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A Conceptual Framework for the Enhancement of Popularity and Relevance of Science Education for Scientific Literacy, based on Stakeholders' Views by Means of a Curricular Delphi Study in Chemistry

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ABSTRACT: *Science educators express wide consensus about the importance of a modern scientific literate society. But focussing on the public understanding of science in Germany, there seems to be no general consensus, neither about how to enhance scientific literacy in the educational practice nor about what the major topics and dimensions of a modern science education are. With the help of the "Curricular Delphi-Study in Chemistry" (CDSC) a working group, this study analyzed topics and dimensions as well as fields of dissent and consensus in the opinions of 114 experts from different stakeholder groups (students, teachers, educators, and scientists). Knowledge about this helps to improve science lessons and makes clear that projects, like PARSEL, are urgently need to enhance the popularity and relevance of science education for scientific literacy.*

KEYWORDS: Delphi study, stakeholder views, popularization, relevance, scientific literacy.

Introduction

In the light of the discussion about a modern formal education in general and scientific literacy specifically, and focussing on a consideration of the image of chemistry in the eyes of the public and the reputation of chemistry lessons from the students' viewpoint, the following question seems to be quite important: On what basis can modern science (or chemistry) education be established, and what goals of formal education as well as what goals of scientific literacy should be addressed?

In this article, I try to draw more refined contours of scientific literacy by showing clues of 'a modern science – especially chemistry – education' starting with suggestions based on German (science) education theories, and, afterwards, by analyzing the subjective views of selected stakeholders by means of a 'Curricular Delphi Study in Chemistry.' The comparison will indicate how overdue it is that projects, like PARSEL, are in finding their way into school science practice, in order to bridge the gap between the entitlement to education and classroom reality.

Theoretical Underpinnings

There is a "far-reaching consensus on the importance of scientific competence: It is an indispensably important aspect of a general education..." (the German OECD-PISA-Consortium states (2001, p. 192). But, if one asked people in the public or experts (as was the case in by the Curricular Delphi Study in Chemistry [CDSC], one might get the answer: "There is *nothing* chemical that really has to be made the subject of discussion in school" (Expert of the CDSC No. 58/09221-W1-2; emphasis as in the original).

On the basis of the German theory of 'formal education' (in German Bildung), 'formal education as one's self-determined personality development' can be defined as "the idea, necessity, task, process, and endeavour to form one's own identity and enlightened world view in a self-determined examination of the world; to gain knowledge and abilities in order to find orientation as well as to become capable of acting and judging" (Bolte, 2003, p. 2). But, one's self-regulated personality development quickly reaches a limit in school education, when one takes the point of self-determined examination seriously. Therefore, an alternative definition is needed. Tenorth (1994) stated that the term 'general education' (in German Allgemeinbildung, which can be translated as the term "Education for all") "summarizes and describes *all efforts of a society, culture, or nation* that serve, by means of societal institutions, to spread that knowledge, and those abilities and attitudes among the adolescent generation, whose mastery is historically regarded as being necessary and indispensable" (Tenorth 1994, p. 7; emphasis added). But, these efforts are not fixed by the students, who are both the subjects of their own and objects of general education.

To make clear what the efforts of a 'society, culture, or nation' in chemistry education should or might be, I will focus on the considerations of two other very well-known German general educators. According to Klafki (1995), 'chemistry-related general education' can be understood as those efforts of general education, which are addressed to all people, contribute to the individual's formation of versatility, and should be promoted in the framework of general global problems, and should be focused on the perspective of chemistry. Whereas Blankertz' (1972) understanding of chemistry-related general education could be interpreted as the efforts for specialization in the field of chemistry; but only, when these efforts are efforts for an 'enlightened specialization.' Bringing these considerations together, the theoretical reflections lead to the questions of research and to one of the starting points of the PARSEL project. Why is science education (especially in physics and chemistry) so unpopular and prone to prejudice?

If one follows the basic suggestions of the PARSEL-Consortium (like Jack Holbrook has offered in the issue), the reason for the rather unpopular stance on the sciences in general, and science as a subject in schools in a large section of the population, is that the relevance of the school science towards societal wealth is not sufficiently apparent. If one leaves out media coverage for a moment, then it seems as if this connection is not made clear enough in science lessons, which we all had the privilege of attending at one point or another. In short, science and science education is unpopular, and this is the unanimous assumption of all PARSEL partners, because the topics covered in lessons are considered irrelevant by students. In their view, relevant aspects of the 'nature of science' are not dealt with in science lessons; neither is the relevance of science itself. Though part of the curriculum, these topics are not adequately discussed in class.

But, why is that still the case, since there is a consensus in society about the importance of science education? In light of the Curricular Delphi Study in Chemistry, it seems important to show whether this statement is in fact true (or not true!). I assume that *the lack in popularity is due to a gap between the expectations of science education and the educational interests of large sections of the population.* I will call this hypothesis *the 'Consensus-Dissent-Hypothesis' or the first hypothesis.*

More specifically, curricula are developed for the most part by experts who are scientifically socialized. The same is true for teachers who are responsible for the way their lessons are run. Both groups regard science as important and so pass on the *'science first'* view to students. But, the students (especially at the secondary level), do not necessarily share this opinion of the importance of science. Their interests revolve around their (everyday) life and what is going on in the world around them. They prefer to know how the world works, how problems in society or around the globe can be solved, and how they can develop (their) future. If science cannot or does not help them with that, then they may well engage with it only because of the next examinations, but it will not trigger their motivation to learn. For the students, it is *'personal relevance first.'* But, this seems not to be recognized in many classrooms. This leads me to the second *Hypothesis of the Consensus-Dissent-Hypothesis,* which I refer to as *'the hypothesis of the educational conflict of the generations'.* For the educational intentions and the educational offers in chemistry, classes are dominated by adults' conceptions of good general education, whereas young people's educational interests remain ignored.

This hypothesis should be more concretely elaborated. If *science lessons are primarily planned and held according to the structures that the pure subject lays out (science first), and problems in society or in the world are only dealt with afterwards* (if time is still available), *then it is obvious that there is an imbalance between the central intentions of chemistry related to formal education (personal relevance first) and chemistry related specialization undertaken in schools.* This is the third hypothesis, which I call the *'Versatility-Versus-One-sidedness or Unbalanced-Balance-Hypothesis.'*

If all these hypotheses are viable, then the educational offered in chemistry lessons may not be appropriate, and this may explain, on the one hand, the poor success of chemistry instruction (in Germany and in many other countries as well) demonstrated by the PISA and TIMSS studies, and, on the other hand, explain the rather low popularity of science and science education. If one follows this line of argumentation, then projects, like PARSEL, are long overdue to make clear the importance and relevance of science education for scientific literacy on a large scale.

To shed some light on these suggestions, I will test these hypotheses with the help of the Curricular Delphi Study in Chemistry, but before doing this, I will first present the basic notions of this method in the next section.

Design of (Curricular) Delphi Studies (in General)

The aim of a Delphi-Study (in general) is to compile the knowledge of so-called 'experts' from different areas of activity, and to classify them in a systematic and comprehensible way. The results of Delphi Studies serve to generate predictions. In this way, they offer guidance and support for accomplishing tasks, which are derived from the obtained predictions (Linstone & Turoff, 1975; Häußler et al., 1980a; 1980b; Mayer, 1992; Häder & Häder, 1998; Welzel et al., 1998).

A Delphi Study (in general) differs from other inquiries in that a fixed group of participants is questioned about one topic in mostly two to four rounds (so called 'waves'). From the second round (or wave) onwards, statistically confirmed 'interim results' of the respective preliminary round are reported back to the participants (the so-called experts or stakeholders). This is done so that the participants, who are now aware of the 'general opinion,' can reflect on that general opinion and their own view, and, if necessary, correct or reinforce it.

In the course of the inquiry, the general question is increasingly sophisticated and, in terms of content or the specified questions, condensed. Another characteristic of a Delphi study is that the participants do not know the names of other participants of the study, so they can formulate their own statements anonymously and without being too much influenced solely by the statements of the scientific community's "big names." A central working group (termed the 'monitoring-team') is responsible for the data collection, analyses, and for the reciprocal information flow among the participants (Häußler et al., 1980a, 1980b; Mayer, 1992; Häder & Häder, 1998).

In the 1980s, the group around Häußler, Frey, Hoffmann, Rost, and Spada carried out a 'curricular' Delphi Study on the topic 'Education in Physics for Today and Tomorrow' (1980a, 1980b). The group used the classic design of the Delphi method, but supplemented it with two 'curricular' elements.

The group developed a catalogue of criteria for choosing the experts or stakeholders, who would then take part in inquiries that deal within curricular matters. Furthermore, the team supplemented and specified the question within a formal statement format, which was divided in three parts (formal statement 'format I' reflected 'situations, contexts, and motives,' formal statement 'format II' was on 'areas and fields of chemistry,' and formal statement 'format III' on 'qualifications developed by doing and learning science or chemistry').

The Curricular Delphi Study in Chemistry

The aim of the curricular Delphi Study in Chemistry is a reflection on content, tasks, and aims, as well as the development of guidelines for a modern scientific – especially chemistry-related – basic education from different stakeholders' views (for example from a student, teacher, educator, or scientist perspective) In the course of the curricular Delphi Study in Chemistry, the following question was investigated: "*What kind of popular education, in terms of chemistry, makes sense and is pedagogically desirable for the individual in today's society and in the near future?*"

The sample of participants was put together by applying fixed criteria, which were derived from curricular theory (Häußler et al., 1980a). These criteria implied that different societal areas should be represented in a balanced degree, as indicated in Table 1.

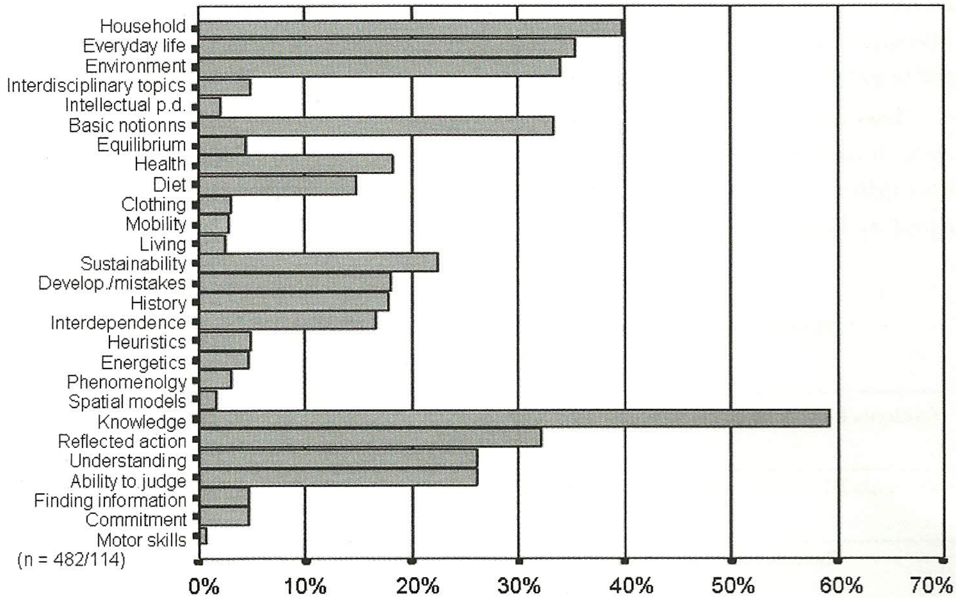
Table 1

Particularizing Criteria (for the Formation of Partial Samples) (446/114)

Students (65/30)

Students I: without chemistry lessons (7/7)		Students II: with chemistry lessons (20/8)
Students III: with A-level course (14/8)		Student IV: with particular interests (24/7)
Candidates for a teaching post, teachers and directors of trainee teachers with chemistry as a subject (104/29)		
Trainee teacher (28/8)		Trainee teacher in practical training (16/7)
Teachers (36/7)		Directors of trainee teachers (24/7)
Job in the area of (university) teacher training (159/31)		
Teacher unions (47/8)		Chemistry educators (34/8)
Sciences educators (48/7)		General pedagogy educators (30/8)
Job in areas, in which chemistry and/or sciences are fundamental or accumulate (138/24)		
People from an occupational area, in which chemistry occurs fundamentally (40/8)	People from an occupational area, in which sciences occur fundamentally (50/8)	People from an occupational area, in which sciences accumulate(48/8)

The Delphi Study in Chemistry is divided into three rounds or waves, as indicated in Figure 1. The task formulation in *the first round* opens up the possibility to express personal ideas (unencumbered by guidelines in terms of content) about a modern – particularly chemistry-related – basic education. Thereby, situations, contexts, and motives are identified, which seem important as a cause for a scientific – particularly chemistry-related – basic education. Furthermore, it is determined which qualifications an individual should have at his/her disposal in the area of chemistry, and with which fields of chemistry a 'scientifically educated human being' should have dealt with. The statements which were formulated by the participants in the first round were analyzed by means of qualitative and quantitative methods, and were reported to the participants in the form of categories (or so called 'statement bundles') and descriptive statistics.



Picture 1: *Overview of the Ways of Communication and Methods of Data Collection and Analysis in the Three Rounds of the Curricular Delphi Study in Chemistry*

In *the second round,* the assembled categories are presented to the participants for evaluation. Now knowing the general opinion, the experts have to assess to what extent the elements of education, which are expressed in the categories, are already in practice, and which priority is allocated to each of them in terms of their realization. The evaluation of the answers to this task will display elements (or characteristics) of chemistry-related education of particular and lower importance, and help to identify possible areas of deficit of chemistry related education. The analyzed deficits are called "Priority-Practice-Differences (PPD)."

The second task of the second round aims at the disclosure of concepts which the participants consider to be important for the promotion of a general education that contains chemistry-related elements. In order to be able to identify these concepts, the participants are asked to compile combinations of categories from the given categories. These combinations give information about the kind and the content of the actions, and the general conditions which are considered to make sense and to be important for the promotion of a chemistry-related education, and its realization in educational practice.

In *the third round,* the concepts of chemistry-related (general) education, which were identified by means of cluster analytical methods, are presented to the participants for evaluation. This is done in the same way as round two. Further questions and the tasks of the third round aim at disclosing perspectives for a preferably successful realization of a chemistry-related education. In this report, I will only concentrate on selected findings and results from the first and second rounds of the Curricular Delphi Study in Chemistry.

A Selection of Results and Findings

Results of the CDSC: The First Round

The results are based on the written replies of 114 participants from a total of 446 reply sheets. The participants' statements were processed in ten coordinated work and development steps.

Results of the Qualitative Analyses in the First Round: At the centre of the qualitative analysis was the question: "What kind of characteristics of a desirable chemistry-related education are to be deduced from the experts' statements? Sixty categories (statement-bundles) resulted from the qualitative analysis of the received written replies. These were used for the analysis and the capture of the experts' statements. The qualitative analysis showed that the originally provided three-part statement format was not ideal and should not be retained. Many participants referred to the fact that the occupation with chemistry-related topics should take place from different points of view. The strong differentiation of these statements made it necessary to subdivide statement 'format II' (areas of chemistry) into three statement formats: statement 'format IIA' relates to 'concepts of chemistry,' statement 'format IIB' to 'chemistry-related topics with a relation to everyday life,' and statement 'format IIC' describes 'branches and perspectives from which chemistry-related issues can be viewed'. Table 2 shows the results of the qualitative analyses.

As expected, the identified characteristics coincide to a great extent with the criteria for 'good chemistry lessons,' as these are cited in the preambles of the chemistry syllabi, or in the general guidelines, and in the recommendations of the chemistry education professional associations and unions of teachers (bmb+f, 1997; GDNÄ, 2000a, 2000b; MNFFV, 2000a, 2000b). Even in the Curricular Delphi Study in Chemistry, the wheel of chemistry education is not reinvented! However, the multitude of statements, which have to be assigned to the statement element perspectives from which chemistry-related issues can be viewed, point to a shift of emphasis as regards the content and the methodological composition of desired chemistry lessons.

Contents that are orientated towards the real world and multi-perspective devotion should shape the events in chemistry lessons according to experts' statement. Suggestions for lessons which are more oriented towards the real world and interdisciplinary lessons have already been discussed for some time in chemistry education (Bünder, 1998; Demuth, 1996; Gräber, 1995; Gräber & Bolte, 1996, 1997; Messner, Rumpf, & Buck, 1997; Münzinger & Frey, 1989; Parchmann, 2001; Ralle, 2001; Stork, 1996; Suhrbier, 1996; Woest, 1996), and one will find these aspects as basic ideas and recommendations in the guidelines of the PARSEL-project too.

Results of the Quantitative Analyses in the First Round: The different establishment of priorities surfaces especially in the quantitative analyses. This leads to the question which stands at the centre of the quantitative analysis. Which priorities of desirable chemistry-related education do the experts voice in their statements? Figure 2 gives a summary of the categories which, were identified relatively frequently (n_i>15%) and relatively infrequently (n_j<5%) in the written replies.

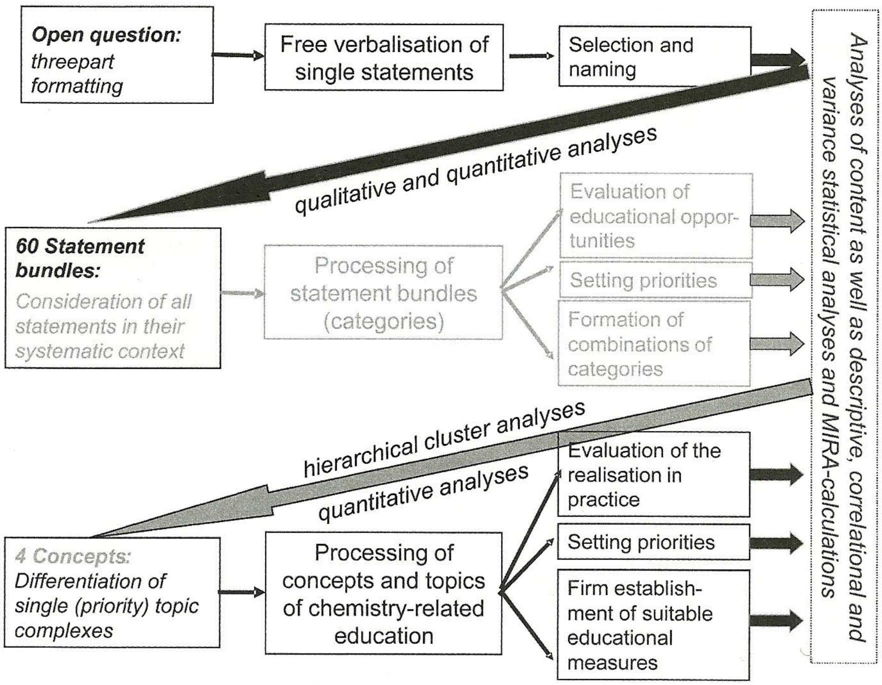
Table 2
Overview of the Categories (Statement-bundles) that Were Used to Analyze the Experts' Statement

I: Situations, Concepts, Motives	IIA: Concepts of Chemistry	IIB: Topics with a Relation to Everyday Life	IIC: Branches and Perspectives	III: Qualifications
• general personality development	• basics	• fire	• qualitative analytics	• experience
• emotional personality development	• specialized language	• water	• quantitative analytics	• knowledge
• intellectual personality development	• particle concept	• earth	• energetics	• finding information
• nature	• donator-acceptor-concept	• air	• kinetics	• editing sources
• household	• structure-property-relation of inorganic substances	• cycles of matter	• spatial models	• understanding
• everyday life	• structure-property-relation of organic substances		• heuristics	• forming transfers
• environment	• energy-concept	• nutrition	• theory of cognition	• pleasure
• media	• equilibrium-concept	• health	• interdependency	• motivation
• leisure time	• working with experiments	• clothing	• (undesirable) development	• ability to judge
• profession		• living	• history	• motor function
• chemistry as a science		• communication, mobility	• current research	• proper handling
• interdisciplinary research			• multidisciplinarity	• discuss
			• values	• acting
			• sustainability	• commitment cooperation
			• phenomenology	

The counting of the individual category allocations and particularly the analyses (Suhrbier, 1996; Woest, 1996), which were differentiated into groups and partial samples, clarify that not every characteristic has the same priority in the participants' opinion. Surprising are less the priorities that result from the analyses (for example, chemistry in the context of household, everyday life or environment, fundamentals of chemistry, building up decision-making and responsibility), and more the aspects which were mentioned relatively rarely by the experts (e.g., the promotion of intellectual personality development, questions of heuristics, energetics or kinetics, special conceptions of models or the sensitization for societal commitment).

Results of the Variance Statistics Analyses in the First Round

The variance statistics applied to the data of the different groups show that 22 categories were in 45 cases quoted significantly differently by two or more groups



Picture 2: *Overview of the Categories Which Were Mentioned Relatively Often and/ or infrequently: Mean value of the Whole Sample (Mean Value Equals the Percentage Assignment of the Category Correlated to All Reply Sheets).*

(see 1st Consensus-Dissent-Hypothesis). Other 35 significant differences can be identified between the students' group and one of the adults' groups and 20 of these significant student-adult-differences were analyzed by means of the comparison of the students' and the educators' group (see 2nd Hypothesis of the Educational Conflict of the Generations). Furthermore, 33 categories were stated by the students in less than 5 % of their answer sheets; 16 categories were not mentioned at all by the students.

Conclusions Concerning the Results of the CDSC: First Round

The results from the CDSC first round offer evidence that innovative approaches (such as PARSEL) have not found their way into being implemented in practice, as they should have. How else could it be explained that numerous characteristics of modern scientific instruction were only occasionally integrated by participants into their argumentation? Another question that remains unanswered relates to whether the characteristics, which were demanded particularly often by the experts, are actually realized extensively in current practice. Considerable doubts are raised about the question on the extent desired and actually realized practice coincide, when one looks back at the empirical results of past studies

(Bader & Vogel,1993; Baumert et al., 1997; Baumert et al., 1998; Becker, 1983, 1989; Bolte, 1994, 1996; Gräber, 1982, 1992a, 1992b, Gräber & Stork, 1984; Heilbronner & Wyss, 1983; Hoffmann, Häußler & Peters-Haft, 1997; Otte & Grabe, 1976; 1977; Pitton, 1996; Spörlein, 2001; Schenk, 2000; Sumfleth, 1992; Todtenhaupt, 1992; Wienekamp, 1990; Woest & Lipski, 1997) at the answers of the students in the Delphi Study in Chemistry (Bolte, 2001a, 2001b) and the impression which arises when one observes chemistry lessons. That leads back to the third Hypothesis and to the question: How varied or one-sided do the students (and the other experts or stakeholders) assess conventional chemistry instruction?

Table 4

Overview of the 22 Categories Which Were Mentioned by the Different Experts' Groups in a Statistically Significant Manner of Differing Frequency

22 Categories	Significance level of the comparison between the groups of the total sample						*Mean values of the category-hits in a specific group and in the total sample*				
	S/T	S/E	S/N	T/E	E/N	T/N	*S*	*T*	*E*	*N*	***Total***
General p.d.	.036	.005	.015				*3,1*	*14,4*	*15,2*	*14,4*	***13,1***
Emotional p.d.		.000	.014				***0,0***	*4,8*	*12,7*	*6,5*	***7,3***
Nature		.000			.001		*4,6*	*14,4*	*24,7*	*8,6*	***14,8***
Chemistry as a science		.006		.010	.000		*13,8*	*16,3*	*32,9*	*10,1*	***19,7***
Interdisciplinarity		.001					***0,0***	*4,8*	*8,9*	*2,9*	***4,9***
Inorganic compounds	.009	.000					*1,5*	*13,5*	*14,6*	*7,2*	***10,3***
Equilibrium concept		.001					***0,0***	*1,9*	*8,9*	*3,6*	***4,5***
Cycles of matter	.017	.004	.028				*1,5*	*12,5*	*12,0*	*10,1*	***10,1***
Qualitative analysis	.044	.000	.014				***0,0***	*6,7*	*10,1*	*6,5*	***6,9***
Quantitative analysis		.001	.001				***0,0***	*4,8*	*8,9*	*10,1*	***7,1***
Energetics		.005	.026				***0,0***	*2,9*	*7,0*	*5,8*	***4,7***
Spatial models		.046		.046			***0,0***	*0,0*	*4,4*	*0,7*	***1,7***
Heuristics		.000			.004		***0,0***	*3,8*	*10,8*	*1,4*	***4,9***
Epistemology	.044	.000					***0,0***	*6,7*	*11,4*	*3,6*	***6,4***
Perception (experience)		.000	.045				***0,0***	*5,8*	*9,5*	*5,0*	***6,0***
Understanding		.001		.002	.005		*15,4*	*19,2*	*39,2*	*21,6*	***26,2***
Transfer		.005		.023			*3,1*	*4,8*	*15,2*	*11,5*	***10,1***
Sensitivity		.000			.036		***0,0***	*3,8*	*10,8*	*2,9*	***5,4***
Ability to judge	.003		.033				*12,3*	*34,6*	*24,7*	*28,1*	***26,2***
Proper handling		.025					*33,8*	*15,4*	*17,7*	*14,4*	***18,5***
Ability to communicate		.006	.001				*1,5*	*4,8*	*11,4*	*14,4*	***9,4***
Reflected action				.036			*24,6*	*43,3*	*26,6*	*33,8*	***32,2***
Number:	**6**	**20**	**9**	**5**	**5**	**0**	***35***	***11***	***30***	***14***	***./.***
		35			**10**						
			45								

Secondly, the result from the variance statistics calculations, which support the hypothesis that the much praised consensus about the importance of scientific education and about how this education should be realized, is seemingly inappropriate (see *Consensus-Dissent-Hypothesis*). Above all, young people and adults voice quite different ideas concerning this matter (see *hypothesis of the educational conflict of the generations).* This is shown particularly by the comparison of the student statements with those of the "(Science) Education" group. Since the differences are particularly a result of the fact that certain characteristics were hardly considered by the student group, the question arises as to whether this is related to the fact that these characteristics hardly ever or only implicitly come up in conventional science instruction (see *Versatility-Versus-One-sidedness-Hypothesis*). However, it could also be the case that I did not develop a valid classification schema with regards to the students' statements, since the categories which were included in the analytical system are just the ones that seem unimportant to the students. Hence, before investigating these unresolved issues, I have to ask and answer the question whether the classification-system analyzed in the first round of the CDSC is valid or not. These and other open questions are to be answered in the second round of the CDSC.

Results of the CDSC: Second Round

In order to answer the general questions of the CDSC and to investigate the questions, which came up during the data-analyses in the first round of the CDSC, the 60 categories that were identified in the first wave were presented to the young and grown-up participants of this study (n=104) for their assessment (Bolte, 2003b). Two aspects had to be assessed on a five-tier scale. What significance is attached to the characteristics of a chemistry-related education of each category, on the one hand, ('*priority*') and, on the other hand, to what extent do the participants think that the respective characteristics are offered in practice ('*practice*')? Furthermore, a so called Priority-Practice-Difference (PPD) was calculated taking the difference of the priority- and the practice-values into the analyses. In order to test whether fewer different opinions can now be indentified (after the participants could take note of the 'general spectrum of opinions'), the data were analyzed by means of descriptive and variance statistic methods.

Results of the Descriptive Statistic Analyses in the Second Round: Characteristics of (Desirable) Chemistry-related Education and Instruction/Lessons

From analyzing the data from the experts' responses to the questions of the second round, from the participants' point of view, only three of the 60 statement bundles (categories), which were identified in the first round, were assessed (by the students' <u>and</u> the adults' groups) as being not so important (Priority-Mean ≤ 2.75). All the other 57 categories were assessed as being important or very important, as indicated in Table 4.

Looking at the experts' anticipations of what occurred in the practice of chemistry classes, pointed to only eight categories were assessed in a way that pointed to these elements being present in chemistry lessons (Practice-Mean ≥ 3.25). Furthermore, all these categories represent chemistry instruction mainly oriented towards chemistry as a science. The other categories representing a kind of chemistry instruction, which is more oriented towards every day life or towards the nature of science topics, were assessed as appearing seldom in chemistry lessons (second column of Table 4, categories in italics).

Finally, the calculated Priority-Practice-Differences make clear that nearly all categories show big Priority-Practice-Differences. Therefore, from the experts' point of view, there are a lot of changes that should be implemented for improving the chemistry-related education in the (schools') practice.

Table 4
Selection of the Total Sample's Category-assessments in Round 2 (Priority-, Practice/Offer- and Priority-Practice-Differences-Means)

Priority	**P***	**Practice/Offer**	**O***	**Priority-Practice-Difference**	**D***
Understanding	4,2	Basic notions	3,8	Motivation/interest	1,7
Inquiry	4,2	Donator-acceptor	3,7	Value-systems	1,5
Motivation/interest	4,2	Technical jargon	3,6	Ability to jugde	1,5
Knowledge	4,1	Knowledge	3,5	Reflected action	1,5
Basic notions	4,1	Chemistry	3,3	Multi-disciplinary	1,5
Experience	4,0	Org. Chemistry	3,2	Health	1,4
Environment	4,0	Inorg. Chemistry	3,2	Inquiry	1,4
Ability to judge	3,9	Particles	3,2	Understanding	1,4
Nature	3,8	*Clothing*	*2,0*	Pleasure	1,4
Reflected action	3,8	*Emotional pers.*	*2,0*	General pers. development	1,3
General pers. develop.	3,8	*development*		Experience	1,3
Social commitment	3,8	*Value systems*	*1,9*	Current chem. research	1,3
Phenomenology	*2,8*	*Mobility*	*1,9*	Interdisciplinary topics	1,3
History	*2,7*	*Leisure*	*1,9*	Heuristics	1,3
Quantitative analyses	*2,7*	*Living*	*1,9*	Sustainability	1,3
Leisure	*2,6*	*Multi-disciplinarity*	*1,7*	Cycles of matter	1,2

Results of the Variance Statistic Analyses in the Second Round

Again, different accentuations by the young people, on the one hand, and the adults, on the other, need to be pointed out in different areas. Table 5 gives a summary of the statistically significant differences in the assessments of the students' and adults' group, based on the data from the second round of CDSC

On comparing the variance statistic results of the first round with those of second round with regard to the priority estimations, one finds that the number of statistically significant differences in opinion between young people and adults has only changed to a minor degree in this respect. Even in the second round, 16 statistically significant differences were identified. Strikingly, only five significant differences were identified after comparing the practice estimations. In contrast to that, the opinions of the young people and the adults diverge more with respect to the priority-practice-difference (11 statistically significant differences). Interestingly enough, it is the adult group that assessed the practice of scientific education in all cases as more deficient than the student group did.

Table 5
Statistically Significant Differences in the Comparison of the Mean Values or rather the Average Differences of the Students' and Adults' Group (Priority-, Practice-Estimation and Priority-Practice-Difference)

Category	S/A	S	A	Category	S/A	S	A
General p.d.	.002	3,17	4,04	*Experience*	*.044*	*3,03*	*2,52*
Emotional p.d.	.009	2,50	3,28	*Understanding*	*.010*	*3,23*	*2,56*
Intellectual p.d.	.003	3,13	3,92	*Joy*	*.030*	*2,76*	*2,12*
Media	.039	2,60	3,31	*Proper handling*	*.010*	*3,31*	*2,74*
Cycles of matter	.002	3,17	3,94	*(social) commitment*	*.001*	*3,13*	*2,32*
Clothing	.018	2,33	3,06	***General p.d.***	***.001***	***,63***	***1,64***
Living	.019	2,47	3,17	***Emotional p.d.***	***.016***	***,57***	***1,34***
Heuristics	.024	2,86	3,47	***Intellectual p.d.***	***.021***	***,33***	***1,00***
History	.015	2,28	2,93	***Nature***	***.008***	***,57***	***1,37***
Chem. Research	.001	3,89	3,14	***Cycles of matter***	***.005***	***,60***	***1,49***
Values	.001	2,68	3,80	***Living***	***.001***	***,50***	***1,36***
Sustainability	.042	3,08	3,87	***Heuristics***	***.043***	***,41***	***1,24***
Understanding	.018	4,57	4,01	***Experience***	***.004***	***,76***	***1,58***
Working with sources	.037	2,64	3,26	***Working with sources***	***.042***	***,43***	***1,23***
Ability to judge	.033	3,41	4,06	***Ability to judge***	***.010***	***,79***	***1,79***
Reflected action	.000	3,24	4,03	***Reflected action***	***.000***	***,52***	***1,83***

Conclusions Concerning the Results of the CDSC: Second Round

First of all, because the adults' groups and the students' group considered nearly all categories (except for three) as relevant for science and chemistry-related general education, the classification-system seems to be valid. Furthermore, the three major hypotheses of the CDSC could not statistically be falsified. The representatives of the adult group and the representatives of the student group hold clearly different views particularly with respect to the assessment of what would be important, but also with respect to the priority-practice-differences. Besides, it cannot be ruled out that the problems in science education are linked to the considerations mentioned in the hypotheses. The descriptive and variance statistic results of the CDSC show some important points for starting a much needed discussion about the "indispensably important aspect of general education" (German -PISA-Consortium, 2001, p. 192). If one focuses especially on the results of the priority-practice-differences from the second round, it becomes clear which dimensions of science instruction should be urgently changed.

Among the aspects which were assessed as being the most deficient, one has to mention the following categories: (intrinsic) 'motivation and interest' (PPD: 1, 7), (discussing) 'value-systems' (PPD: 1, 5), (fostering the) 'ability to judge' (PPD: 1, 5), (promoting) 'reflected action' (PPD: 1, 5) and a 'multi-disciplinary' approach (PPD: 1, 5) rate among the aspects which were assessed as being the most deficient ones. Exactly those five aspects belong to the central criteria, which the PARSEL-consortium employed to choose and optimize the PARSEL-Materials

The results of the CDSC show that science instruction still needs reforms. First of all, science education in Germany (and there might not be significant differences to find in other countries) has to deal with the problem of the practice, which is normally still over-oriented on the topics of the natural sciences as such, and less oriented towards the issues of general education, as it is demanded in the course on discussions about scientific literacy. In this context, science teachers have to become aware of and take into account that the 'state of the art of science lessons,' as it is assessed by the experts, does not coincide with a desirable science education, which is in accordance with the public's opinion, neither from the adults-experts' points of view, nor according to students' educational interests. Thus, to enhance scientific literacy, it is necessary to have both sides in mind and to focus on both, the educational expectations of society (or of 'the adults') and the educational interests of the younger generation. Aims and topics of science instruction should be negotiated with both the students and the adults, as representatives of society. The findings of the CDSC and the work of the PARSEL-group can help to bridge the gap between these two sides of the one major aim of general and science education in order to foster scientific literacy – if not for all, then at least – for as many citizens as possible.

Conclusion

The PARSEL project was a coordinated-action programme, in which nine partners in eight countries were involved. Each of these partners had brought ideas into the project, based on their different country-specific and cultural background. In many of the partner countries, the problems in terms of science education were the same and the answers were looked for in the relevant literature on chemistry education. The German contribution to the PARSEL project (mainly the contribution of the PARSEL group from the Freie Universität Berlin) is rather unique in that it raised the question why chemistry is unpopular, and why the topics covered in lessons are considered irrelevant, by looking at the problem from an education theory and chemistry education point of view and by obtaining first empirical analyses. The results of the CDSC underpin the demands of the PARSEL-Consortium that science lessons should be planned with consideration for the needs and interests of the students, because this makes what is meant to be learnt relevant and raises motivation. The main recommendations of the PARSEL-Consortium as well as the selected, adapted, and optimized PARSEL materials, and the lesson model tried out in the PARSEL project, can help to reduce the deficits that the CDSC had identified. The PARSEL approach allows the connection between the goals of a formal and general education as well as a scientific education to be made. If this connection works, then the wish "Education through Science" is not just a slogan, but a dictum that promises success and enhancement of the Popularity and Relevance of Science Education for Scientific Literacy.

Prospects

If one believes the predictions, a modern society in the future will be much more dependable upon a scientifically educated public and upon experts who are specialized in the sciences, even more so than nowadays (bmb+f, 1998). This is true for all the sciences without exception and, therefore, also for chemistry (Bolte, 2001a). Chemistry lessons in secondary schools will play an important role in order to meet these requirements.

It is long overdue that the negative image of the sciences – especially that of chemistry and chemistry lessons – has to be corrected and that it is made clear what the genuine contribution of chemistry to our contemporary world view is and on which scientific-cultural attainments the prosperity and the quality of life in the industrialized countries is founded. The branch of chemistry education is asked to develop concepts for lessons, which the teachers want to be fruitful and the students want to be relevant for them. The suggestions brought forward by the PARSEL project will help to achieve this in practice.

To what extent this is successful in general and in practice will also decide how successful the adolescents will be in finding their way in tomorrow's society – which occupational outlooks will open up for them, how they will lead their life, and how they will shape society. I am convinced that the Curricular Delphi Study in Chemistry, on the one hand, and the PARSEL recommendations, on the other hand, reveal worthwhile suggestions for the design of modern science and/or chemistry lessons. These suggestions are in keeping with the conceptual framework of the PARSEL project. Hence, the CDSC as well as the PARSEL framework serve as a solid foundation, helping to select teaching and learning materials, optimizing these materials and then implementing them in practice.

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