Common Reference Framework for Natural Sciences (CRFS)

Minimum Standards for Natural Science-Related Education.

A Suggestion.

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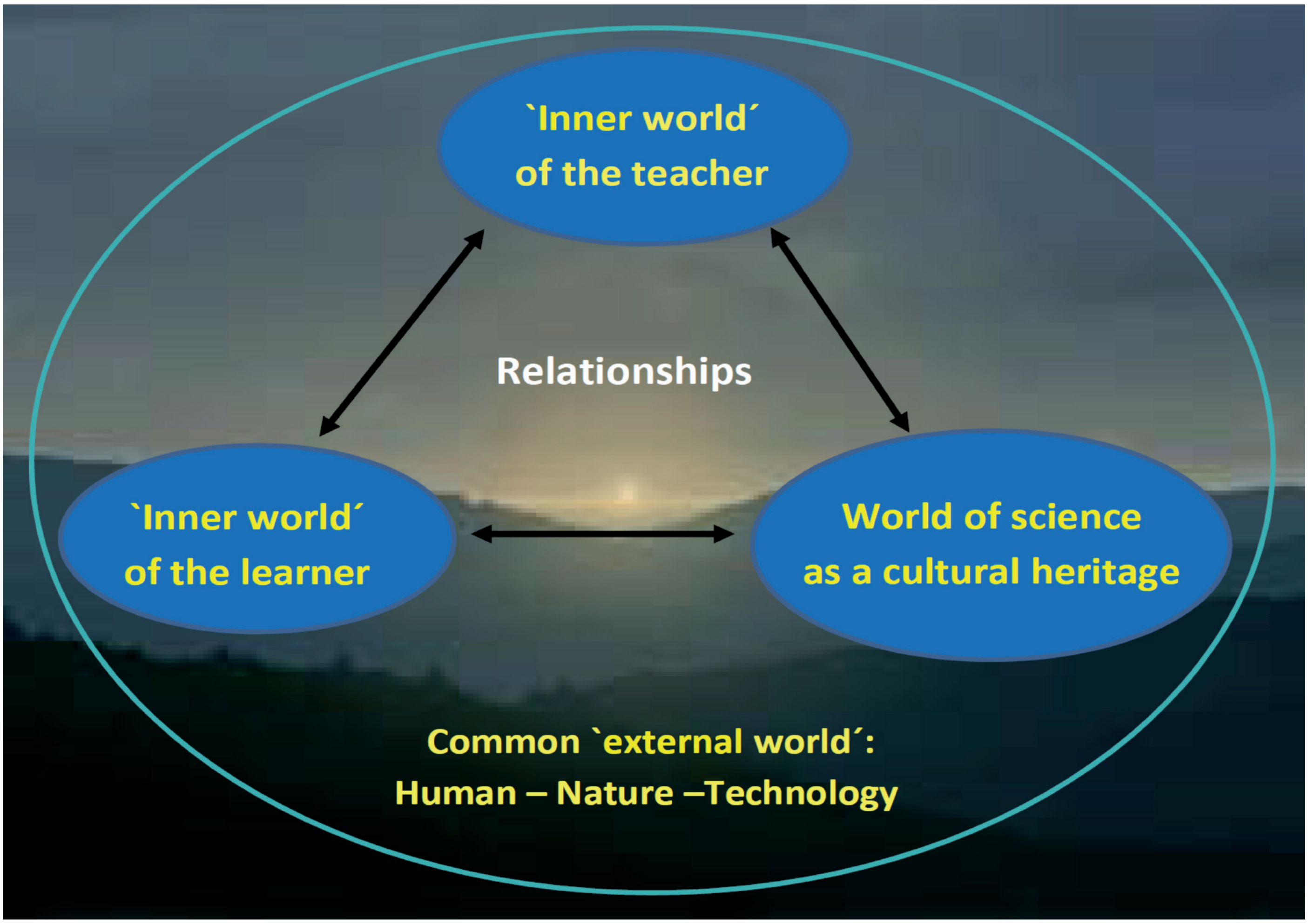

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01 Improving education: changing the way in which science is learned and taught

Scientific education forms part of general education, just as do, for example, music, literature and philosophy. Natural sciences, as a cultural heritage, form the basis for the future of humankind. Upcoming difficult decisions in the politics of climate, in medicine, or in the digital age will only be possible if the normal citizen has at least a basic understanding of them. This in turn can only be expected in a scientifically responsible society.

Teaching in natural sciences needs to continually adapt to new demands, which can result from new knowledge in the scientific disciplines, from changes in society and ecology and also from well-founded empirical results on the effectiveness of teaching itself.

In this article we shall first address and bundle some well-known previous suggestions on the organisation of science teaching; we shall however also turn aside from previous models, in order to give education in natural sciences the validity which it requires for the understanding of today's scientifically based world and for the solution of future problems. Thus we shall be dealing with the sustainable realisation of the goals which are discussed in the following Chapters 2 to 4 of the suggested Common Reference Framework for Natural Sciences (CRFS).

01.1 The Present Situation and Previous Attempts at its Improvement

The present situation

For many decades it has been deplored, both nationally and internationally and not only within the subjects themselves, that learners lose much of their initial interest in scientific and scientific-technological topics during their progression through school. After seven to ten years, chemistry and physics are among the least popular subjects, although the pupils are often highly motivated by the general science taught at primary school.

One must thus assume that, at secondary school level, the curricular demands provide the learners with challenges with which they cannot cope or which they find uninteresting. The problem of a steep decline in interest in science was observed internationally as early as the 1960s. The term "swing from science" was coined in the scientific literature (DAINTON-Report, 1968), and was shown to apply even in those countries which large-scale education studies showed to be doing relatively well (OSBORNE, SIMON & COLLINS, 2003, LYONS, 2006). In Germany there were no regular studies and statistical analyses on the performance of the educational system prior to the end of the last century. Starting with the Third International Mathematics and Science Study carried out in 1995 and from the PISA studies carried out every three years from 2000 on, German pupils exhibited continually increasing performance in the area of natural sciences. A critical aspect is however the fact that until today the fraction of pupils whose performance is in the lowest levels of competence is much too high.

In 2007 the EU Commission published a reference framework for life-long learning which lists eight key competences, the third being the scientific competence, defined as follows: "the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to draw evidence-based conclusions".

The preconditions for this are that the learners have the necessary knowledge (basic principles, methods), abilities (concepts) and attitudes (critical appreciation, curiosity, interest, respect). With

respect to this functional education concept, it is vital that all those directly and indirectly involved in the education processes ask themselves which basic principles, scientific concepts and methods need to be presented in order to achieve an appropriate orientation in a world which is becoming ever more complex.
Because of the poor learning results achieved in the past, it is necessary to question critically whether transformatory processes in natural science teaching can be encouraged and to understand their implications. Calls for transformatory education require, on the one hand, that learners are prepared for their future life in such a way that they will be capable of observing important developments and changes in society and environment, to understand as far as possible their implications or to inform themselves about them in a suitable manner. On the other hand it is important to give learners the capability of actively taking part in societal decision-making processes in an ever more complex world, so that they may themselves make a contribution to sustainable development (Brookfield, S. D., 2012; Koller, H.-C., 2012; 2016).

There is however no consensus as to which areas should be in the focus of teaching in natural sciences. There is agreement that a broad societal participation by informed citizens in the relevant scientific and technological decision processes is necessary; this itself requires differentiated and appropriate subject competence in the general population.
This Common Reference Framework for Natural Sciences (CRFS) has a responsibility to attempt to fill this need. The content-related goals as well as the selection and analysis of the required competences have been carried out against the background of the following questions:

1. What relevance has the topic being learned for the orientation of the learner, both now and in the future?
2. Which overarching metacognitive competences may be stimulated and strengthened by the topic being learned?
3. How does the learning object affect the individual meanings and beliefs that are deeply rooted in the learner in the context of sustainable development?

Because of the enormous growth in scientific knowledge and the plurality of discussion in society, it is not easy to answer these questions, which require a high degree of communicative validation by those taking part. The transformative education perspective also needs to take into account that people's everyday ideas are relatively constant (Kattmann, 2015). The enhanced educative aspirations of the CRFS allow not only the questioning of individual perspectives on phenomena and concepts with a scientific connotation, but also of the related societal developments and decision processes. This aspiration thus goes further than a material, functional and also formal (learning to learn) education. It requires a high degree of reflexivity, autonomy and inner consistence of learners and finally also defines their attitudes.

A suggestion built on such foundations can never be complete, but must be regularly modified both didactically and societally. The model for the CRFS is the Common European Framework for Languages (CEFR) (https://www.coe.int/en/web/common-european-framework-reference-languages/level-descriptions). This has proved itself because of its ability to qualify and certify language abilities at various levels. Like the CEFR, the CRFS is not a curriculum! It does not list the topics to be covered in teaching, but makes statements as to which scientific (and overarching) competences should be present in our society, independent of the education pathway, defined at five levels. Certificates given on the basis of differentiated tasks can be used to certify the scientific competences.

Studies about Interest and Attempts at Improving the Situation

Many attempts have been made to improve the attractivity of teaching in science. Corresponding programmes, such as the Nuffield courses in England and the PSSC physics courses (Physical Science Study Committee, 1956), attempt to support the ability of the student to act independently and to connect with his/her interests. This, as well as other approaches, made however but little difference to the situation. Attempts to make teaching in natural science more attractive simply by using didactic methods, but without taking into account the structure of the content and the perspective of the learner, were not successful (KRAPP, 1992, p. 756).

As a result of these findings, projects for the implementation of curricula which are closely oriented to the world around the student started in various countries (e.g. England: Salters Chemistry/Physics/Biology; USA: Chemistry in the Community, Germany: Chemie/Physik/Biologie im Kontext). Previous results with respect to the influence of this type of curricula on the development of the individual interest of the learner, as well as on his or her cognitive development, are encouraging (e.g. PARCHMANN et al., 2006; DEMUTH, GRÄSEL, PARCHMANN & RALLE, 2008); however, they do not permit any final conclusions to be drawn. It must however be taken into account that context-oriented teaching sticks to (must stick to) the defined curricula and does not generally clearly reduce the degree of abstractness and the complexity of the formal learning topics, notions and concepts

Knowledge in science and technology is considered to be very important in society. As surveys have shown, it needs to be completely incorporated into school curricula (e.g. OSBORNE & COLLINS, 2000, S. 5). For more than 30 years the necessity has been seen, both nationally and internationally, to make modificaions to natural science teaching. We therefore call for profound changes in learning and teaching in science. We consider one prerequisite to be a structuring of the curricula and learning processes which is oriented towards the abilities, previous knowledge and interests of the learner. In addition it is important to consider the teaching process itself.

01.2 Consequences

Since it has previously not been possible to make real improvements to the results of education in science, we suggest that there be a change in perspective and that we look more closely at the process of education itself, in order to address the consequences for science learning and teaching.

Change in Perspective

Any teaching can only be effective when one takes into account that it also always involves relationships, on the one hand between the learner and the teacher, and on the other between the learner and the topic being taught (Fig. 1).

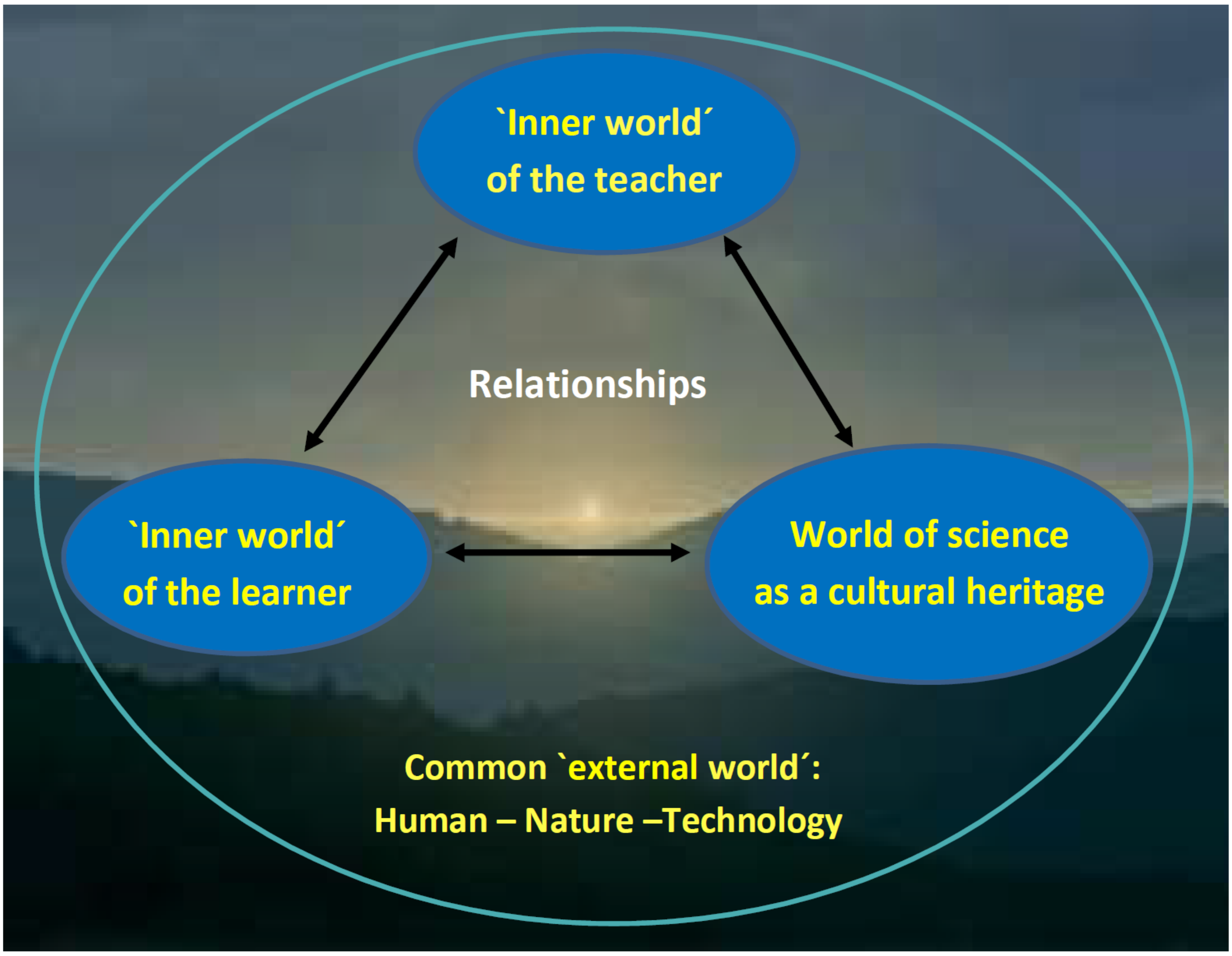

Fig. 1. Relationships in education, shown in a modified didactic triangle

In order that science education be successful, at least four different „worlds" should be taken into account, differentiated between, and brought together in the educational process:

1. the *„external world"*, the common environment of the teacher and the learner
2. the *„inner world"* of personal experience, personal knowledge and thinking of the *learner*
3. the *„inner world"* of personal experience, personal knowledge and thinking of the *teacher* and
4. the *„world of science",* a cultural heritage devised by man.

It is thus not sufficient to carry out a clever didactic treatment and reduction of the fields of experience of the various natural sciences. The necessary "rethinking" requires that, apart from all the didactic considerations, we look very carefully and in detail at the "inner world of the learner". Thus attention must not be focussed solely on the structure and content of the science to be taught. If one also takes equal account of developmental experience, the learners' perspective of the world around them, the present stage of their cognitive structures, their personal experience and their everyday knowledge and understanding of natural phenomena and technology, then basic knowledge of developmental and cognitive psychology become much more central to teaching and learning (PLAPPERT, 2016). Such a perspective of the learning preconditions and learning processes requires that we immerse ourselves much more into the thought processes of the learner, as HATTIE (2014, p. 14) formulates it:

"Before teachers can help pupils to „construct" knowledge and understanding, they must be conversant with the different ways in which pupils think".

If this is not taken into account, the learners can feel cognitively overstrained, and they will resign and turn away – often for their whole lives – from scientific topics.

Taking the way in which pupils think into account forms the basis for, among others, educational reconstruction (KATTMANN, DUIT, GROPENGIEßER & KOMOREK, 1997; DUIT et al. 2012). Even when this process brings to light ideas expressed by the learner which differ from those which are considered to be factually correct, these every day conceptions must not be treated as misconceptions, but as learning preconditions which may under no circumstances be ignored. After all, they have been developed by the learner across a period of years on the basis of his or her daily experience and thus have for him or her their own individual significance (DUIT, 1993; 2009; HAMMANN & ASSHOFF, 2014; KATTMANN, 2015).

All learning takes place on the basis of what has already been learned, eperienced and discovered. This can be revised (looked at anew), but not readily be replaced. In the process of educational reconstruction, subject-based statements and concepts expressed by the learner are thus systematically related to each other in order to organize teaching which will support fruitful and sustainable learning. When the teacher is familiar with the learner's perspectives, he or she can see which obstacles and possibilities, and which thought processes, should be taken into account in learning subject matter. It must also be remembered that there is no simple route from the learner's preconcepts, derived from everyday experience, to scientific concepts. The process of "conceptual change" may on no account be understood as a simple replacement of everyday ideas by scientifically reliable concepts. The teacher must always remember that the learners have so far got along fairly well with their ideas, and that they were in general satisfied with them. It is thus necessary to start from these concepts in order to use them for a meaningful learning process (conceptual reconstruction).

In addition, schools and other education institutions have the task of realising an education concept in which those attitudes which are particularly related to natural science as a cultural asset are encouraged; these indeed have a much greater general importance. They include exactness, honesty – also with respect to the limits of scientific approaches – and a wish to be able to recognize and understand interrelationships. Such attitudes are essential for gaining knowledge and for the ability of the learner to assess societal problems (SCHAEFER, 2007). They are thus important elements of a transformative scientific education.

Stepped education - different Degrees of Understanding

The education process must take account of the development of the learner from early childhood to adulthood. Independent of the maturity of the learner, he or she should have a possibility in any learning situation to open him or herself to the phenomena in the world around, in order to „link up with them", i.e. to have a personal relationship with them on an emotional level. Dependent on their personal cognitive abilities and interests, the learners should be guided more or less far towards scientific terms and concepts. Thus, the learners can incorporate the scientific conceptions into their personal network of conceptions and be able to advance from a superficial to a deeper structure of knowledge, i.e. to a deep understanding of scientific relationships. In such a way those emotional-psychological aspects which influence the affective attitudes and convictions of the learner are also taken into account. Thus one takes into account the realisation that the enjoyment of involvement with a learning topic has an effect not only on the appreciation of the issue at hand, but also on the willingness to deal more closely with this topic in the future (AINLEY & AINLEY, 2011). This type of teaching should lead to a niveau progression which not only leads to a better general scientific general knowledge but also encourages particularly talented and interested learners.

Education as a Process

A precondition for a successful science education is that both the teachers and the learners have a „research attitude“. This will allow the teachers to connect their own ideas with the „inner world of the learner“ in a constant process, in direct contact and in dialogue with the learner. It is vital to replace the "culture of quick answers" by a „culture of questioning“; this requires patience and perseverance from both teacher and learner, and must include the idea of a *provisional* nature of answers. This research attitude has great general educational value, and is a precondition for a self-controlling lifestyle.

A futher basic assumption is that education can only then reach the learner's underlying structure if the latter can initially describe what he or she experiences, and what is dealt with in teaching, appropriately *using his or her own everyday language*. This leads to a first comparison between the new material and available mental pictures. It is thus possible to compare and combine this newly treated material with personal preconceptions.

Everyday conceptions – very often assessed as learning difficulties – can be made usable for the teaching process by means of educational reconstruction (KATTMANN, 2015; 2017). According to their type this can be done in four different ways:

– Connection: an aspect of everyday experience is found which corresponds to a subject-based one and which thus offers a way towards developing ideas appropriate to the subject under consideration. For instance, the everyday concept of "energy consumption" can be dealt with by explaining that energy flows through a system. Thus "consumption" can thus be replaced by intake and output, and according to the teaching concept can lead to the term entropy generation or the so-called energy degradation.

– Completion by using a different point of view (change of perspective): the way of thinking used in everyday life is added to by using another point of view, which revises the everyday perspective (lets it appear in a new light). Thus the everday concept of substances as „energy carriers“ is revised by taking into account the reaction partner oxygen, which is initially ignored because it is not visible. In this manner the energy, which is initially ascribed to only one reaction partner, is recognised as a reaction energy, which only becomes available via the chemical reaction between both reaction partners.

– Contrast: the scientific experience is contrasted to the everyday experience as an alternative. This can lead to a cognitive conflict. The electricity meter known from everyday life does not, scientifically expressed, measure electric current but the electrical energy used. The electrical current strength is always exactly the same in both the forward and reverse lines.

– Build a bridge: sometimes preconcepts provide a chance to progress to more correct solutions than without their being present, sometimes even without showing them to be incorrect. Thus the tendency of learners to arrange organisms according to their habitat leads to the possibility of revising the predarwinian classification according to characteristics, and to replace it by descent communities, the evolution of which can be understood on an ecological basis.

Such an educational approach in natural sciences requires time. It thus requires a concentration on fundamental examples, by means of which the learners recognize elementary relationships and concepts and can proceed to more profound insights. This allows a successful use of "basic concepts".

Teaching also becomes more successful when the learners are taught according to their stage of development. For example, mathematisation in physics, the clear differentiation between substances and particles in chemistry, and the molecular level in biology, are much easier to deal with at higher school levels than at elementary level. There they can much more readily be really understood than when they are taught too early, often with the help of a large amount of exercises (and still too often *not* really understood). Teachers should never be satisfied with introducing concepts and material using empty phrases such as those found in subject terminology, which can be learned by rote without any degree of understanding. Terms which are presented must be “alive”, i.e. they can be grasped intellectually and linked to meanings. It must be taken into account that the subject terminology forms a part of the scientific cultural heritage; designations are often not unambiguous, and can even lead to mistakes if they are understood by the learners in terms of their own everyday literal sense. Thus for example “bond energy” is not chemically the energy which bonds parts of the molecule together but the energy which is required in order to cleave the bonds between them. Or the “electrical current strength” is not the “strength”, force or velocity of electrical current, but tells us only how great the electrical charge energy flowing through a certain cross-sectional area in a unit of time is. The term „ecological niche“ does not describe a particular space, but relationships between a particular species and its environment. Technical terms are not *on their own* vehicles of meaning. Learners must first themselves experience and get to know the subject-based content of a particular concept, in order that the concept (the thought construct) is „internally available“ to him or her *before* this concept is designated by the corresponding scientific technical term. Thus we can say: *„First the concept, then the word”.* Learning which is meaningfully experienced and makes sense to the learner should also be possible using the context-oriented configuration of learning (*Situated learning, z.B.* BROWN, COLLINS & DUGUID, 1989; *Resonanzpädagogik,* ROSA & ENDRES, 2016).

Several intermediate steps can be defined between experiencing nature and disposing of differentiated concepts and ideas of science and its application, as is discussed in Chapter 2. It is important for both learning and teaching to know that all these steps, from experiencing onwards, must be gone through in order to be able to deal with scientific concepts in a competent manner. Each new topic should afford the possibility for all learners (also older ones) to experience the subject being taught, in order to give it a personal meaning. It is important to take account of the fact that not every learner will achieve the greatest depth of understanding of all the topics discussed. While some will for example be capable of mathematic abstraction, others will grasp the topic in a descriptive manner (see the forms of representation discussed by BRUNER, 1960). This difference must of course be taken into account in testing and grading.

01.3 Discussion of Education Content on the Basis of the CRFS

An important instrument for the realisation of the suggestions and requirements presented here is the scientific interpretation, suggested by us in Chapter 03, of the European Reference Framework (EUROPEAN COMMISSION, 2007); our ideas need to be discussed at a European level, in order that they may become a common foundation for scientific education which is as broad as possible, as is already the case for the European Reference Framework for Languages.

In order to come nearer to the required goal of effective teaching in natural sciences, it is inconceivable that there will not often be a painful discussion about content. The CFRS can be very useful here. A central criterion for teaching content cannot be its role in teaching today, but the question as to whether the topics taught today are suitable for encouraging and stabilising those competences which the CRFS demands.

01.4 Looking Ahead: Conclusions for Science Learning and Teaching

As with every subject, science teaching and learning can succeed only on the basis of a perceptive relationship between the teacher, the learner and the learning topic. We can thus list some basic requirements:

- It is not sufficient just to carry out a skilful didactic treatment or reduction of scientific material.
- It is important to build bridges between the „experiential world“ of the learner and the „scientific world“. In doing so the teachers must address the current cognitive structures, personal experience and everyday prior knowledge of the learners.
- The learners must be given time to discuss and reflect on their own individual perceptions, so that the steps taken towards viable common perceptions are more readily achieved.
- It is not a good idea to teach learners how to handle abstract terms and models when they are not yet ready for them.
- The learners must have the possibility to deal with a topic in a stepwise manner, from experiencing a phenomenon via an increasingly systematic discussion, to either comprehension with terminological clarity or to mathematisation.
- Both learners and teachers should use a research approach, i.e. a culture of questioning rather than a culture of quick answers.
- The material to be taught in science subjects should be selected in such a way that the competences listed in the CRFS can be achieved in a sustainable manner at the various levels.

To rethink education in the natural sciences is of particular importance at the present time. If societal decisions are made on the basis of undifferentiated considerations, of emotions, or of slogans which are simply repeated uncritically, the community itself will be endangered. The future of Europe is highly dependent on technological developments, which however be supported by the general population on the basis of well-reflected acceptance. This is only possible when there is a basic understanding of scientific subjects, with a positive fundamental attitude and the will to engage in constructive criticism. How can democratic decision processes involving the introduction of alternative technologies occur otherwise? Or how can enough young people be motivated to choose scientifically and technically oriented jobs?

At the risk of repeating ourselves, we must make it clear that the unsatisfactory situation in basic science education will only be changed for the better when the deficits are broadly known and accepted as such. Only then will there be a chance of obtaining a stable basic understanding of scientific topics across all levels of society. This is the goal of the MNU.

Our conclusions for the learning and teaching of science apply to all formal and non-formal education institutions. The present authors have amassed a great deal of relevant occupational experience: four of them have taught a scientific subject for many years, and because of their occupations all of them have regular experience in the actual conditions of teaching in Germany. They are aware that very many of their colleagues are excellent teachers and are highly motivated.

It is important to improve the standing of education in our society in the interest of all those involved in the education process. A look at the observed and empirically measured situation of education, particularly in science, shows however that much too little of the effort made in schools and other educational institutions is successful in the long run. We thus see an urgent necessity for change, both in the demands made by the State and in the design of science education across all school types. Syllabus specifications, particularly at primary and lower secondary levels, should take more account of the learning preconditions of the learner than has previously been the case.

If we are successful in taking into account more closely the personal ideas and cognitive possibilities of the learners, so that they turn away less from natural sciences as they progress through school, we shall have reached a vital goal.

02 Reference Levels for Process- and Content-related Scientific Competences – Minimum Standards

In the following tables we shall show in an exemplary manner how sustainable adult competences, related to scientific processes and content, should be defined at different levels.

Elementary Education related to Science		**General Knowledge related to Science**		
A1	**A2**	**B1**	**B1+**	**B2**
Experience of and dealing with phenomena in science and technology	**Reflecting on observations and meanings in the course of dealing with phenomena in science and technology**	**Knowing and apply-ing basic scientific concepts**	**Knowing central concepts and ideas in science as well as independently applying and relecting on them**	**Knowing central concepts and theories of science; independently reflecting on evaluating them**
Pre-School/ISCED Level 0	Primary Educati-on/ISCED Level 1	End of Compulsory Schooling/ISCED Level 2	End of "Sekundarstufe I" (10 Years Schooling (High School)*/ ISCED Level 244	High school graduation/ISCED Level 344

Tab. 1. Reference levels for scientific education with assignment to education levels

* at the end of the „Sekundarstufe I" (Secondary Level I) pupils are qualified to take courses at the Upper Level of the German Gymnasium (Secondary Level 2).

Common Reference Levels – Descriptions

Reference levels describe an anticipated final situation. They are in no way related to the processes of teaching or of informal education (outside school). However, the listed levels of process-related competences resulting from the teaching process can themselves afford important impulses, since the competences can be understood as minimum standards; in comparison with many present-day education plans these may at first appear to be lower. This limitation to a minimum is intended to provide time for profound learning processes carried out in dialogue. The education institutions are provided with a target, which puts them under an obligation to do all they can to make sure that the learners in their care reach the defined levels in a sustainable manner at the end of the relevant stage of education. In order be able to make use of viable concepts instead of empty phrases, it is appropriate to refer to all previous levels in the teaching process or, if necessary, to go through these levels for the first time: by this we mean building on the diagnosed initial situation consistently, independent of the age of the pupil but dependent on his or her previous development. This will provide the prerequisites for proceeding from a superficial to a deep understanding of scientific interrelationships. The reference levels which we have defined (in analogy to the reference framework for languages) are listed and described in Table 1. There are however two important differences to the level scheme used for languages:

We have introduced an additional level B1+, as it has emerged that many more abstract aspects of natural sciences go further than does the level B1. B1+ thus describes competences which are a precondition for a well-educated non-scientist to reach level B2, without however already having reached its depth. One example is knowing about atoms and molecules (see also 03.4.1 Chemistry. Matter: how properties, composition and substances are connected).

We have defined level B1+ in terms of the German scheme of education. An international discussion of the CFRS will need to deal with referring it to other the situtation in other countries. We have added ISCED levels (ISCED, 2011) to aid in this discussion.

The penultimate line of Table 1 contains statements on the expected level of activity, ability or depth of understanding of a person at this level.

Science-Related Education of an Expert	
C1	**C2**
To know, understand and evaluate central concepts and theories as well as subject-related specific statements in natural sciences.	**To be familiar with scientific concepts and theories as well as subject-related specific statements, to understand them and to evaluate them.**
Bachelor	**Master**

Tab. 2. Reference levels of the science-related education of experts who have studied science subjects: not further discussed in the CRFS

The second difference to the language reference framework is shown by Table 2. It is certainly an interesting challenge to describe the two C levels; however, this is the task of universities rather than schools and will not be discussed further in the CRFS.

Common Reference Niveaus: An Outline

The process-related competences as initially formulated form the basis for education in science. Topics which do not appear in the subject-related competences listed in a second step can be dealt with by making use of the process-related competences. Thus the list of competences should not be considered as being complete. In the CFRS we have therefore elected to make use of an ordered presentation which uses some of the central theories or concepts of the particular subject. These will be discussed using examples which involve basic subject knowledge as well as its connections with everyday life.

In the case of the content-related competences we have included a third column containing everyday concepts. These are to a high degree independent of level, since they remain available across the stages. They however show how important the competences formulated are, by listing as examples which ideas and concepts can be reckoned with in the learner in the context under consideration: these can then be dealt with in the teaching process. The learner's initial ideas will then be revised when the appropriate level is reached (BARKE, 2006; DUIT, 2009; HAMMANN & ASSHOFF, 2014; KATTMANN, 2015). „Revision“ means that the concept is seen in a new light, so that a new level of understanding is reached.

Teachers will at first sight miss the presence of experimental competences, as these are of great importance for the teaching process. They must however be excluded in this model, as the levels are intended for adults, who normally no longer carry out experiments. Other process-related competences, particularly in the areas of the acquiring of knowledge and evaluation, will be listed at the beginning of the next chapter and are summarised here:

03.1 Process-related Competences

An educated adult should be capable of studying phenomena and simple interrelationships, to make sensible use of qualitative subject terminology and elementary viable models, and to provide elementary personal evaluations of scientific topics.

In Chapter 03.2 three important interdisciplinary topics are listed prior to to the subject-related tables. As has become clear, particularly from the treatment of the "planetary boundaries" (STEFFEN, 2015), there are several ecological limits on earth which cannot be exceeded without putting the basis of human existence in danger. We shall however here only discuss the climate problem in detail, as it is the one which is attracting the most public attention at present.

03.2 Content-related competences involving interdisciplinary topics

03.2.1 The Nature of Science (NOS): The cultural importance of science

An educated adult should be capable of explaining that the development of social systems is closely related to the development of science and technology. The realisation that the further development of our highly technical world, with all its possibilities and risks, inevitably leads to a change in the social environment, requires that people act in a responsible and forward-looking manner.

03.2.2 Nature, Human, Technology: The Climate Problem

An educated adult should realise that human influence on the development of the earth's climate is a central question for the survival of humankind. The lives of all adults alive today will be deeply affected by the success or failure of efforts made to fulfil the goals of the Climate Change Convention. In order to be able make appropriate personal and societal decisions, an educated adult requires not only economic and sociological knowledge, but in addition a profound knowledge of natural sciences and a corresponding competence to act. Only so can responsibly used creativity lead to farsighted intelligent solutions.

03.2.3 The senses: Perception and Measurement

An educated adult should know that the senses are the „gateway to the world". In order to deal in a responsible manner with the information provided by the senses, it is of central importance to distinguish between external stimuli which can be scientifically measured, and inner perceptions or sensory impressions. Just as important is the relationship between external stimuli and inner perceptions, i.e. that the latter arise from internal interpretation of the former. Communication between people also requires that one realises that the message transmitted by the sender can differ from the perception of the receiver.

Even when the natural sciences are referred to as a whole, each science subject has its own " spectacles" through which the world and its occurrences are observed and reflected on (MNU, 2004). This is the reason that the tables which follow are ordered according to the science subject concerned. The selected subject-related competence areas can be summarised as follows:

03.3 Subject-related Competences – Biology

03.3.1 Evolution: Explaining natural history on a scientific basis

An educated adult should look at nature in terms of natural history, consider variety as something positive, and be able to justify the universal validity of the theory of evolution and natural selection.

03.3.2 Our body: What health and illness mean

An educated adult should have the knowledge in cell biology, physiology and genetics as well as the necessary attitudes to be able to maintain and improve his or her health, as well as to be able to deal with illness and disability.

03.3.3 Relationships between man and nature: shaping and preserving the environment

An educated adult should be able to judge human activity in biological contexts, to recognize and evaluate mutual dependencies, and to take a reasoned position on different man-nature relationships.

03.2 Subject-related Competences - Chemistry

03.2.1 Matter: How properties, composition and substances are connected

An educated adult should possess that knowledge on the world around him or her which is necessary in order that he or she can orient him- or herself within it, to make use of certain properties of chemical substances, or to avoid possible damage to him- or herself or the environment which can be caused by chemical substances.

03.2.2 Chemical reactions: What it means to say „a new substance is formed“

An educated adult should know that a chemical reaction does not always occur when substances are mixed or heated. He or she should recognize chemical reactions as processes in which a new pure substance is formed, and in which energy is converted from one form (e.g. chemical) to another (e.g. electrical). He or she should know that the total mass of the substances involved never changes, also when gases are involved.

03.3 Subject-related Competences - Physics

03.3.1 Matter: From the very large to the very small

An educated adult should be able to comprehend the dimensions of both the very large (e.g. the cosmos) and the very small (e.g. quarks). The results obtained from experiments in physics should enlarge his or her understanding of the world (e.g. via ideas on relativity theory or quantum physics). Epistemological questions, as well as the methods of obtaining knowledge, should make an important contribution to the construction and consolidation of his or her picture of the world.

03.3.2 Theory: Making nature predictable

An educated adult should be able to consider the development of physics in an historical manner and to comprehend that mechanics, which can readily be mathematised, has become the prototype of a modern science. It should be clear that the extension of classical mechanics by relativity theory and quantum mechanics provides a new importance for our understanding of the world, taking into account the basic terms space, time and cause-and-effect. An educated adult should realise that there are limits to the boundaries of being able to calculate natural phenomena; this idea has come to the forefront because of the development of chaos theory.

03.3.3 Energy: The supply of electrical energy in everyday life

An educated adult should know that life as we know it is impossible without a reliable supply of electrical energy. He or she should have the physical knowledge necessary in order for him or her to take part in societal discussion of the turnaround in energy policy and to take his or her own decisions in a responsible manner.

03 Competences in Natural Sciences

03.1 Process-related Competences

Level		CRFS Competences On reaching level...the student can...
A1	Devising a personal relationship from experience with phenomena	"research in a way which is fun" at leisure.
		express him- or herself using personal everyday language in a random childish manner without using technical terms
		ask questions regarding phenomena in nature and technology and devise personal explanations.
A2	Establishing a personal relationship to, and consolidating experience with, phenomena	study simple phenomena and relationships qualitatively and describe them in an appropriate manner using everyday language.
		communicate, justify and feflect on his or her own interpretations in a plausible manner.
		distinguish between everyday language and technical terms and make use of helpful technical terms.
B1	Establishing a personal relationship to, and providing appropriate descriptions of, phenomena and interrelationships as the basis of science	study phenomena and simple connections
		deal with qualitative terms and feasible elementary models in an increasingly competent manner.
		provide elementary personal evaluation of scientific facts.
B1+	Establishing a personal relationship to, as well as describing and justifying of, phenomena and interrelationships appropriately and scientifically	study relationships independently in a qualitative and quantitative maner.
		deal with important scientific terms and concepts, also using models.
		reflect critically on the limits of models.
		justify personal evaluations of simple relationships.
B2	Establishing a personal relationship as well as appropriate and deepened scientific description and explanation.	study and research relationships of increasing complexity in an independent manner.
		use technical terms and concepts qualitatively and quantitatively with increasing precision and complexity.
		be able to criticise statements regarding scientific topics.
		understand epistemiological considerations.
		make personal judgements of interrelationships of increasing complexity and formulate these in an audience-oriented manner.

03.2 Subject-related competences involving interdisciplinary topics

The competences described here describe a situation which is to be aimed at, but do not initially make any statements regarding the teaching process. They can however afford important impulses, as they are in addition considered to be a basis for the formulation of minimum standards.

03.2.1 Nature of Science: The Cultural Importance of Natural Sciences

An educated adult should be able to explain that the development of structures in society is closely related to the development of science and technology.
The realisation that the further development of our highly technical world, with all its possibilities and risks, will inevitably lead to changes in societal structures, makes it vital that human beings be capable of acting in a manner which is responsible and geared to the future.

CRFS Competences On reaching level...people can		Examples and Explanations		Everyday ideas, which can be revised[1] when this competence is reached
A1	use examples to explain that human beings have involved themselves with science and technology for a very long time.	Discovering science in everyday experience: transport, cooking, foodstuffs, tools.		
	use examples from their own environment to demonstrate how changes occurring across the years are due to advances in science and technology.			
	describe possible changes in the future in an imaginative manner.			Technological progress is good. Technological progress destroys the environment.

A2	use examples to show that science and technology affect each other and influence our daily lives.	Nutrition, mobility, tools, electrical energy, heating; breeding animals and plants; medical apparatus; clothes, artificial fertilizer, medicines as examples of formulation and reflection of relationships between science, technology and culture.		Technological advances are entirely due to serendipitous discoveries.
	Illustrate examples of technological developments using suitable everyday language and name their advantages and disadvantages.			
	assess the importance of technological developments and discoveries for human beings; gauge their effects (which can be ambivalent) for mankind and his environment.	Printing, bridges, computers.		
	Show, using topical examples, that both men and women carry out research in science and technology.			
B1	show by means of simple examples how scientific knowledge has developed.	Ideas on atoms; burns; from the origin of life to reproduction of species; from the geo- to the heliocentric view of the world.		Scientific statements are always correct.
	describe examples of the development of technological applications of scientific laws.	The industrial revolution (the discovery and development of steam engines), development of transport systems, use of electrical energy (for lighting and propulsion); vaccination; simple examples of genetic engineering; extraction of metals from ores; oil refining.		Science and technology are the same thing.
	outline the biographies of selected researchers in their historical context.	Pioneers who described and explained important scientific phenomena ideologically, e.g. NEWTON, DARWIN, LAVOISIER, EINSTEIN, WEGENER.		
	use one example to illustrate that scientific descriptions often simplify by using models.	The motion of planets in the solar system; combustion in air (excluding by-products such as nitrogen oxides).		Science describes reality as it is.

B1+	describe in an illustrative manner how scientific laws are used in technology.	Electromagnetic induction for supplying electricity; duplication of DNA via PCR; catalysts in automobiles with control of air supply; MRT.		
	classify biographies and scientific output of selected researchers in a historical context.	Röntgen; Ohm; Darwin; Hahn and Meitner; Fleming, Liebig.		Science is independent of historical and societal conditions.
	explain how scientific descriptions, models and laws have undergone change.	Changes in the world view as described by Aristotle, Ptolemy, Copernicus und Kepler, as far as modern cosmology; atomic models; theories of catalysis; the concept of geness; plate tectonics.		Scientific statements are valid for ever.
B2	show using selected examples how scientific theories have been developed	Historical development of antique ideas on the nature of light, via particle models (Newton) and beam models of light to the concept of photons in quantum physics; identification of genetic materials of protons to DNA and epigenetic influence; the development of oxidation theory by Lavoisier; the term „acid“ from acidic solutions via certain substances to proton donors.		
	describe in an illustrative manner how scientific and technological knowledge influence one another.	Advancement of the development of vacuum pumps by research in the 17th century and its influence on the formulation of gas laws; advancing knowledge of cytology and microbiology via the development of light and electron microscopes; oxidation and reduction in the manunfacture of metals.		Scientific knowledge influences technological progress; the reverse is not true.
	illustrate in principle methods of knowledge production, their hypothetical character and their limits.	Critical-rational limitation of science to hypotheses, which can be checked by observation and by experiment; science as a specific approach to our understanding of the world. Exact predictions are valid only under certain conditions (conditional statements of if and then).		Scientific theories are verified knowledge. The sciences are the sole source of knowledge.

	outline social structures which exist in historical and contemporary scientific research.	Any successful researcher today belongs to a large team consisting of team leaders, assis-tants and many other people. Cooperation between people from different disciplines.		Researchers work like hermits.
	explain that scientific knowledge is provisional.	The provisional character of the modern world view: development of theories on the nature of light, theories on the nature of heredity, the phlogiston theory versus oxidation theory, discovery of the nanoscale as an additional dimension between the substance and particle levels.		Present ideas on scientific topics will never need to be revised in the future.
	recognize and evaluate natural science as being a cross-cultural achievement.	The development of science has taken place over thousands of years in different cultural areas.		Sciences are an achievement of the western world.

03.2.2 Nature, Man, Technology: The Climate Problem

An educated adult should recognize the human influence on the development of the earth's climate as being a central question for the future of humanity. All adolescents living today will be deeply affected by the success or failure of efforts made to fulfil the goals of the Climate Change Convention. In order to be able make appropriate personal and societal decisions, an educated adult requires not only economic and sociological knowledge, but in addition a profound knowledge of natural sciences and a corresponding competence to act. Only so can creativity, responsibly used, lead to farsighted intelligent solutions.

CRFS Competences On reaching level...people can...		Examples and Explanations	Everyday ideas, which can be revised when this competence is reached
	experience and communicate the beauty and seasonal development of nature, as well as develop a relationship to those elements of nature which need preservation.	During playing, walking and walking, by plant-ing in beds and borders.	
	explain in their own words how simple processes for food production work.	Baking bread or cakes, milling grain, jam-making; products derived from aniimals; basic knowledge on cultivation and living conditions of resources (e.g. on the farm).	Food is naturally always there.
	deal carefully with natural and man-made resources and with energy.	Lighting, heating and ventilation; sensible use and handling of food.	Personal behaviour is not in any way connected to global developments.

A2	describe basic relationships in food manufacture, mobility, air conditioning in houses, the use of electrical energy and consumption in general using appropriate everyday language.	Energy consumption in production processes of consumer products, e.g.: fruit and vegeta-bles, milk, cheese, noodles, sugar, salt, cooking oil; different types of heating; different ways of supplying electrical energy.	
	reflect on their own behaviour with respect to using resources and develop alternative possibilities.	Sensible use of food, intelligent heating, economical use of electrical energy, organized purchasing.	Driving a car faster means less fuel consumption, because the journey time is shorter.
	take a „research attitude“, i.e. observe their environ-ment in a structured manner, document their results and classify these in basic systemic correlations.	Discovering the users of a local environment, e.g. a wood, documenting the observations (e.g. using photographs, sketches, sound recordings etc.), making clear how different users are related.	
	communicate their own interpretations (e.g of correlations) in a comprehensible and audience-orientated manner.	Placards (e.g. on the usage of reusable water bottles), poster presentations (e.g. on the advantages and disadvantages of the use of bicycles), open letters to regional (online) newspapers (e.g. on infrastructure topics).	
	describe the importance of the warming up of the earth.		

B1	name important plants and animals which are to be found in their personal environment.		
	explain the greenhouse effect in a qualitative manner.	Radiation equilibrium sun-earth, different effect of visible light and thermal radiation, the most important greenhouse gases.	The so-called Greenhouse Effect takes its name from the analogy with a greenhouse, where glass stops heat exchange with the outside.
	list the important components of air in approximate concentrations.	Nitrogen (ca. 80%), oxygen (ca. 20%), carbon dioxide (ca. 0,04%), water (ca. 3-4%). Concept: relative humidity.	Carbon dioxide and oxygen as the main components of air.
	describe the origins and effect of the anthropogenic contribution to the heating up of the atmosphere.	Carbon cycle, effect of the most important greenhouse gases, increase in greenhouse gases in the past, central postulates of climate models	„Artificial“ carbon dioxide does not enter the cycle, but remains in the atmosphere.
	name and account for important societal methods of decreasing the anthropogenic contribution.	Examples: nutrition, mobility, heating, supply of electrical energy, other forms of consump-tion.	
	explain what the two degree goal is.	Reducing emission of carbon dioxide and other gases which have negative effects on climate; removing carbon dioxide from the atmosphere, dynamic equilibrium.	It is only important to reduce the amount of carbon dioxide in the air, because it is the only gas which is harmful to the environment.

B1+	explain how thermal power stations work and what their energetic efficiency is.	Coal, atomic and solar power plants.	
	plan, realise and evaluate their own projects for the energy revolution.	„Renewable“ energy	
	describe the greenhouse effect more exactly using quantitative arguments.	Quantitative estimation of the impact ratio of the most important greenhouse gases, predictions of climate models and the relation-ship between temperature rise and its effects on life on earth.	Confusion and mixing with the stratospheric ozone problem.
	justify, in a quantitative manner, societal and personal methods for the reduction of the anthropogenic contribution.	Comparison of energy flow diagrams for vegetarian and animal foodstuffs, quantitative comparison of different methods for insulating houses.	
B2	explain the importance of entropy generation or energy degradation for the efficient use of energy in a quantitative manner, naming alternatives.	The heat pump: heating with a minimum entropy generation, the electric motor in comparison with the combustion engine with minimum entropy generation.	
	design quantitative measures for the country, the city and for themselves, and evaluate them using ecological, economic and sociological criteria.	Ecological footprint.	
	explain the system concept using the example of the greenhouse effect with its anthropogenic contribution.	Examples of systems: electrical current cycle, water circulation cycle: local changes always affect the whole system.	
	outline the natural development of climate and human influence on climate using valid technical terms in a differentiated manner with central quantitative statements.	Report on the present state of scientific knowledge, the World Climate Council.	Ideas from „fake news“ and alternative models.
	outline global and personal efforts to reduce the anthropogenic greenhouse effect using valid technical terms.	The international climate convention, global computational models.	
	use a suitable example to describe the interaction between ecological, economic and social effects of a particular action, and justify his or her personal decision.		

	make and justify suggestions as to how the acceptance of climate protection measures in politics, the economy and in the general population can be increased.	Environmental psychology, sociology and politics.	

03.2.3 The Senses: Perception and Measurement

An adult should know that the senses are his or her „door to the world“. In order that he or she can deal responsibly with the information provided by the senses, it is vital to be able to distinguish between the external stimuli, which can be scientifically measured, and the internal sensory impressions. Just as important is the relationship between the stimuli and the inner perceptions, i.e. that the latter arise from internal interpretation of the former. Constructive communication between human beings also requires that they realise that the message transmitted can differ from the perception of its receiver.

CRFS Competences On reaching level... people can…		Examples and Explanations	Everyday ideas, which can be revised when this competence is reached
	experience and name the variety of the different types of qualities of the sensations they experience in everyday life.	Smelling, tasting, seeing, hearing, feeling of warmth, personal movement, feeling of strength.	
	experience ears and eyes as sense organs and name them as such.		
	themselves act as „transmitters“.	Speaking, singing, painting, moving, creating.	
	carry out simple sensory measuremens.	Length, volume.	
A2	using examples, experience differentiated qualities of perception and link them to external stimuli.	Powerful hit on the drum -> loud; Many lamps -> bright; A lot of salt -> strong salty taste; Mixing watercolours.	
	build simple musical instruments and explain how they work.		
	formulate simple descriptions, also in the form of drawings.	Native flowers and animals.	

B1	explain the difference and connection between stimulus and sensory perception.	Stimulus (light, heat, pressure etc.) as a trigger for electrical pulses, which travel from receptors via nerves to the brain or the spinal cord and on to the target organ, thus leading to sensory impressions.	Light has a colour. Smells or pictures are transferred to the brain. Stimuli are transferred to the brain by means of nerves.
	experience and explain, using examples, that sensory perception is an internal interpretation.	Coloured shadows, generation of colours by a monitor, melody, optical illusions, pictures generated by the brain during listening to stories.	„Optical illusions“ are generated by mistakes in the processing of optical stimuli. Colours have a physical existence.
	show, using simple examples, that for us observations and descriptions are only possible by means of comparison.	The smell of a rose.	
	explain that the introduction of units of measurement has made possible objective measurement of external stimuli (as a cultural technology).	Amplitude and frequency, velocity of sound and light	
	name important physical quantities in acoustics and explain their relationship to corresponding sensory impressions.	External: frequency, amplitude, velocity of sound. Internal: pitch, loudness, tones, sounds, noises, the meaning of texts.	A sound emanates from a tuning fork or a loudspeaker.
	name and explain phenomena and applications of optics.	Reflection, refraction, dispersion, transmission.	
	explain qualitatively the beam path of simple optical instruments.	Camera, projector, microscope.	
B1+	establish the relationship between heat radiation, UV irradiation and visible light and explain examples of its application.	Thermal imaging camera, greenhouse effect, sunburn, risk of skin cancer.	
	Explain that human beings can only experience tiny segments of the electromagnetic spectrum (seeing, hearing) (mesocosmos).		Human beings can detect everything in the world.

B2	explain the development of scientific models using light as an example.	Light rays; beam, particle, wave and photon models.		
	Explain perception as a construction performance of the brain.			
	Justify the concept that observations and descriptions always arise from (individual) prior experience, i.e. that pure description does not exist.			
	Vary the transmitter-receiver model so that transmitted information is not the same as that received.			Transmitting and receiving as objective information transfer.
	explain the most important concepts of the wave model.	Interference at a double slit, lattice.		
	describe interference phenomena which occur in everyday life.	Interference on thin layers and at lattice structures.		
	explain the main concepts of quantum physics.	Stochastic occurrence of individual events and deterministic behaviour of the collective, non-locality, complementarity.		An electron is always somewhere. Atoms are like little balls.

03.3 Subject-related Competences - Biology

03.3.1 Evolution: Explaining Natural History on a Scientific Basis

An adult should see nature from a natural history point of view, regard variety as something positive, and be able to justify the universal validity of evolution and selection theory.

CRFS Competences On reaching level...people can...		Examples and Explanations		Everyday ideas, which can be revised when this competence is reached
A1	name creatures living in prehistory	Dinosaurs		
	name animals and their habitat and describe the relationship between habitat and the way they live.	Animals can be characterised according to their habitat. The way they live is defined by the habitat.		
A2	explain that creatures evolved at various times.	Appearance of the „first“ animals and humans		Humans and dinosaurs lived at the same time.
	explain heredity using simple examples.	Phenotypical development of characteristics in animals		Passing on of parts of the body and their properties.
B1	describe the relationship between living creatures as the evolution from common ancestors.	Apes, including humans		Species living today are ancestors of more developed species. Apes are ancestors of Man.
	describe the relationships between living creatures in historical terms.	Vertebrates, emerging from water to live on land		Relationship means similarity.
	describe how different living conditions influence change and adaptation of populations.	Variation and selection, e.g. the evolution of the giraffe and the okapi		Living creatures adapt purpose-fully to their environment. Evolu-tion means higher development
	explain that living creatures influence and fashion their environment and are, vice versa, influenced by it.	The idea of interactions		The environment defines the creatures living in it unilaterally.
	describe how Earth was modified by living creatures in the course of history	Accumulation of oxygen, bioplanet Earth		Living creatures are adapted passively to their environment.

B 1+	name mutations and recombination as the origins of variability.			Mutations are always harmful.
	adaptation as the result of mutation, recombination and selection			Adaptation occurs purposefully.
	state why adaptation is never complete.			Living creatures are perfectly adapted.
	provide genetic arguments against racism.	Differences between groups of humans are due only to the influence of their alleles.		
B2	evolution as a phenomenon which has been explained by science.			Evolution is „only“ a theory.
	compare different concepts of species and define the formation of species in terms of the genetic isolation of populations.			Species is a uniform type of living creature: all its individuals are the same. Species change as does an individual: all members of the species mutate at the same time and in the same way.
	explain how co-evolution is a source of continual evolution.			If the environment does not change there is no evolution.
	apply evolution theory to various areas of biology.	Behaviour, immune response, resistances		
	use the theory of evolution to explain the role of theories in science.			„Theories“ are non-binding thought models.
	compare different theories of evolution, distinguish them from non-scientific concepts and reflect on the different assertions.	Ideas about creation, creationism		Evolution and religious ideas contradict one another.
	make it clear that the idea of „race“ in human beings is outdated.	Greater differences (variety) within groups, gradual transitions of characteristics		There are races of humans. Races differ in their nature.

03.3.2 Our body: What health and illness mean

An educated adult should have the knowledge (of cell biology, physiology, and genetics) and responsibility to maintain and improve his or her health, as well as to cope with illness and disability.

CRFS Competences On reaching level...people can...		Examples and Explanations	Everyday ideas, which can be revised when this competence level is reached
A1	relate sensory perceptions and senses to one another.	Understand that we hear with the ears and see with the eyes	
	talk about illness and death, and include their own experiences.	Ill or dead animals; being ill oneself	
	use and justify simple measures of personal hygiene.	Washing our hands, preparing foodstuffs	There are good and bad bacteria.
A2	list the positions and functions of important organs in the body.	Lungs, heart, brain	
	relate a healthy way of life (diet, exercise) to the organs of the body.		
	describe digestion as a process in which food is processed between its ingestion and excretion, including the role of microorganisms in the intestine	Mouth, stomach and intestine are responsible for digestion and are homes for bacteria.	Food stays in the body, digestion occurs in the body. Digestion occurs in the stomach and intestine.
	describe human development from the formation of the egg cell to adulthood.	Embryonic development, growth, getting old	Growing means getting bigger.
	indicate how one can protect oneslf against infections.	Hygiene, vaccination	Vaccination is bad for you.
	distinguish between illnesses which lead to physical and psychological impairment.	Not regarding disability as an illness	

B1	use simple models to explain functional interactions.	Movement (antagonists), circulation, gas exchange, digestion of food and sugar (oxygen!), energetic treatment of metabolic processes (photosynthesis, cell respiration)	Blood flows in several circuits, the heart purifies the blood and loads it with oxygen. Air which is breathed out is bad or used air. Breathing means only that gases are taken up or expelled. Food supplies energ (without oxygen or other chemcial transformation).
	explain how cells are the primary building blocks of life, including cell division and cell growth.		Cells are containers. Cell division and cell production means getting bigger.
	describe the main components of cells and their functions.		Cells are empty.
	explain the transfer of genetic material in mitosis.	Distribution of already doubled chromosomes; cancer as unhindered cell division	Cancer is scary.
	describe the chemical role of enzymes in metabolism in an exemplary manner.		Enzymes are paticipants which split or build up.
	describe the female menstrual cycle and evaluate methods for contraception.		Females are always fertile.
	list biological and social risks and advantages of reproductive techniques and assess them.	Artificial insemination, sperm donation, surrogate mothers, clones	
	distinguish between genotypes and phenotypes.	Eye colour	Genes and characteristics are the same thing
	describe the manifestation of characteristics as a process and explain the influences of genes and the environment	Gene → enzyme → characteristic, modifications	Only genes determine characteris-tics.
	describe the difference between stimuli and sensory preception.	Stimulus (light, heat, pressure etc.) as the trigger for excitation (electrical impulse), which is tranmitted from the receptors via nerves to the brain or the spinal cord and from there to the target organ	A sound comes from the tuning fork. Light has a colour. Stimuli (e.g. smells, pictures) are transmitted to the brain by nerves.
	assess the influence of drugs on the body.		
	describe possibilities for protection against infection		All microbes are dangerous.

	in terms of microbes.		
	justify and accept that illness and disability are a part of human life	Breaking down physical, psychological and social barriers against the ill and the disabled	Illness and disabilities are not normal.
B1+	describe the advantages and limits of fuctional models.	Models for breathing, blood circulation, muscle action, stimulus/excitation	
	describe interactions with the help of control loops.		
	describe specific cells in tissue and/or organs.	Nerve or muscle cells	All cells are equal.
	compare and contrast mitosis and meiosis, their results and functions.	No individual stages	
B2	describe the interactions between nerves and muscles.	Motor nerves, triggering by conduction to the muscle (synapse, nerve cell, muscle)	
	show how muscle contraction involves the sliding into each other of muscle fibrils chemically.	Sarcomere (fibrils, ATP)	
	describe the role of ATP in the body.	Energy transmission	
	explain learning in terms of the linkage of neurons.	Synapses, changes in their linkage during learning	Learning takes place according to the funnel model.
	show how perception is a constructive performance of the brain.	Colours, sounds, meaning and sense are generated by the brain.	Information is taken up from the outside; not generated, but transmitted.
	use examples to show how nerves interact with the hormonal system.	Homeostasis in temperature regulation	
	describe types of cells and their function in terms of gene regulation and compartmentalisation.		
	explain the replication, sequence and regulation of protein biosynthesis as chemical processes and describe the role of the proteins.		
	name factors (including epigenetic ones) involved in the formation of characteristics.	The role of physiological and environmental factors in gene regulation	Only genes determine characteristics and contain information. Dominant genes „govern“ recessive ones.
	describe and evaluate methods for family planning.		
	describe and evaluate cloning.		

	evaluate the chances and the risks of genetic engineering.			"Green" gene technology is „evil", "red" good.
	explain why eugenics is useless and thus to be rejected both scientifically and socially.			Degradation of the genetic material by an increase of those with hereditary illnesses.
	critically evaluate definitions of health, illness and disability.			Good health is an ideal state which excludes illness and disabiliy.

03.3.3 Relationships between man and nature: shaping and preserving the environment

An educated adult should judge human activity in terms of biological relationships, recognize and evaluate mutual dependencies, and be able to give a well-founded opinion on different relationships between man and nature.

CRFS Competences **On reaching level... people can...**		**Examples and Explanations**		**Everyday ideas, which can be revised when this competence is reached**
A1	observe animals and interpret animal behaviour to some extent.	Soil fauna As emotional relationships should stay in place, anthropomorphic ideas are to be accepted.		Animals are like humans (anthropomorphic interpretations).
	experience and explore the natural environment.	Noises, smells, animals and plants typical of a certain environment		
A2	describe plant and animal species in terms of their structure and their life, and distinguish between various systematic groups.			Plants do not move and are thus uninteresting.
	use examples to explain relationships between animal or plant species.	Predator-prey, food chain		
	explain the basic principles of photosynthesis.	Light as a source of energy; plants form foodstuffs themselves		A plant gets its food from the soil.

	describe and reflect on possible impacts of human behaviour on the environment.	Plastic waste in the sea; effect on the local living environment (depositing waste in woods or pumping waste water into lakes)		
	name examples of nature protection measures and take part in them.			
B1	compare photosynthesis and cell breathing and show how they are related in plants and animals.	The energetic relationship between water cleavage and water formation, plant respira-tion		Plants do not breathe.
	order life forms in ecological categories.	Producers, consumers, decomposers		Decomposers are of no importance, as decomposition processes occur without their help.
	describe interactions in ecosystems.			
	describe dynamic processes in ecosystems and explain why there is no „biological equilibrium“.	Simple successions, mosaic cycles in woods		Nature sees an equilibrium as the ideal state.
	name basic principles of conservative and formative nature protection.	Bayerischer Wald, Lüneburger Heide, mud flats (salt marshes)		
	explain how Man plays a double role in nature, as a part of it and as an opponent.	Cultivating and looking after a garden		Man stands outside nature. He interferes with natural processes and thus destroys the natural equilibrium.
	show how microbes are necessary decomposers and symbionts in organisms and ecosystems.			Microbes are unimportant or harmful „Decomposition“ occurs without the help of life forms.
B1+	name basic taxonomic groups.	Differences between the main groups of life forms (eukaryotes, prokaryotes)		
	evaluate motives and criteria for both conservative and formative nature protection.	„Leave nature be“ versus the maintenance of nature protection areas (e.g. restricting scrub encroachment in heath and moor areas); differing necessity for intervention in different environments		Nature must be protected from Man.

B2	describe the dynamics of ecosystems.	Relationships between predator and prey (prey regulates the predators)		Equilibria are stable ideal states. Prey regulates the predators.
	explain what an „ecological niche“ is.	Definition as a relational structure: species – environment		Niche is a place or a space.
	describe energy flow and mass transfer (including cycles) in and between systems.	Ecological and organism levels		Energy, just like substances, is subject to cycles.
	explain interactions in complex systems.			
	evaluate how technology can make contributions to the environment.	Use of „renewable“ energy, ecosystem management using computer models (digitalisation)		Technology is an enemy of nature.
	evaluate the naturalistic fallacy.			Natural is good.

03.4 Subject-related Competences – Chemistry.

03.4.1 Matter: how properties, composition and substances are connected

An educated adult should have sufficient knowledge about the substances present in the world about him or her to allow his or her orientation in it, to use chemical substances in a responsible manner, and to avoid potential dangers to him or herself, or the environment, which emanate from such substances.

CRFS Competences On reaching level...people can...		Examples and Explanations		Everyday ideas, which can be revised when this competence is reached
A1	describe phenomena of solid and liquid substances often found in everyday life, and of some gaseous substances, using everyday language and an experience perspective.	Something is soft, sticky, liquid, hard; playing with different materials; cooking and baking; air, water vapour		

A2	describe phenomena of solid and liquid substances and of the air, in an appropriate manner using initial technical terms at the phenomenon level.	Use sieves to separate objects of various sizes; separate liquids from solids by filtration	
	name some examples of substances which, on mixing, either dissolve one other or separate again after a certain time.	Soluble: sugar and water Separating after mixing: cooking oil and water	
	show that air takes up room and is not nothing.	Explain wind as moving air	Gases are put on a level with air. Air and other gases do not have a mass. Air is considered as being "nothing".
	interpret the labelling of hazardous substances.	Justify a suggested solution for the disposal of paints	
B1	assign a substance to a class of substances on the basis of its properties.	Metal, salt, volatile substance, pure substance; mixture, solution	Volatile substances which have evaporated no longer exist ("dissolve in nothing").
	indicate the composition and importance of the substance „air“.	Approximate volume ratio of nitrogen, oxygen and carbon dioxide in air; the role of these gases in the human body and in photosynthesis	Oxygen is the largest component of air.
	describe, at the substance level, how soap works.	Soap is soluble in water and fat. It helps to make fats and oils soluble in water.	
	Link simple material phenomena with the concept that substances are made up of small particles.	Interpret a change in the state of aggregation; the attraction between particles correlates with their boiling point	Substances are continually being created. Particles are interpreted as being small portions of substance, i.e. they are considered to have substance properties.
	show how the Periodic Table is a table of kinds of atoms.	All existing small particles of substances are built up from atoms in the Periodic Table.	
	assign radioactivity to the atomic nucleus.	Explain radioactivity in terms of the decomposition of atomic nuclei	

B1+	assign substance classes in terms of the type of their small particles.	Atoms in a lattice (metals), ions in a lattice (salts); molecules (volatile substances); elements (small particles or lattices made from one single type of atom); compounds (small particles or lattices made up of atoms of differing types)	
	explain solubility phenomena in terms of the structures of the particles.	Small amounts of an „insoluble“ substance in a solvent (e.g. petrol in water), the function of emulsifiers	Some substances are completely insoluble.
	understand that chemical formulae are abstract representations of the structure of small particles.	Interpret the shape of molecules	H_2O is another name of water; H, He, Li etc. are short names of the substances hydrogen, helium, lithium etc.
	interpret the Periodic Table in terms of the structure of the atomic shell as the ordering principle.	The atomic shell is formed from certain discrete numbers of electrons of equal energy	Electrons are small objects. Electrons rotate around the atom’s nucleus at different distances.
	formulate scientific questions on statements about the danger of chemical substances.	Who defines limit values? What are the dangers of exceeding them?	

B2	assign natural and synthetic macromolecules as small particles and describe their functions.	Functions of proteins in the human body; use of plastics to save weight and cost	
	explain the properties of substances as the result of chemical bonds and interactions beetween small particles.	High temperature stability of substances with a lattice structure or with large cross-linked molecules	Particles themselves have the properties of substances. The same portion of any substance changes its temperature by the same amount when thermal energy is supplied.
	understand classification schemes for organic molecules.	Order according to the functional groups present	
	judge statements on dangers and usefulness of substances.	Understand the importance of the term „is carcinogenic“.	Substances which can cause cancer always do so if one comes into contact with them.

0.3.4.2 Chemical Reactions: What it means to say „a new substance is formed“

An educated adult should know that a chemical reaction will not always occur when substances are mixed or heated. He or she should recognize chemical reactons as processes in which a new pure substance is formed and during which energy is converted from one form (e.g. chemical) into another (e.g. electrical). He or she should know that during chemical reactions the total mass of all substances involved never varies, even when gases are taking part.

CRFS Competences On reaching level... people can...		Examples and Explanations	Everyday ideas, which can be revised when this competence is reached
A1	describe, using everyday language, processes in which material changes occur.	Burning a sparkler, dissolving an effervescent tablet, ice and snow melting, dissolving sugar in water No conscious difference between chemical reactions and a change of state of a substance	
	start simple reactions and define the material changes which occur in terms of a comparison of substance properties.	Put effervescent tablet into water, name the new substance formed as a gas Light a candle, observe that the wax is a substance which is consumed	Starting materials are still present in products (as in a mixture).
	describe processes in which thermal energy (heat) and light are formed.	„It is warm and bright next to a fire.” Examples: campfire, grill, sparkler, pocket warmer	
A2	make use of processes involving material changes, taking into account possible dangers.	Build a campfire, light it and extinguish it with water, without theoretical explanations	
	observe, describe and interpret conversion of materials in everyday life.	Material changes, e.g. change in smell or colour during frying	Chemistry only takes place in the laboratory.

B1	describe the importance of fuel, oxygen and combustion temperature for the occurrence of a fire and to explain measures for putting out a fire.	All three preconditions must be present before a fire can occur. Thermal energy can only be used from a system fuel/oxygen.	Energy is contained in the fuel and will be released from it during combustion.
	explain the preconditions and dangers of incomplete combustion.	If there is a fire in a closed room, a poisonous gas is formed because there is insufficient air present.	
	use information on a fuel to predict the products of its combustion.	Petrol: carbon dioxide and water; hydrogen: only water; wood and coal: also particulate matter, smoke and poisonous gases	Combustion leads to the destruction of a substance, without the formation of a new one.
	explain the chemical reaction as the formation of new small particles (product particles) from the educt particles.		In certain processes substances disappear forever.
	apply the law of conservation of mass.	Understand the calculation of the carbon dioxide emission from a combustion engine	If gases are formed, the reaction mixture becomes lighter.
	explain that energy turnover is always linked to a process and its conditions, not only to one single substance.		Coal, oil and gas are energy.
	name technical equipment in which chemical reactions occur which produce energy, and distinguish between the forms of energy involved.	Batteries (electrical energy); incinerators (thermal energy); rocket engines, explosives (mechanical energy)	
	recognize from a given simple reaction equation (reaction symbol) that a chemical reaction is being described.	Explain formulae and symbols: educt(s), reaction arrow and product(s)	

B1+	use the law of definite proportions to distingusih between chemical reactions and the formation of	The composition of mixtures can be chosen at will, while in a chemical reaction all the portions of the substances involved are in constant mass ratios, independent of their amounts.	If a prepared mixture reacts, none of it will ever remain.
	explain chemical reactions at the level of the small particles of the substances involved.	Bonds are broken and new ones formed; this is normally accompanied by changes of the small particles and their structure, but with conservation of mass.	
	explain and understand the process occurring in a simple reaction equation.	Photosynthesis equation: Formation of two substances (oxygen and glucose) from carbon dioxide and water in specific ratios.	Reaction equations and formulae are the same thing.
	explain chemical reactions as the formation of new samll particles from the educt particles, taking into account that atoms are neither completely destoyed nor newly generated in chemical reactions.	In the combustion of magnesium, the oxygen atom is converted to an oxygen ion (oxide ion); the atom type remains the same and the atom is not completely destroyed.	Substances and atoms remain (unchanged) in the products
	describe the way in which a catalyst works.	Catalysts in cars, for the faster reaction of exhaust gases to produce less poisonous substances.	
	name technical systems in which the energy required is taken up not in the form of thermal energy but of electrical energy.	Charging batteries, ageing of batteries; electrolysis	
	name technical systems in which reactions occur which provide electrical and thermal energy.	Fuel cells, power stations	
	understand that the splitting of a chemical bond always requires energy, and that its formation involves the liberation of energy.	If hydrogen and oxygen react to give water, energy is required to cleave the bonds in the hydrogen and oxygen molecules, but produced in the formation of bonds between hydrogen and oxygen atoms in the water molecules. In this case the latter energy contribution to the reaction is greater.	The formation of chemical bonds reqires energy. This is then present in the bonds and can be used by splitting them. Chemical bonds are only present in molecules.

	explain the reasons for different rates of chemical reactions.	Influence of temperature on cooking and baking processes; the degree of fragmentation as an accelerator of fires and explosions (e.g. dust explosion)		
B2	explain simple chemical reactions as generally involving acceptor-donor processes involving particles of the subsances involved.	Acid-base reactions, redox reactions		
	construct simple reaction equations for the description of chemical reactions.			
	use examples to explain chemical equilibria and possibilities of influencing them.	Composition of the contents of a bottle of sparkling wine before, during and after opening		Reactions either run to completion or do not occur at all.
	explain processes in galvanic cells and electrolysis as redox processes involving energy conversion.	The principle of the storage of electrical energy in a battery		
	explain the concept of the synthesis of macromolecules.	Molecules of one or a few types, which each contain two or more reactive positions, undergo bond formation to give very large molecules (macromolecules).		
	explain why, in the synthesis of new substances, it is necessary to consider the formation of possible by-products.	The amounts of useless by-products are minimised (atom economy concept).		
	set out the basic principles of selected commercial processes and syntheses (e.g. Haber-Bosch process, oil refining).	The starting material for fertiliser production (ammonia) can be produced on a large scale from readily available substances such as air and water. Oil must be treated and modified chemically before it can be used in various applications.		

03.5 Subject-Related Competences - Physics.

03.5.1 Matter: From the very large to the very small

An educated adult should be able to deal with dimensions from the very large, e.g. cosmology, to the very small, e.g. quarks. Results obtained from experiments in physics, e.g. concepts of relativity theory and quantum physics, should extend his or her understanding of the world. Epistemiological questions and methods of gaining knowledge should play an important role in constructing and consolidating his or her personal view of the world.

CRFS Competences On reaching level... people can...		Examples and Explanations		Everyday ideas, which can be revised when this competence is reached
A1	observe their environment in a playful and inquisitive manner.	Build dams, build huts, work creatively with simple tools		
	express their observations in their own language.	When leaves move there is always a wind; my shadow always stays behind me.		
	invent their own ways of classifying things.	Sorting things which occur in nature according to their own criteria		
	talk about subjective theories with respect to their own observations.	Stones sink in water because the water attracts them; bubbles rise in water because they are attracted by the air above the water.		
A2	use experiments to find out how objects change because of external influences.	Thermal expansion and contraction, compressibility of gases, liquids and solids, states of aggregation, magnetisation, electrical conductivity, changes in the state of aggregation		
	name phenomena in their surroundings which are caused by external influences and describe these using appropriate everyday language.	Airbeds in the sun, expansion joints, bridge bearings, the explosive effect of frozen ice, the compass		Objects have „human“ character.

B1	use typical units for basic quantities in everyday life correctly.	Density, mass, volume		
	describe a contemporary atomic model in pictorial form.	The quantum physical atomic model in figurative form		Atoms are really tiny spheres.
	name phenomena which were only discovered because of the advances in atomic and nuclear physics.	Radioactivity, nuclear fusion, atomic power plant, X-ray machine		Atomic energy is a „clean" energy.
B1+	list methods or research organisations which have made possible the present state of knowledge in physics regarding the structure of matter.	Particle accelerators, spectral analysis		Particle physics is only of interest for physicists and has no relevance for technological ladvance.
	present historical and epistemiological considerations regarding models for the structure of matter.	The historical development of models and concepts, future model development, the relationship between model and reality		
	set up qualitative balances using mass-energy equivalence.	Nuclear fusion as a source of energy, atomic energy		Mass always remains unchanged.
	understand conclusions on the construction of the cosmos and the processes occurring there.	Calculation of the orbits of planets, development of stars		The cosmos is immortal and static.
B2	describe methods involving more advanced physical concepts, with the help of which the knowledge of physics about the structure of matter was made possible.	Basic principles of nuclear research reactors and fusion reactors, interpretation of light spectra, double slit experiments with light, electrons and molecules		
	explain important properties of the quantum physical atomic model, using more advanced physical terms and concepts.	Probability of locating electrons, natural oscillations comparable to Chladni figures		Electrons are like very small „objects"; they are always in a certain place, independent of the technique used to study them.
	explain the basis of quantum physics and relativity theory in an appropriate manner.	Basic principles of quantum physics and relativity theory, standard model of particle physics		There is nothing more left to research or discover in physics.
	present historical and epistemiological considerations.	Different cosmological models of the world, different interpretations of quantum physics		

03.5.2 Theory: Making nature predictable

An eduated adult should be able to look at the development of physics from a historical perspective and to be aware that the mathematisability of mechanics has made it a prototype of a modern science. Because of the extension of classical mechanics by relativity theory and quantum mechanics, the terms space, time and determinism have gained a new meaning. An educated adult should realise that there are boundaries to the possibilities of calculating natural phenomena; these have become a source of interest because of chaos research.

CRFS Competences On reaching level...people can...		Examples and Explanations	Everyday ideas, which can be revised when this competence is reached
A1	deliberately influence the movement of objects.	Throw, roll or kick a ball; turn objects over	
	describe his or her experience with movement in everyday language.	Swinging, seesawing, climbing, riding a bicycle, driving a car	
A2	describe the equilibrium of a seesaw using a simple form of the lever principle.	Use of the lever in everyday objects: pliers, scissors, car jack (without using a mathematical formula)	
	carry out simple calculations with respect to uniform movement.	Distance, velocity (as an independent quantity, not as distance covered per unit of time)	
	carry out volume, weight and length measurements and make comparisons.	In baking (kitchen balance, measuring beaker), using a ruler	
	use some important units of measurement correctly.	Millimeter/centimetre, gram/kilogram, litre	

B1	describe, and in simple examples calculate (using a selection of mathematical formulae), some mechanical effects in terms of the physical quantities velocity, force, impulse and energy.	Taking up force or impulse as the reason for velocity change; the interplay of forces in movement		Strength is something which one has.
	describe pulleys, bicycles and car transmissions as examples of „power converters“.	The golden rule of mechanics: the law of conservation of energy (qualitative)		Energy can be spared.
	explain the acceleration of rockets and the flying of birds and aeroplanes by means of the concept of thrust.			Rockets push themselves up from the earth.
	illustrate the impulse and conservation of energy qualitatively using impacts as an example.	Change in velocities when cars hit each other		
	relate the rules for security in traffic to the relevant laws of physics.			
B1+	analyse more complex processes of motion kinematically.	Video analysis, equations of movement		
	use a collection of formulae to calculate more complex movement processes, including impacts.	Conservation of energy, conservation of momentum		
	illustrate the boundaries of forecasting natural phenomena using selected chaotic processes.	Ait and water currents, weather, dice		
	name processes in the world around him or her which can and cannot be calculated.	Movements of the planets, frictionless fall, weather forecast, one’s risk of becoming ill		Everything can be calculated when enough information is available.
B2	describe the basic principles of relativity theory and quantum mechanics.			Space and time are given fundamentals. Electrons, atoms and molecules can be considered as extremely tiny spheres
	understand what effects relativity theory and quantum mechanics have on the predictability and calculability of physical events.	Tunnel effect, the modern conception of the structure of the atom, the uncertainty principle		The world can be clearly divided into subject and object (the „Cartesian Dualism”).

03.5.3 Energy: the supply of electrical energy in everyday life

An educated adult should be aware that life as we know it would no longer be possible without constant delivery of electrical energy. In order to be able to take part in societal discussion on the energy revolution, and to make his or her own decisions in a responsible manner, adults need the necessary information which physics can provide in this area.

CRFS Competences On reaching level...people can...		Examples and Explanations		Everyday ideas, which can be revised when this competence is reached
A1	deal properly with liquids in everyday life and describe this in their own words.	Build dams or brooks, let water flow through pipes or funnels		
	deal properly with electrical appliances and equipment in everyday life.	Electric light, connecting electrical applances with a plug, torch, changing batteries, the correct way of dealing with plugs and sockets		
	behave in such a manner that „electricity“ is used sparingly.			
	bescribe dangers associated with using electricity in their own words.			
A2	carry out experiments with simple current circuits and provide their own interpretations (subjective theories)	Motors, solar cells, switches, batteries		
	describe how a lighting system for a bicycle works.	Dynamo, wiring, lamp/LED		
	describe the supply of electricity in a household.	Model circuits using simple components		
	describe the dangers of, and the correct way of dealing with, electricity.	Experiments with, for example, batteries, insulated wires, the safe use of plugs and sockets; what to do in a thunderstorm		
	name examples of electrical storage devices.	Smartphone, parking lights for bicycles, e-bikes, electric cars		
	make it clear that energy users need electrical suppliers.	Battery, solar cell, dynamo, power plant		

B1	recognize and describe electrical circuits as systems.	Circuit models, e.g water circuit, marble run		Electricity comes out of the wall socket.
	differentiate between the physical quantities electric current, electric voltage, electric energy and electric power	Define the important units A, V, J and W		Electricity is consumed.
	handle an energy cost meter (power meter) correctly.			
	compare the energy efficiency of different types of lighting in the household.	Light bulb, neon tube, LED and halogen lamps		
	describe the importance of generators and trans-formers for the supply of electrical energy.			
	name the supply and storage of electrical energy and the necessary processes of energy conversion which they require.			
	name and evaluate different energy sources for the supply of electrical energy, both in households and globally.	Thermal power plants, solar power plants, wind turbines, biogas power plants		The amount of electricity used in the house is measured.
B1+	describe physically electrostatic phenomena which occur in everyday life.	Floor carpet, lightning		
	distinguish between electrical charge carriers.	Electrons, ions		
	compare and evaluate different systems for the provision of electrical energy and mobility (also quantitatively).	Different energy scenarios, cars with combus-tion engines, fuel cells, or electric transmission		

B2	provide a more detailed description of electrical energy transport systems.	Electrical and magnetic fields as energy storage facilities, electromagnetic waves for the transport of energy		Electrical energy is localised in the electrical charge and is carried by particles as in a „rucksack“.
	categorize the dangers associated with the transport of electrical energy.	Electrosmog		
	describe and evaluate (also quantitatively) electrical energy supply systems using the relevant laws of physics.	Construction of electrical energy supply systems, voltage stability, problems with storage of so-called regenerative energy (which is not always permanently available), storage systems		

04 A Look to the Future

It was the goal of the Common European Framework of Reference for Languages: Learning, Teaching, Assessment to *„make the different European language certificates comparable and to provide a benchmark for the acquisition of language competences".* Both goals have been met in an exemplary manner. This European Framework of Reference has had a clear effect on the culture of language learning in schools and has had a very positive effect on language teaching in our schools.

A comparable advance has so far not been observed for education in natural sciences. In spite of the rapid increase in the knowledge of science, the level of scientific education has remained relatively low. Meanwhile scientific knowledge has an ever increasing direct effect on societal developments. Young people can only evaluate scientifically relevant societal decisions when the conclusions for learning and teaching referred to in section 01.4 can be drawn. Similar goals are being followed in the programme of transformative learning (Brookfield, 2012; Koller, 2012; Singer-Borowski, 2016, Laros, Fuhr, & Taylor, 2017; Eilks, Markic @ Ralle, 2018). According to our analysis, which is derived from subject didactic research and practice, the main reason for these deficits in lies in today's teaching, and additionally to some extent in education offered outside school.

What should the GeRRN be used for in the future:

1. Improvement of the reality of teaching
2. Development of competence development models and learning trajectories
3. The conception of suitable further education modules
4. Definition of minimum standards
5. Certificates for scientific education

Our present overloaded curricula give the teacher hardly any time to stop and reflect and to introduce their pupils to a research approach to the most important scientific interrelationships. It is also true that many of the intended education offers are not provided in a manner suitable for the age of the recipient. Learners are often not able to absorb them cognitively and to assimilate them: a deeper understanding is thus not possible. The inner world of the recipient is hardly ever referred to during teaching, and their fruitful everyday conceptions are not used for individual learning. The result is that many pupils do no more than learning something (by heart), that they do not understand what is taught and have no feeling for its relevance. What has been learned is quickly forgotten again, often after the next examination or test. These aspects of a badly acquired scientific education are well known; they have been researched using didactic methods and evaluated in practice. Fundamental basic knowledge, an understanding of important relationships and the ability to apply the acquired knowledge cannot be achieved in such a manner.

The present suggestion for a Common Reference Framework for Natural Sciences aspires to demonstrate ways to a basic education in natural sciences which is sustainable. The material on offer must be limited in order to leave more time for deeper learning of central concepts. Is it however possible to obtain a better scientific education when less, but carefully chosen, material is presented?

Such a conjecture naturally requires empirical validation. The MNU traditionally brings together the didactic and practical expertise of its members. Thus we see the Reference Framework as an invitation to practice and research to introduce the necessary change in perspective to that of the learner and to evaluate the results of such a change. This can occur even before a corresponding concept- and content-related modification of the curricula has been realised.

The establishment of learning lines as a stepwise orientation could be useful in the development of fundamental concepts. The planning and empirical verification of competence development models based on cumulation is considered by our commission as one of the next necessary tasks, which it alone can however not realise.

The change foreseen in teaching in scientific subjects can however only be successful when, at the same time, those colleagues who actually do the teaching are encouraged to develop their attidudes in teaching practice further, in the direction described in section 1.04. We consider that one way to success can lie in the conception of training courses which start from personal experience in practice, develop testing schemes stepwise, and then reflect on attempts to realise these in open discussions.

Parallel to these projects, those responsible in Germany for defining curricula should think deeply about their reformation in a direction which is oriented to the quintessence of the Common Reference Framework and which should have the goal of replacing the present core curricula. In a land such as Germany, which is poor in resources, it simply cannot be accepted that the niveau of education in natural sciences remains at its present Iow level. We therefore suggest discarding the present fear of defining minimum standards. Politics and society must make sure that a sustainable grounding in natural sciences be made available to all pupils.

At the end of such a process it would be possible to award certificates for scientific education, in analogy to those based on the Reference Framework for Languages. This would allow citizens as well as employers in the economy, whether in manufacturing industry, service industries or others, to assess the required level of scientific knowledge and competences. In today's highly mobile job market, national boundaries will become increasingly irrelevant. It is thus desirable to convert the present national Reference Framework to a European one. Certificates require the design of tests which are oriented towards the change we have discussed here in the perspective of learning and teaching in natural sciences. Test modules and questions can be used to check whether the relevant education niveau has been reached. Such a task can again not be dealt with by our commission alone.

Thus we appeal to colleagues in schools and universities to work with us. If you feel the goals and tasks discussed and presented here to be attractive and that you feel motivated to work with us, please get in touch with the MNU offices or with a member of the team of authors.

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Postscript

The present third edition of the Gemeinsamen Referenzrahmens für Naturwissenschaften (GeRRN), brings its development, with which the MNU has been involved since 2014, to a provisional completion. We thank all those who have provided suggestions for its modification: via the open GeRRN Forum on our homepage, during the Forum at the MNU Federal Congress in 2018 and during lectures and workshops at other meetings; these have all been discussed and taken into account. We are particularly thankful for the support from the Gesellschaft für Didaktik des Sachunterrichts GDSU with respect to questions of elementary science education. The following must be named personally (in some cases they have also involved their colleagues): Prof. Dr. Mirjam STEFFENSKY, Prof. Dr. Kornelia MÖLLER, Prof. Dr. Lydia MURMANN, Prof. Dr. Kim LANGE-SCHUBERT, Prof. Dr. Matthias BARTH und Prof. Dr. Andreas HARTINGER,

We are very happy to be able to report that other subjects have followed our example. Colleagues from Didactics of Geography, a group of Informatics colleagues from the Gesellschaft for Informatics GI and from the MNU (led by the MNU subject expert Gerhard RÖHNER) as well as a technology working group from the Verein Deutscher Ingenieure VDI (led by Marvin MÜLLER) are already so advanced in the development of Reference Frameworks that it appears possible to combine these frameworks to give a GeRRMINT in the foreseeable future.

Our goal of discussing the GeRRN on an international basis has not been abandoned. During the first international presentation of the GeRRN at the Federal MNU Congress, clear interest was shown by our foreign partner societies, and they are now already working within their own organisations.
The real work can begin now that the GeRRN has been provisonally completed: on the basis of the Reference Framework it is now necessary to realise considerable modifications to natural science teaching, so that education in this area can emerge from its present rather shadowy existence. The education of science teachers as well as their further education will then need to be discussed politically and optimised. Our vision is that during job interviews candidates will not only be asked about their knowledge of foreign languages but also about their science education, and we shall stick to this vision! Why should another working group not use the GeRRN to devise a certification system for natural science education?
The GeRRN is a successful example of the work which the MNU has been carrying out for 125 years. According to its constitution the association makes clear „the great economic benefit conferred, in particular by MINT teachers, by a modern quality of education on a future-oriented and democratic Germany". This has been realised by the initiators, those members of the working groups who carried out the initial hard work, but also of course particularly by the authors responsible for formulating the present document: Birgit EISNER, Prof. Dr. Ulrich KATTMANN, Matthias KREMER, Jürgen LANGLET, Dieter PLAPPERT and Prof. Dr. Bernd RALLE.

Each individual teacher should concern him- or herself with the improvement of natural science education using the GeRRN/CRFS as a basis. All who continue the work on the areas referred to in the chapter „Outlook" can be sure that they will receive the support of the MNU and its Board.

Düsseldorf, August 2019

For the board of the MNU

Gerwald HECKMANN, Chair

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