard to inclusive science aspects. With the help of the Framework 2.0, the audiographed and transcribed VSRs are analysed to determine which inclusive science characteristics the student teachers notice in their own teaching videos. In doing so, their perception is analysed in terms of professional vision (Sherin, 2007). The application of the Framework 2.0 for the analysis of the VSR describes a further validation on practice (fig.

2, p. 5). The applicability – or more precisely the reliability and coherence – of the Framework is reviewed again.

In terms of the transferability of the Framework 2.0, colleagues from other subjects are welcome to transfer the Framework to their subjects in the future. In the first step, the characteristics of other subjects need to be identified. The next step would be to check which inclusive approaches could be related to the other subject characteristics and where adaptations would be needed.

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APPENDIX

The Framework 2.0 Excel file is available for download on www.leuphana.de/inclusive-science-education

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