GDNÄ-Bildungskommission

General Education through Science Teaching

Memorandum of the Educational Commission of GDNÄ
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Abridged version 2010

GDNÄ
Gesellschaft Deutscher
Naturforscher und Ärzte e.V.

General Education through Science Teaching

Abridgment of the Memorandum

„Allgemeinbildung durch Naturwissenschaften“ (2007)

of the Educational Commission of

Gesellschaft Deutscher Naturforscher und Ärzte (GDNÄ)

(Society of German Natural Researchers and Medicals)

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In order to make accessible to a broader readership, in particular in English speaking countries, the main ideas of the memorandum "Allgemeinbildung durch Naturwissenschaften" (1st edition 2002, extended 2nd edition 2007), the essentials of the memorandum are published here in the English language in a concise, handy version. Basic guidelines pursued by the Commission are presented on the opposite page so readers may understand them right at the beginning before going into detail on the following pages.

Science teaching is not seen here, as often is the case in the general public, as a vehicle only to scientific professions, but also – and in particular – as a vehicle to *general citizenship.*

Hamburg, July 2010
The Editor

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Guidelines

1. “General Education” does not only proceed from a broad spectrum of school subjects, but can also result from a **broad spectrum of views within each subject;** (except the normal subject-matter of the discipline: trans- and interdisciplinary topics, technical applications, history, language, ethics, esthetics, philosophy, etc.).

2. In order to reach this goal, we do not need “integrated science” (for which we do not have, so far, the “integrated science teacher” trained adequately), but a new type of **subject-transcending subject teaching** according to the principle: Out of the subject – beyond the subject! The school subjects, as structural units of the syllabus, should be maintained, however be reformed inside.

3. If we want to transmit to the learners a long-lasting and multiply applicable conceptual framework for problem-solving, the accent of teaching has to be shifted from special subject-matter – which, of course, is needed for particular problem areas – to **super-ordinate trans- or interdisciplinary major concepts** pertaining to all subjects and all sorts of problems in life.

4. Besides this shift of accent, training **processes of thinking and acting**, i.e. general **skills**, should be given more emphasis than just static knowledge which fades away too soon.

5. Furthermore, beside the cognitive and pragmatic (psychomotor) domains, essential fundaments of General Education are to be seen in the **affective domain**. Particular emphasis should be laid in science teaching on **attitudes towards science** and, apart from that and possibly even more essential, on **scientific and moral attitudes** which should become long-lasting components of the student’s personality.

6. Consequently, following the principle of Pestalozzi’s “education through heart and spirit and hand”, science teaching should not only focus on the **education of the head**, but also on an **education of the heart** achieving a balanced relation between the two components at the end.

1. Theoretical Foundations

1.1 Two approaches to General Education

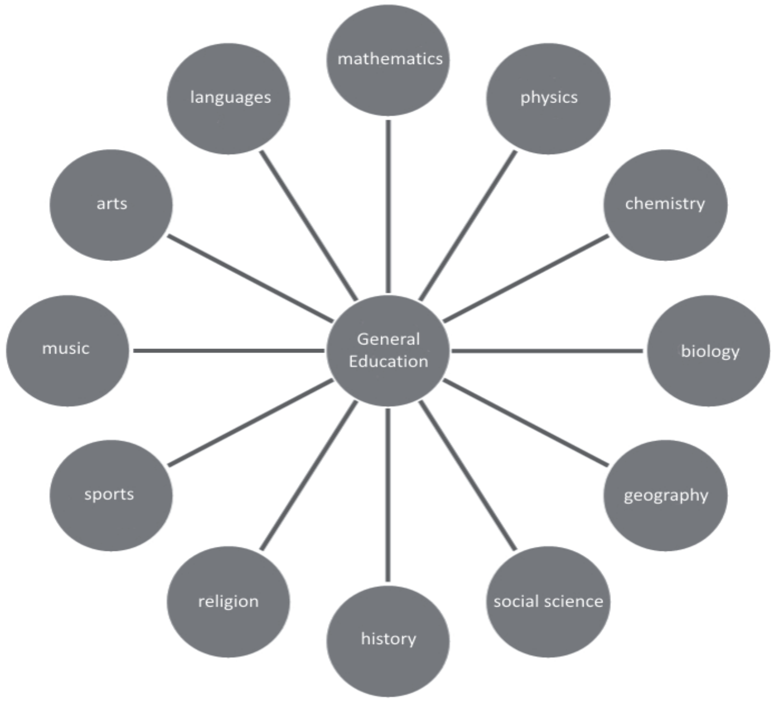


Fig.1, 1st approach: General Education by adding different school subjects

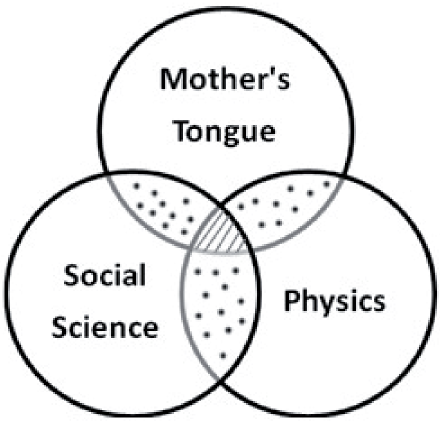


Fig. 2, 2nd approach: General Education within each subject
by adding overlapping fields from other subjects.
First challenge: dotted areas between two subjects. Second and greatest challenge: central (hatched) zone which all school subjects have in common, even those which seem "far from each other" (like the 3 examples above; cf. zone 1 in fig. 3)

Among the two approaches outlined in figures 1 and 2 the Educational Commission of GDNÄ decided, principally, for the second one (fig. 2). Consequently it developed for science teaching a rosette figure (fig. 3) in which knowledge and skills of the three science subjects are overlapping, and furthermore, in the centre of the figure (zone 1) even basic concepts and skills of *all* school subjects, incl. the humanities, are represented. Fig. 3, therefore, is a special variant of fig. 2 focussing on "General Education through Science Teaching".

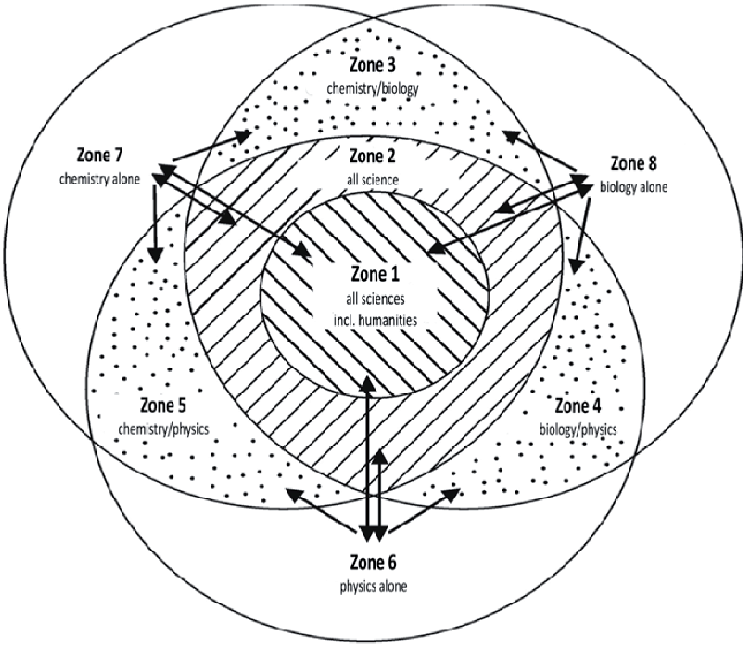


Fig. 3: Rosette of basic concepts and skills of science.
Arrows indicate the emphasis given to subject-transcending contents

The contents of the large "physics circle" constitute what may be called "subject-transcending physics teaching", that of the large chemistry circle "subject-transcending chemistry teaching", etc..

In zones 3, 4 and 5 we find contents of two neighbouring disciplines, in zone 2 those of all science disciplines, such as "molecule", "energy", "pressure", and in zone 1, as already mentioned, basic concepts for all school subjects such as "structure", "system", "order", "law" (table 4) and basic skills like *observing*, *describing*, *explaining*, *defining* (table 5).

In the centre of the rosette also *affective* components of science teaching should be placed, since they belong to the core of General Education. However, this is difficult in a 2-dimensional rosette. Thus the Commission decided to use, in addition, as a 3-dimensional model the so-called "Tree of Education" (fig. 4). It symbolizes on top, in the crown, the various sorts of *knowledge*, in the lower big branches basic *skills* producing and "carrying" the knowledge, on bottom of the crown the attitudes towards subjects and contents, and finally, down in the trunk, basic scientific and moral attitudes necessary for scientific work.These latter are pre-conditions for, but also results of, science teaching in school and are regarded to be an essential pillar of General Education.

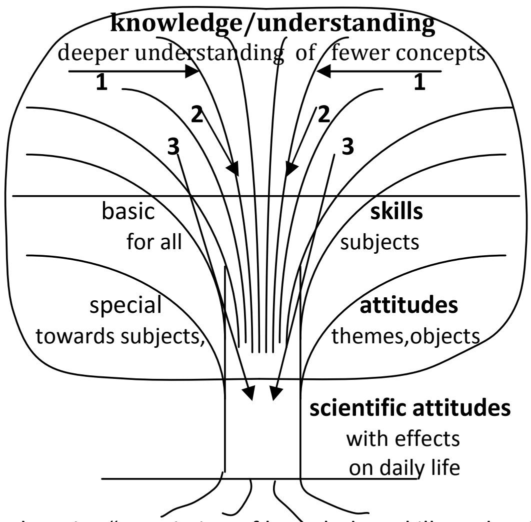


Fig. 4: „Tree of Education" consisting of knowledge, skills and attitudes.
The arrows indicate a shift of teaching necessary in future:
1. from subject-bound to subject-transcending concepts,
2. from knowledge (concepts, substantives) to skills, actions (verbs),
3. from knowledge and skills to attitudes.

It appears particularly important to the Commission when pursuing the 2nd approach to link, *within* the school subjects, those competences acquired in science teaching with other competences of general education. Fig. 5 symbolizes this task by a "wheel of competences".

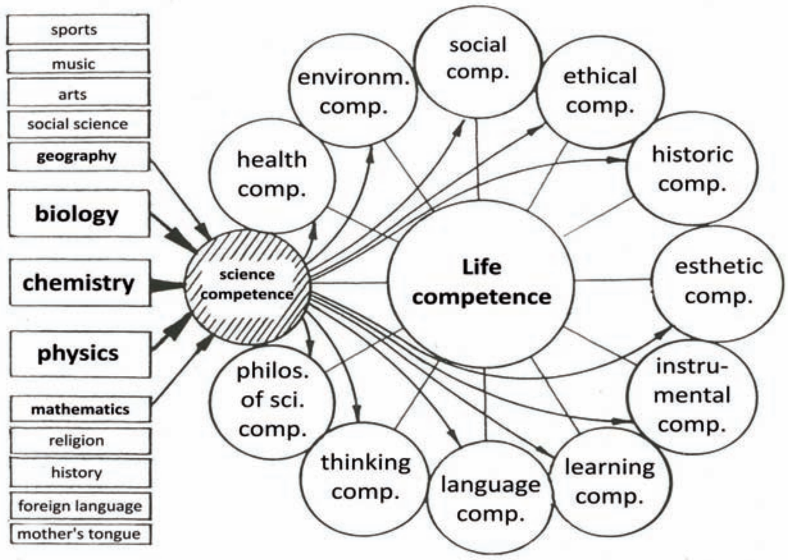


Fig.5: "Wheel of Competences" for subject-transcending subject teaching, linking science competence to 11 other general competences of life

1.2 Basic concepts of science education in a ranking order

In indexes of science textbooks of schools we find, altogether, approximately 10,000 words, or concepts. It is impossible, for time reasons, and also makes no sense for psychological reasons, to teach all these concepts in school. So the Commission in 2002 selected about 470 concepts regarded to be "basic" with respect to *general* instead of disciplinary education. The criteria of selection were:

1. Criteria of *action*: a. societal actions; b. individual actions in everyday life.
2. Criteria of *reception*: a. primary experience by the senses; b. complex experience by higher cognition, views of life, theories.

These 470 basic concepts, after having been selected, were then classified in a 3-rank system according to their "degree of interlinkage" with other concepts. In a previous publication of the Commission (Wittenberger Initiative 2000, p. 49 f.) the procedure has been explained in detail: For each concept, the percentage of logical links to other concepts of the same sample in relation to the maximal possible number in this sample was determined. Links of particular importance were given double weight. Differentiation in 3 ranks was then performed according to this variable (see Memorandum, p. 132/133).

The result is demonstrated for physics, chemistry and biology in the following 3 tables. On the left side, together with 1st rank concepts and on the same level, also principles of "EPA" have been integrated in the tables (EPA = agreement of German Ministers of Education on standards for "Abitur", the final examination in German gymnasia).

Comparing the tables for biology and chemistry it is striking to see that in biology the subject-specific columns (zone 8) are by far dominating over the subject-transcending columns (zones 1+2), but in chemistry vice-versa. This apparently is due to the fact that in biology subject-specific concepts, according to the high complexity of living systems, represent already a huge variety of biological phenomena, i.e. they stand for a broad network of *consequences* of natural laws in interaction with each other, whereas the laws themselves, in their simple, elementary form, are the main focus of physics and chemistry.

However, in the left columns of the biology table we do find some fundamental concepts of general scientific significance such as chaos, order, system, structure, determinism, up to history, language, meaning, culture, ethics. They all belong to zone 1 of the rosette indicating that biology is already "trans-disciplinary" in itself because it pertains to all areas of human culture. Paradox, as it sounds, it is a subject which is already "subject-transcending".

The figures quoted at the bottom of the tables do not mean reduction of subject-matter down to just 104, 74 or 102 "eminent basic concepts" – including about 30 to 40 first rank concepts − , and definitely they do not mean reduction of the number of teaching lessons.

Among some other reasons, the reduction recommended here is aiming at a *deeper understanding* of the 470 concepts taught. To reach this goal, more teaching time is needed for each concept, so the number of lessons should by no means be reduced, but rather reformed in contents.

To avoid any misunderstanding, it should be stressed here that the 3 following concept tables do not specify the knowledge needed by *scientists*, but they outline a *general science basis of education.* They illustrate the notion of "physics for non-physicists", "chemistry for non-chemists", and "biology for non-biologists" which means: the primary teaching objective of school is *general education,* not science. Science teaching, on the other hand, is seen by the GDNÄ Commission as an excellent *vehicle towards general education.* This is the main thrust of the Memorandum.

1.2.1 Basic concepts for physics teaching

EPA principles	Rank 1		Rank 2		Rank 3	
	zones 1 + 2	zone 6	zone 2	zones 4,5,6	zone 2	zones 4,5,6
fields	Coulomb force gravitation charge interaction		voltage current amperage	electromagnetic induction nuclear force (=strong force) magnetism (ferro-) force in the magn. field		electric circuit direct/alter-nating current capacity electric resis-tence Ohm's law electric motor generator
waves	light	interfe-rence	amplitude frequency sound oscillation	speed of light el.magn.spectrum refraction, lense reflexion focal distance gamma-rays,laser beam course	absorp-tion polariza-tion	X-rays colour resonance optical disper-sion
quanta	random probability particle	law of un-certainty	photon radioactivi-ty	elementary charge anti-particles		quantum number light-electric effect energy level
matter	energy mass conservati-on variable atom at. nucleus force tempera-ture	theory of relativity universe Newton's axioms	entropy fundamen-tal particle semi-con-ductor inertia work speed heat	energy-mass relation galaxis, big bang celestial body solid body, liquid, gas impulse, shock centrifugal-/cen-tripetal force	density pressure accelera-tion	resting energy mass defect half value per-iod, speed-de-pendent mass helio-/geo-centric view Kepler's laws buoyancy,fric-tion, law of levers,braking distance, heat-force machine
further import. concepts	variable,(basic)unit,time length,power,invariance linearity/ non-linearity		volume			
sum:	**26**	**5**	**17**	**26**	**5**	**25**

Table 1: 31 first rank basic concepts for school physics (incl. 4 EPA principles); in toto 104 eminent basic concepts including trans- and interdisciplinary ones from zones 1 and 2 to which physics essentially contributes

1.2.2 Basic concepts for chemistry teaching

EPA principles	Rank 1		Rank 2		Rank 3	
	zones 2 + 3	zones7+8	zones 1, 2, 3	zone 7	zones 2, 3, 5	zone 7
matter/ particle principle	substance (matter) particle atom molecule element	pure substance mixture chem. reaction material cycling	ion electron	analysis synthesis	formula (chem.) periodic table salt polymer spectroscopy	metal non-metal complex compound chemotechnical procedure
structure/ property principle	state of aggregation solubility chemical bonding		polarity (inter-molecular) interaction	ionic, covalent, metal bonding nucleophile/electrophile	isomery hydrogen bond dipole-dipole interaction	van der Waals force
donator/ acceptor-principle	acidity/ basicity oxidation/ reduction			neutralization	reaction mechanism	electrochemical series
energy principle	enthalpy -GIBBS' free -reaction e. entropy activation energy	catalysis	bonding energy		galvanic element electrolysis battery accumulator	
equilibrium principle	concentration(of matter)		equilibrium (influence on)	mass action law		
further import. concepts	compound, class of material, acid/base, reversibility/irreversibility		lattice energy carrier stability		separation technique, elementary analysis, volumetric analysis, recycling, molecular substance	
sum:	**23**	**5**	**9**	**9**	**18**	**6**

Table 2: 28 (32, respectively) first rank basic concepts for school chemistry incl. 4 additional EPA principles (implying 8 single concepts); in toto 74 eminent, partly trans- or interdisciplinary basic concepts from zones 2, 3, 5 and 8 of the rosette to which chemistry essentially contributes

1.2.3 Basic concepts for biology teaching

EPA principles ↓	Rank 1		Rank 2		Rank 3	
	zones 1+2	zone 8	zones 1 + 2	zone 8	z. 1 + 2	zone 8
structure and function	life/death chaos order system structure function	life (organic) *order/chaos polarity* suitability	sense correlation causality linearity/ non-linearity interaction	*entanglement/ disentanglement* (complexity)	symmetry	
substance and energy metabolism	substance (matter) energy i.biol.context	*de-/upgrading*		material cycling metabolism, photosynthesis (assimilation), decomposer, producer, parasite,symbiont		dissimilation, enzyme, hormone, consumer, probiosis, food web/ chain
reproduction		growth		species, gene norm of reaction sexual/asexual reproduction		generation
control and regulation	feedback	*auto-/heteroregulation*		*active movement/ quiescence,* regulation/circ.,homeostasis,periodicity	determinism, health/ disease	
variability and adaptedness		*variability/ uniformity adaptation/persev.*	random probability	mutation,select.n *transformation/ preservation*	culture, responsibility, ethics, conflict, sustainability	modification, recombination
history and relationship	history development	bioevolution man,animal plant (types)	time (scientfic)	ecosystem, population, bacterium, fungus (types)		isolation biol biosphere virus (type) fossil
information and communication	language		sign meaning	*syntactic/semantic polarity* *information storage/extinction*		immune reaction stimulus/ irritability
compartmentalization		cell organism		*closing/opening of borders(demarcation polarity)*		tissue, organ system
further concepts	reduction/ism,contrast,polarity,nature,environment					
sum:	**20**	**14**	**10**	**27**	**8**	**19**

Table 3: 38 first rank basic concepts or polarities for school biology, incl. EPA principles (4 concepts)**;** in toto 102 eminent basic concepts incl. trans- and interdisciplinary ones from zones 1 and 2 to which biology essentially contributes.
„Polarities of life"(in italics) have been counted once each and not as two single concepts.

1.3 Subject-transcending fundamental concepts

The centre of the rosette, zone 1, contains, beside general skills presented in the next chapter, basic concepts of fundamental significance for all school subjects. These "fundamental concepts" are regarded to be the conceptual core of subject-transcending teaching.

Since mathematics, together with philosophy, forms the rational basis of all sciences, mathematical concepts like structure, function, deduction, probability etc. are not incidentally placed in this centre. The question, often raised, where in the rosette mathematics can be located, is easy to answer: if at all (mathematics is not "science" in the strict sense of a "natural science" and thus was not intended, as a school subject, to be part of the rosette), then it can be found in zone 1 of the figure. These concepts are presented in table 4.

Table 4: "Fundamental concepts" from zone 1 important for all school subjects

cause causality chaos complex concept	effect empiricism environment esthetics ethics	meaning method model natural science nature	scientific/-ficity sense sign social science structure
conflict contrast control experiment correctness correlation	boundary condition freedom function health / disease history	necessity objectivity order polarity probability	subjectivity sustainability symbol symmetry synthesis
criterion culture death deduction determinism	humanities hypothesis induction language law	process randomness reality reduction/-ism responsibility	system theory time truth variability
development	life	rule	

In the years after publication of the GDNÄ Memorandum teachers frequently asked whether these fundamental concepts were regarded as equally important, or whether they could, and should, in some way be structured, weighted, and placed in a rank order.

Therefore at the outset a terminological clarification seems necessary. The term "subject-transcending" simply means that the concept referred to is not just restricted to the discipline under consideration but clearly transcends its borders. This can happen in two different ways:

subject-transcending

"horizontally"
over to concrete neighbouring disciplines

***inter*disciplinary concepts**
e.g. protein (biology-chemistry, zone 3),
energy (all science subjects, zone 2)

"vertically"
up to abstract, formal disciplines

***trans*disciplinary (fundamental) concepts**
e.g. structure, theory, sign, model, culture
(all school subjects, zone 1)

Thus the two terms "transdisciplinary concept" and "fundamental concept" are used synonymously here. They are suitable tools of higher-level cognition.

During a meeting of the GDNÄ Commission members tried in parallel groups to tackle the task of structuring these concepts. It turned out that depending on the primary interest of the group different concepts could be used as starting points and all others linked to them in some logical way. This means there is no pre-given general structure inherent in the collection of concepts presented in table 4 (apart from sub-sets, see below, fig. 6). The whole collection allows logical structuring in different ways depending on the primary interest.

Such an example is presented here in fig. 6. Based on this example readers may feel they might like to build up a concept structure of their own according to their point of interest. This exercise, by the way, is an excellent opportunity for students in upper grades of school to discover the power of language in scientific work.

The example shown in fig. 6 starts with the classical relation “individual/environment”. The environment appears to the individual both as “nature” and “culture”. It undergoes, or should undergo, (A) sustainable development, and (B) encompassing health/disease as well as life/death.

Here the individual finds order and structure in complex systems containing symmetries, but also contrasts, polarities, and even chaos (G).

Approaches of Man to environment may proceed in a subjective or objective way, e.g. aesthetically (B) or scientifically (D). Sciences, on the other hand, are divided into natural, social sciences and humanities. Languages (F), with their concepts, meanings, signs, and symbols, serve as instruments of communication as well as classification and storage of knowledge.

The individual itself moves between freedom and responsibility. In case of conflict it finds assistance by ethics, “sense” (of life) and truth (C), but also through scientific methods and criteria (E): Construction of reality is achieved by the aid of reductionist, inductive as well as deductive treatment of empirical data aiming, at the end, at theories based on hypotheses, rules, models, laws as pre-steps.

Apparent coherence between empirical data is then modeled − despite the obvious uncertainty of these concepts − in dimensions of process and time (H). Correlations found can sometimes be formulated as causalities, if functional cause-effect relations can be proved by experiment. In this connection various questions around probability, random, necessity and determinism emerge and demand answers.

When comparing different concept arrangements developed in this way, it becomes evident that certain clusters, like A, B, C --- in fig. 6, appear again and again. Obviously they are grounded on objective, logical relations between the concepts involved, independent of the initial starting point. They are high-order building stones flexibly applicable to various situations and fields of reality. Therefore they are suitable elements of any structure of a discipline in school, in particular they may motivate teachers to develop special modules for “subject-transcending subject teaching” (see, for example, tables 8-10 on pages 20-22).

In the Tree of Education, fig. 4, emphasis was laid by the Commission upon such fundamental concepts and their clusters. This was indicated by arrows with number “1”. Curriculum experts – and this pertains to all school subjects – should pay attention in the near future to such shifts of accent. Certainly it may be difficult for science teachers to move away from the usual disciplinary way of thinking they learnt at the university, however, in view of the general educational commitment a subject has in school *beyond* its special disciplinary task, such shifts are inevitable to arrive, at the end, at a “general citizenship through science teaching”.

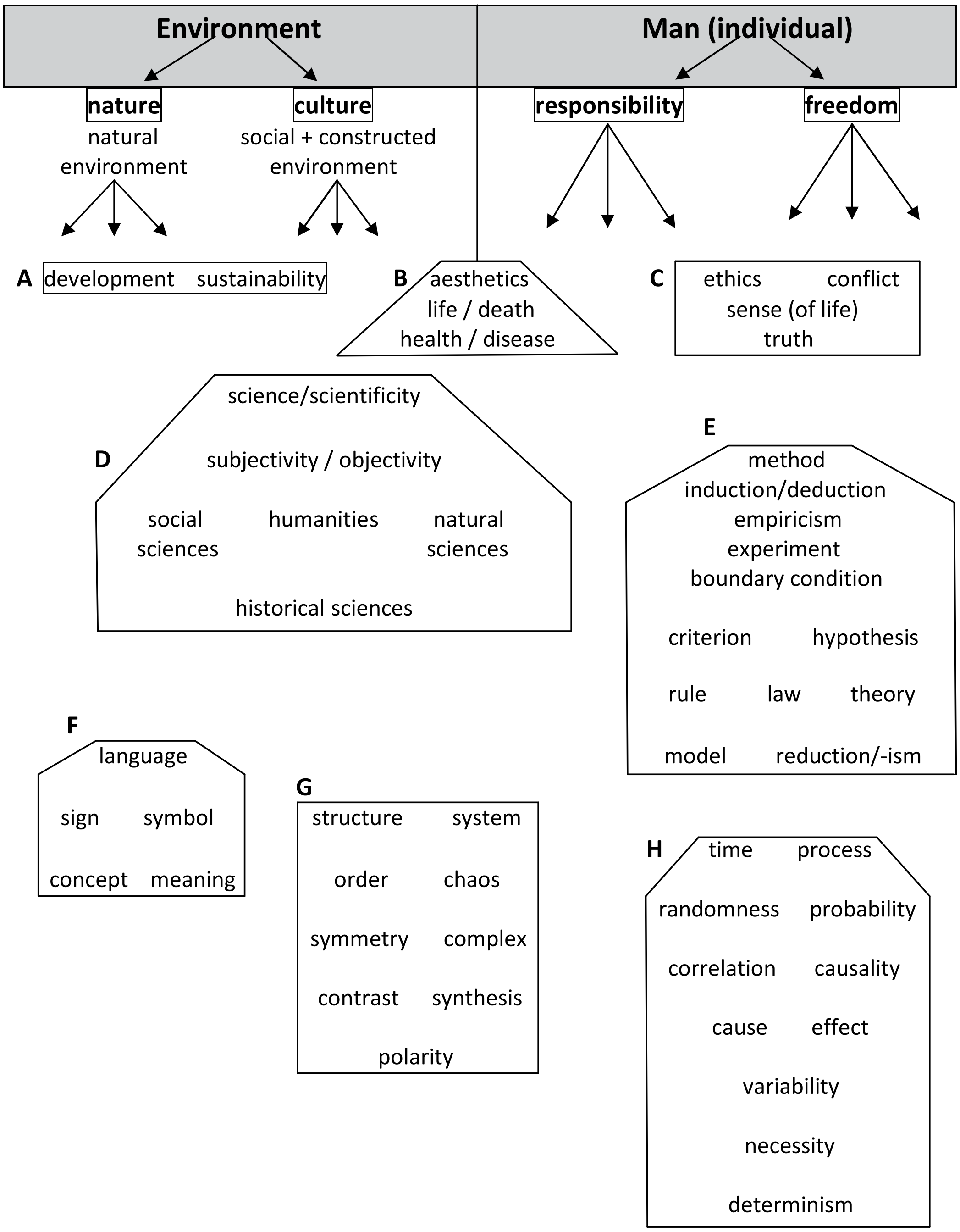


Fig. 6: One among various possibilities to structure fundamental concepts from zone 1 of the GDNÄ-rosette

1.4 Scientific skills, categorized and weighted

In zone 1 of the GDNÄ rosette, beside transdisciplinary fundamental concepts dealt with in the previous chapter, there are also 35 skills which are characteristic of, and necessary for, any kind of scientific work. They can be regarded as indicators of general "scientificity" because they represent the *scientific method* which in fact is the essence of science. The skills are demonstrated on the opposite page in table 5.

As much as experts of school agree upon the principal significance of such skills for general education, unfortunately there is less agreement on number, ranking order, and even on a precise definition of skills. For instance, it is surprising to see how little agreement there is in schools about what people think about the proper meaning of "explaining", "understanding", "defining", "measuring", and "proving".

In the unabridged version of the GDNÄ Memorandum 2007 these skills are explicitly defined so the reader may check there to determine what precisely the Commission means by skills.

In table 5 the attempt has been made to group the skills in 3 categories and to build up a ranking order in each category based on their intellectual demand. This is a rather difficult task since some skills are not precisely defined, others are multi-functional and can be classified in more than one category.

Anyhow – table 5 may be a stimulus for teachers to look at skills with more attention, to put more emphasis on the psychomotor components of education, and possibly to improve the taxonomy of skills presented here.

In this context it should also be considered whether it might be useful to change some of the concepts placed in zone 1, and formulated as substantives, into *verbs* and thus to convert "knowledge into skills". The proximity of meaning between fundamental concepts of zone 1 and scientific skills is great, anyhow, since both constitute the *methodology* of scientific work.

Consequently, a concept originally called "model" in Memorandum 2002 has been changed already into a skill in the second edition 2007, namely into "modeling". This skill is not only used and trained in mathematics, but increasingly also in science teaching to-day.

Such a "verbification of substantives" may essentially promote a shift of teaching from knowledge to actions, from concepts to skills, as pointed out in guideline 4 at the beginning of this paper and illustrated in the Tree of Education, fig. 4, by arrows with number "2".

Some further examples:

concept → conceiving, grasping
hypothesis → forming a hypothesis
life → living
structure → structuring
system → systemic thinking
etc.

Everybody who knows the reality of school, knows how little one really "knows" when mastering substantives, and how much more important, however difficult, it is to *perform* the actions (as verbs).

For instance, "hypothesis": A hypothesis, once formulated, serves as an instrument of logical reasoning to check reality and eliminate errors (Popper's method). The question, however, is how the hypothesis originated. The *process* of developing a hypothesis is not only a rational, logical one, but is interlinked with numerous associative, emotional and intuitive factors. Insofar, tracing back the product (the hypothesis) to its process (generating the hypothesis) seems an important step towards General Education.

Another example: “system”. Systems do not exist in nature, they are man-made. Anybody who does not know, understand and has never experienced for himself the process of *demarcation* of areas out of reality, their subsequent breakdown into *elements,* and the discovery of *relations* between them, will probably poorly understand the final outcome: the “system”.

Table 5: Categorizing and weighting of 35 scientific skills in 1st approximation
(Explanation of the skills under the given number in the unabridged Memorandum)

intell. level	skill	ex-plan	intell. level	skill	ex-plan	intell. level	skill	ex-plan
increasing **abstraction** ↑	*formalizing*	10	increasing **complexity** ↑	*problem solving*	20	increasing **theory production/ theory dependence** ↑	*valuing, rating*	34
	measuring	9		*proving*	19		*understanding*	33
	counting	8		*falsifying/ verifying*	18		*explaining*	32
	guessing, assessing	7		*analyzing errors*	17		*judging*	31
	defining (in the sense of „conceptual demarcation“)	6		*experimenting*	16		*mathematizing(=translating into a mathematical language)*	30
	generalizing, classifying	5		*modifying/ varying*	15		*modeling*	29
	discovering similarities	4		*concluding, deducing*	14		*developing alternatives*	28
	commenting upon…	3		*interpreting*	13		*defining (in the sense of „logically integrating”)*	27
	describing, formulating	2		*argumenting, giving reasons for*	12		*making plausible*	26
	observing	1		*analyzing*	11		*orientating oneself*	25
							analogizing	24
							transferring	23
							comparing	22
							considering critically	21
predominantly **descriptive skills**			predominantly **cause-analytical skills**			predominantly **theory-bound skills**		

1.5 Affective basis of General Education: attitudes

"Competence" – a word increasingly used in modern societies– is generally understood as the comprehensive precondition (i.e. capability *and* readiness) for problem-solving in a specific field of reality. It does not only imply the knowledge required to solve special tasks (cognitive condition), and not only the practical skills required to perform the problem-solving activities (psychomotor condition), but foremost it implies attitudes without which no motivation would exist to tackle the problem at all (affective condition).

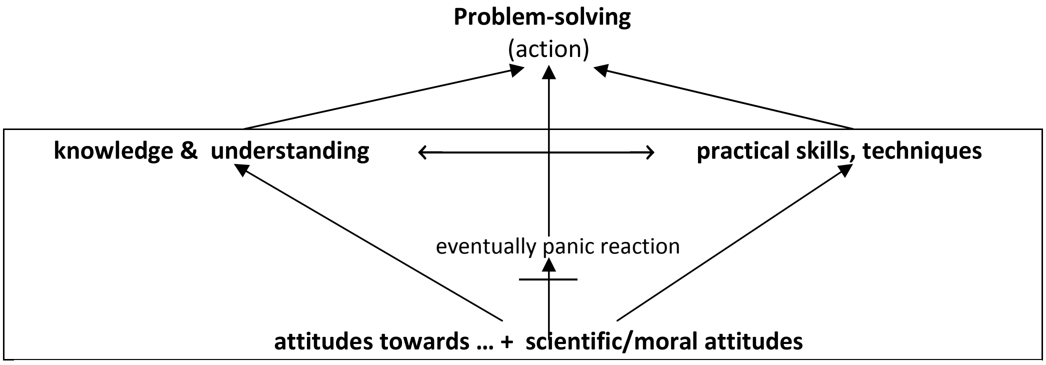


Fig. 7: Tripartite structure of a "competence" consisting of knowledge, skills and attitudes

Accordingly, the 12 "general competences" illustrated in fig. 5 at the beginning of the paper are also to be understood in this tripartite way. General Education, in its deeper sense, necessarily implies the acquisition of attitudes or, with other words: General Education does not mean "training the head" alone, but means also "training the heart".

In the Memorandum – opposite to colloquial language, but following Gardner 1975 – a clear distinction is made between "attitudes towards … " (e.g. science, arts, sports etc.) and "scientific or moral attitudes".

The first kind, just as interests, may be compared with searchlights in a horizontal position. They are directed by subjective, emotional valuation of things such as pleasant/unpleasant, interesting/not interesting, worth/worthless, and are completely subjective, i.e. person-bound. They are of medium stability and may change over night by any unexpected event.

The second kind of attitudes, however, is oriented – metaphorically speaking – in the "vertical" by objective, person-transcending values, standards, norms "above" the individual. Goldin (2002), in the context of mathematical "belief research", circumscribes this category tentatively with "values, ethics and morals". For this category the German language offers an excellent word: Haltung (verbally "conduct", however not restricted to the body alone, but likewise used for "conduct of the mind").

The fundamental difference between the two kinds of attitudes manifests itself, for example, in situations when one category stands against the other: There may be a positive *attitude towards* something or somebody saying "yes", and still there may be a cautionary note in us saying "no", perhaps a *moral, religious, ecological or scientific attitude* which may be subsumed under the term "conscience". By means of attitudes of this second kind basing on stable, trans-personal values and norms, the human personality gains stability, and reliability; so these attitudes are frequently regarded as "traits of the character".

1.5.1 Scientific attitudes

The Commission, in its Memorandum, identified eight such attitudes extracted from several biographies of scientists (fig. 8). They have been operationalized and empirically investigated in a cross-cultural German/Japanese study (Langlet/Schaefer 2008), have since been applied in schools (7th grades) and are strongly recommended to be taken as affective objectives of science teaching in future.

In fig. 8, however, only one side of a bipolar couple of attitudes is represented because scientific work and success mainly depends on this one side. But even within science a polarity of attitudes is relevant to some extent. For instance, accuracy in calculation, overdone and exceeding the accuracy of measurement, is pedantry which is not appropriate.

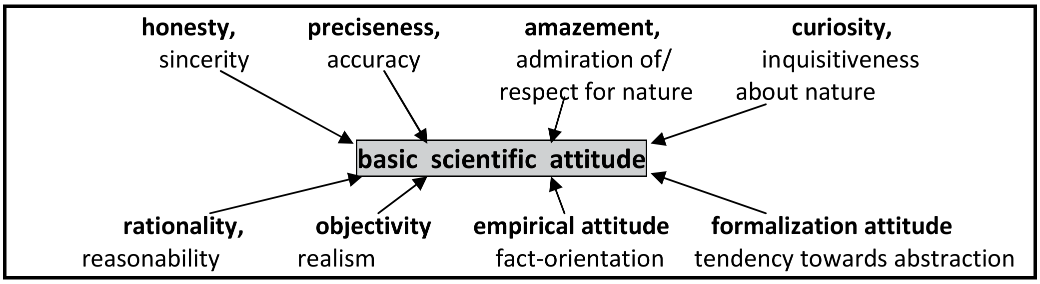


Fig. 8: Eight single attitudes which together form something like a “basic scientific attitude”

1.5.2 Polarity of attitudes

Attitudes of the second kind are – corresponding to the general polarity of life – always structured in this bipolar, controversial way: To each attitude there is a counter-attitude contradicting it, but also essential for life. By counteracting each other they prevent over-action on one side and thus are necessary to find a balance point appropriate to the present situation (fig. 9).

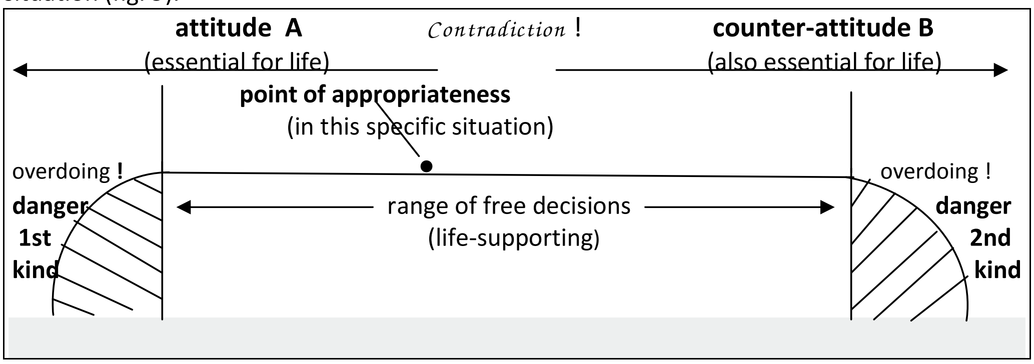


Fig. 9: Polarity of attitudes as a basic property of life

In the following table (table 6) the polarity of the eight scientific attitudes presented in fig. 8 is explained. It is essential to note that *both* sides of a bipolar couple of attitudes have to be valued positively within a certain range, but that *both* sides of the couple can also become negative when over-done. The table is recommended for use in upper secondary classes when discussing scientific methods, their pros and contras, and their role in everyday life.

Table 6: Polarity of the eight scientific attitudes of fig. 8

attitude			counter-attitude		
negative range (overdoing)		*positive range in daily life* ↓ **special accent in science**			*neg. range (overdoing)*
truth fanaticism honesty at any price up to in-humanity		**honesty, sincerity:** regarding own motives, but also own failures; appreciation of others' merits	**appropriate discretion:** tact in dealing with other people, but without falsifying facts		**dishonesty:** lies, falsehood, holdback of own failures
pedantry: up to ineffecti-vity		**preciseness, accuracy:** inclination towards order in actions, calculations, words	**generosity:** ignoring trifles, focus-sing on essentials only		**slovenliness:** inaccuracy, negligence
adoring nature: ignoring that as a part of it we have to interact		**admiration, respect to nature**: caution in inter-actions; attitude of care, wishing to preserve it	**exploration of nature:** for the sake of shaping/organizing nature in full respect to it		**abuse of nature:** its shameless exploitation for own purposes
craving for knowledge about nature: leading even to research mania		**curiosity about nature:** desire for recognition/ knowledge in order to treat nature adequately and to avoid mistakes	**slight reserve in curiosity about nature:** because of broad spectrum of other inter-ests		**total disinterest in nature:** „All the same-attitu-de" because of other interests
rationalism: craving for logi-cal analysis of everything; re-jection of intuition/emoti		**rationality:** not only capability of, but also *desire* for logical analy-sis/structuring of the world as a supplement to, not replacement of, intuition	**intuitionality:** intuitive, holistic perception of the world as a supplement to (not replacement of) logical, analytical understanding		**irrationality:** total rejection of logical, ana-lytical cognition; purely emotional
objectivism: belief in the existence of an „objective world" perceptible by Man		**objectivity:** not only capability of, but also *desire* for control of one's own views by facts; even pleasure to replace subjective views by inter-subjective ones	**appropriate subjectivity:** courage to form own opinions / hypotheses and to stand to them against opponents; creative phantasy		**subjectivism:** „fixed subjecti-vity"; reluctance to any control of own views by facts
empiricism: adoration of facts; devaluation of creative		**empirical basic attitude:** desire to ground views of life on facts and to provide facts to control speculative phantasy	**creative phantasy:** desire to supplement empirical data by speculative phantasy, i.e. facts by theories		**speculationism:** obsession by phantasy irrespective of facts
formalism: tendency to for-malize everything and to describe reality in symbols only		**formalization attitude:** desire to reduce reality to essentials: superordinate terms, schemes, formulas, tables, figures, theories. Pleasure of reduction	**concretization attitude:** desire to represent abstract thoughts by sensory experience; phenomenon-orientation		**concretism:** aversion against any kind of abstraction; „anti-mathema-tical attitude"

2. Application to Teaching

2.1 Theme patterns for trans- and interdisciplinary modules

When trying to put the idea of “subject-transcending subject teaching” into practice it is helpful to develop a number of subject-transcending modules according to the 44 theme patterns presented in the Memorandum. They meet the general obligation of school which is: *Students should be enabled to find their place in the present world.* For this purpose each school subject should not primarily be seen in connection with the future profession of the student, but as a *bridge to general citizenship*. Thus the 44 patterns have not been selected according to the structure of the disciplines, but to criteria of general education (cf. p.7, above). Table 7 shows the general structure of such patterns.

On behalf of general applicability in all kinds of schools, they are divided into three levels of achievement. Contents of levels 1 and 2 are supposed to be followed up also in subsequent levels (see arrows) and are not repeated in these levels.

Level 1: Pragmatic understanding for everybody.

Focal points of teaching are here to be mastered by *all* students at the end of school (whenever this end may be). There should be no student leaving school without having achieved these standards.

Level 2: Deeper subject understanding.

On this level focal points of the 1st level are picked up, extended and deepened by more profound and detailed subject matter. This level is conceived for students leaving school after the lower secondary grades (9 or 10) and thus also defines the entrance qualification to upper secondary grades.

Level 3: Comprehensive understanding.

Here knowledge, skills and attitudes achieved in the previous phases should be integrated into a broader scientific and societal view and raised to a metacognitive level. This phase, after all, is the level of “multidimensional scientific literacy”. In some countries it leads to a final exam (e.g. Germany: Abitur).

Table 7: Formal theme pattern for developing subject-transcending modules

Concrete objects/events of daily life	specification of objects, themes, events from daily life concerning every citizen		
Level of achievement ⟶	**1: Pragmatic understanding for everybody**	**2: Deeper subject understanding**	**3: Comprehensive understanding**
Basic + special concepts from the discipline	concepts from the discipline necessary for understanding	⟶	⟶ ⟶
Links to other subjects	to chemistry, biology, geo-science, physics, social science, arts, languages, sports etc.	⟶	⟶ ⟶
General science concepts	concepts from zone 2 of the GDNÄ rosette	⟶	⟶ ⟶
Fundamental concepts and *skills* for all sciences	fundamental concepts and basic skills from zone 1 of the GDNÄ rosette	⟶	⟶ ⟶
General competences from the „competence wheel“	competences *specially* enhanced by the subject matter taught here	⟶	⟶ ⟶
Basic scientific attitudes	one or more of the eight scientific attitudes	⟶	⟶ ⟶

2.1.1 Theme patterns for biology

a. Survey of themes

Theme pattern 1: Cells – the "dwarves of life"
Theme pattern 2: Dealing with genes – Pros and contras
Theme pattern 3: Everything just for us? - Significance of plants and animals for our own life
Theme pattern 4: „Eating and drinking keep body & mind together" - Questions around human nutrition
Theme pattern 5: Body power, body strength? - Bioenergies in the organism
Theme pattern 6: Hormones – Little cause, huge effect
Theme pattern 7: Afraid of infection? – Modern immune biology
Theme pattern 8: Watching and listening – Team work of sensory organs and nervous system
Theme pattern 9: Free or pre-programmed? – About ethology and ethics
Theme pattern 10: Reproduction, growth,, development, death – Stages of human life
Theme pattern 11: Drugs – Dashdown into chemical slavery
Theme pattern12: Could we live without green plants? – Photosynthesis in the economy of nature
Theme pattern 13: Ecosystems – Levels of organization of the living
Theme pattern 14: History and future of life on earth – Questions around biological evolution.

b. Table 8: Example Bio 12 „Could we live without green plants?" (Photosynthesis)

objects/events of everyday life	forest, lake/sea, cultural plants, nature protection, food chain, plant/animal/man, agriculture, forestry, horticulture, raw material		
Achievem.level →	**1:pragmatic understanding**	**2:deeper understandg.**	**3: compreh.understdg.**
Basic + special concepts from the discipline	leaf, cell,chloroplast, chlorophyll,light,water,sugar,starch; photosynthesis (simplified); change/fixation; ecosystem (simplified), food chain/web	⟶ nutrient,assimilation/dissimilation,metabolism, catalysis(enzyme),flow of matter/energy i.cell,gross equation of photosynthesis (formula);organism/ organ/tissue; producer/	⟶ capillarity, osmosis,chlo - roplast struct., light-dark reactions, subst.cycles in cell (e.g.Calvin cycle,simplified), sec.plant products, energy flow in biosphere, energy quality(up-/degrading),C-cycle;bioevolution
Links to other subjects	**chemistry:** carbon dioxide, oxygen, water, mineral salt, carbohydrate; chem.reaction **physics:** energy, energy transformation, energy law **geography:** producer countries of plant and animal products **social science:** hunger areas, world nutrition, globalization	consumer/decomposer ⟶ **chemistry:** chem. equation; empirical/structural formula; organic/ inorganic	⟶ **chemistry:** balance of substance, mono-,di-, polysaccharids **physics:** entropy, energy quality, heat
General science concepts (zone 2)	substance, light, energy/transformation, temperature, time, absorption	⟶ formula(chem.), element, diffusion, concentration	⟶ macromolecule, ion, charge,photon, frequency
Fundamental concepts / *skills* for all sciences (zone 1)	environment, nature/culture, cause/effect, sustainability, concept, esthetics; *describing, commenting, giving reasons, comparing,valuating,experim.*	⟶ function, sense(meaning), symbol; *explaining, defining,formalizing, interpreting*	⟶ synthesis,complexity,hypothesis, theory, model; *analyzing, generalizing*
General competences	environmental, language-, esthetic + instrumental comp.	⟶	⟶ philosophy of science + historic comp.
Basic scientific attitudes	curiosity, honesty, respect for nature + empirical attitude	⟶ preciseness, formalization attitude	⟶ rationality, objectivity

2.1.2 Theme patterns for chemistry

a. Survey of themes

Theme pattern 1: Substances – From manifoldness to systematics
Theme pattern 2: Setup of substances – From composition to structure
Theme pattern 3: Chemical reactions – Transformation of substances
Theme pattern 4: Fuels – About old and new chemical energy carriers
Theme pattern 5: Metals – Materials and more
Theme pattern 6: Acids – bases – salts
Theme pattern 7: Chemistry in the household – Chemistry in everyday life
Theme pattern 8: Stains, dyes – Pretty and useful
Theme pattern 9: Plastic – New materials and more
Theme pattern 10: Natural substances – From bio-materials up to molecules of life.

b. Table 9: Example Che 3 „Chemical reactions – transformation of substances"

objects/events of everyday life	explosion, fire, burning, cake baking, cooking, frying, oxidation, tarnishing of silver spoon, corrosion, rust, plaster damage by acid rain, catalyst, enzyme, alcoholic fermentation		
Achievem.level →	**1:pragmatic understanding**	**2:deeper understandg.**	**3: compreh.understdg.**
Basic + special concepts from the discipline	chem.reaction,chem.equation, chemotechn.process,activation energy, stable/unstable compound,acid-base,neutralization titration, stoichiometry	⟶ chem.equilibrium, catalysis, intermediate product, inhibitor, thermic/photo-chem.activation, reaction speed, addition, elimination, substitution, reduction, oxidation, bonding energy, functional group	⟶ chem.bonding, reaction mechanisms, photolysis, law of mass action,radical nucleophily/electrophily, enthalpy,kinetics,thermodynamics, spectroscopy
Links to other subjects	**physics:** energy/-forms **biology:** metabolism **geoscience:** mineral, ore, raw material	⟶ **biology:** enzyme, photosynthesis	⟶ **physics:** electromagnetic spectrum, energy level **biology:** biorhythm **social science:** responsibility, risk assessment
General science concepts (zone 2)	energy, equation of variables, Periodic Table, particle, time, volume,pressure,temperature, mass, force, charge	⟶ energy law, equilibrium, dipole, concentration	⟶ light, absorption, wave/ -length, frequency,potential, oscillation, entropy
Fundamental concepts / *skills* for all sciences (zone 1)	empiricism, law,rule, causality, control experiment, method, model, symbol; *experimenting, observing, giving reasons, describing, interpreting, counting, comparing, discovering connections*	⟶ reduction, system, hypothesis, deduction/induction, theory, history; *proving,simulating, classifying, mathematizing*	⟶ science/scientificity, correlation, cause; *analyzing, valuating, falsifying/verifying*
General competences	environmental, language-, learning-, social, instrumental competence	⟶ thinking comp. (abstraction),historic competence	⟶ philosophical competence (philos. of science)
Basic scientific attitudes	curiosity, preciseness, respect for nature, empirical attitude	⟶ rationality, objectivity	⟶ formalization attitude

2.1.3 Theme patterns for physics

a. Survey of themes

Theme pattern 1: Driving with knowledge – Knowing and practicing laws of motion
Theme pattern 2: Measuring – An indispensable cultural technique
Theme pattern 3: Solid, liquid, gaseous – States of matter
Theme pattern 4: Why is the rainbow coloured? – Optical phenomena
Theme pattern 5: Expecting current with tension (voltage)! – Electricity in everyday life
Theme pattern 6: Who heats us to-morrow? – Energy to-day and in future
Theme pattern 7: Mobile telephone, SMS, television, computer – Physics of information technology
Theme pattern 8: Sun, moon and stars – Position of Man in the cosmos
Theme pattern 9: Nature does make jumps! – Quantum structure of matter
Theme pattern 10: Is everything pre-determined?– Determinism and randomness.

b. Table 10: Example Phy 10 „Is everything pre-determined?– Determinism and randomness"

objects/events of everyday life	Probability, likeliness, random, chance, natural law, inaccuracy, chaos, gambling		
Achievem.level →	**1:pragmatic understanding**	**2:deeper understandg.**	**3: compreh.understdg.**
Basic + special concepts from the discipline	mean value, probability, error of measurement	⟶ standard deviation, order/disorder, law of decay	⟶ differential equation, non-linearity, initial state, deterministic chaos, entropy, attractor, duration, impulse, uncertainty law
Links to other subjects	**history:** historical accidents **biology:** variability of life **geography:** weather forecast **mother's tongue:** fate novels **social science:** predictability of political affairs (computer projections)	⟶ **chemistry:** chem.reaction **biology:** mutation, recombination **mathematics:** random, theory of probabilities **social science:** insurances, risks **geoscience:** radioactivity	⟶ **biology:** behaviour patterns, course of evolution **chemistry:** self-organizing substances in solutions, growth of crystals
General science concepts (zone 2)	dispersion (of data), unfocussed measurements	⟶ validity range, gas laws, approximation, half value period	⟶ energy,entropy,evolution, radioactivity, quantum, feedback, interaction
Fundamental concepts / *skills* for all sciences (zone 1)	cause/effect, law/rule,random, probability, side-parameter, nature, necessity/freedom, variability, history; *observing, describing, measuring, guessing*	⟶ order, development, method; *thinking, proving, explaining, concluding, formalizing, mathematizing*	⟶ empiricism, induction, causality, chaos, determinism, subjectivity/objectivity, theory,natural/social science; *verifying/ falsifying, generalizing*
General competences	historic + thinking competence (stochastic thinking)	⟶ learning comp.(sporadic vs.systematic learn.)	⟶ philosoph. comp. (philosophy of science)
Basic scientific attitudes	curiosity, honesty, respect for nature, empirical attitude	⟶ rationality, preciseness, objectivity	⟶ formalization attitude

2.2 Exercise of attitudes, exemplified by "objectivity"

Although attitudes certainly cannot, ex cathedra, be explicitly "taught" but explained and understood by the *way of teaching*, i.e. by the personality of the teacher, there are certain themes and procedures which are particularly suitable to let students become aware of the importance basic attitudes have in life. For this purpose special exercises are useful which are outlined here taking "objectivity" as an example.

2.2.1 General strategy of the exercise

1. The attitude in question, as well as its counter-attitude (principle of *polarity*, see fig.9 and table 6 in this brochure), are known to the *teacher* only at beginning of the exercise.
2. The teacher, when preparing the exercise at home, draws a "tree of education" specially focussing on this attitude. In this figure all basic skills and concepts from zones 1 and 2 of the GDNÄ-rosette are registered which he/she regards to be useful for understanding and training this attitude. Example: Tree of education for "objectivity", next page, above.
3. Now a special task is handed out to the learners dealing with this attitude, but without telling them at this moment which attitude is concerned (see task for "objectivity", next page, below).
4. Learners should work on the task separately. After having finished, they are informed about the attitude + counter-attitude relevant for the task. They are asked to reflect about the markings they made and to place themselves on an appropriate position within a 5-step scale.

   Example: **attitude** … **counter-attitude**

	x			
1	2	3	4	5
strongly developed	clearly existent	medium position (fifty-fifty)	clearly existent	strongly developed

5. After the separate work students should form groups and talk within the groups. They are asked to collect their individual markings in a 5-step group scale and discuss them.
6. After group discussion follows a *plenary discussion* in the class. Teacher collects, e.g. on a transparency and again in a 5-step scale, all marks the students have made.

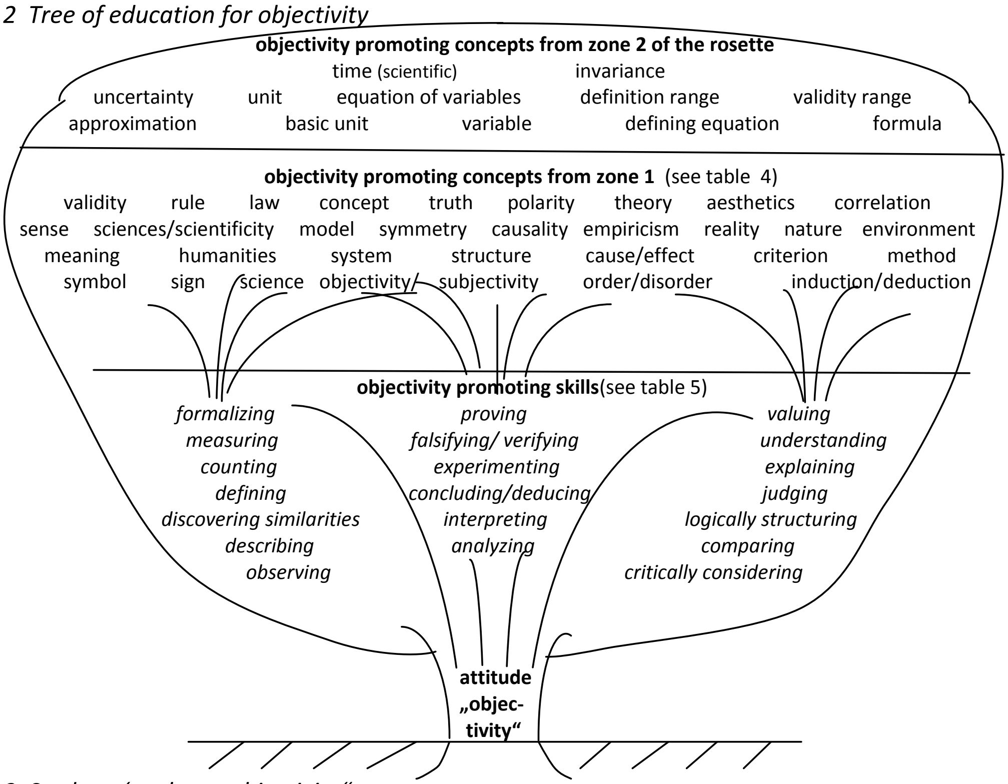
   Example:

attitude 1	2	3	4	5 **counter-attitude**
xxxx	xxxxxx	xxxxxx	xxx	xx

7. Class discusses result which generally surprises students. Teacher restrains with own comment.
8. Now a change from the descriptive to the normative phase is necessary, according to the educational commitment of school. This means for science teaching: the accent is put on one side of the polarity, i.e. on *one* attitude. This will be explained with the strict methodology of science which has been so successful in the last 200 years. However, it should also be pointed out that in science sometimes the counter-attitude is not only allowed but even necessary to avoid exaggeration of one side (see pages 17 and 18 of this brochure).
9. Finally, various examples from daily life are collected by students demonstrating the high significance of the attitude under consideration. Here, again, it is not a matter of "teaching" the attitude (in the sense of a „virtue lesson"), but of students' *own discovery* of the importance of values in life. Here the personality of the teacher plays – as always in school – an essential role as an example. He/she should personify a special "attitude of polarity" which means: 1. principal appreciation of both sides of a polarity (i.e. both types of students, an attitude of tolerance!), 2. yet the courage to priorize one side (e.g. in science), if there are good reasons for it.

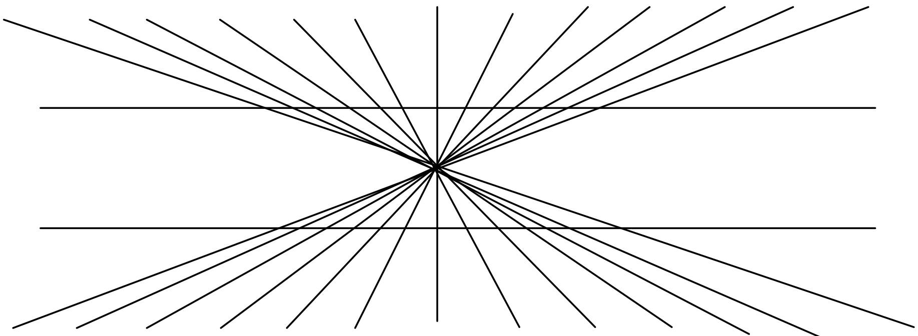
On the following page the general procedure described above is concretized by the example of "objectivity". Two teaching aids are shown: (i) the "tree of education "(designed by, and for the teacher alone), and (ii) students' task (optical illusion). Other exercises are supposed to proceed in a similar manner.

2.2.2 Tree of education for objectivity



2.2.3 Students' task on „objectivity"

In the figure below you can recognize two parallel lines which seem slightly bent and not rectilinear. However, if you use a ruler you will notice that they are in fact straight lines and not at all bent. What is your reaction? Mark what you think would apply to you! (More than one mark is possible).



1 .I find this phenomenon quite funny, but not really exciting
2. I do not trust the ruler and try another one, as normally I can rely upon my eyes
3. I distrust my eyes; maybe I have an eye defect
4. I distrust my brain; maybe it miscomputes the signals of my eyes
5. Both my subjective impression and the objective result of the ruler are correct; they complement each other
6. My subjective impression can never be disproved by external means like a ruler. What I experience personally I do actually experience, and therefore it is true
7. I find this task too hard and do not wish to comment it.