



1st PARSEL-Project-Symposium
– Lisbon, 26th – 29th October 2006

Popularity and Relevance of Science Education and Scientific Literacy

Reflections from the Department of Chemistry Education of the Freie Universität Berlin

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- 1 Research on the Questions: What means the Term Scientific Literacy and what is good Science Instruction?
- 2 Findings from Research on the Effects of Motivational Learning Environments in Science Classes
- 3 Results from the Curricular Delphi Study on Science – especially on Chemistry – Education
- 4 Findings from the Evaluation of the ParIS-Berlin Project “Renewable Energy – Focus Bioenergy“ and “Introduction of Biochemistry“
- 5 Results from the Evaluation of Science Informal Learning Environments “KieWi & Co.”

1 The problem of acceptance or: “The quarrel of the two cultures“

There is „far reaching consensus on the importance of natural-scientific competence: It is an indispensably important aspect of general education ...“ (German PISA-Consortium 2001, 192).

„If ... the one or the other student ... should never have come into touch with chemistry (in the sense of educational content) in their school career, then this would be...

very unfortunare for chemists and chemistry teachers like me, but not as bad as all that (as seen from the point of view of society as a whole).

„There is **nothing** chemical that really has to be made the subject of discussion in school“ (expert 58/09221-W1-2; emphasis as in the original).

1 The problem of acceptance or: “The quarrel of the two cultures“

- Wilhelm von Humboldt (1793; 1809)
- Friedrich Paulsen (1912, 496)
- Theodor Litt (1963, 98)
- Dietrich Schwanitz (1999, 482)

Werner Kutschmann's thesis of the subjectively experienced

- social,
- ecological and
- economic crises (1999, 42).

Hypothesis 1 - The Consensus-Dissent-Hypothesis:

➡ *There is a gap between the educational expectations and interests of large sections of the population and of the educational success which is achieved in and by means of chemistry lessons.*

➡ *What characteristics should an educational offer have so that as many people as possible find an access to the science of chemistry?*

1 Explanation of terms: Literacy and (Chemistry-related) General Education

Literacy as the necessity, the task, the idea and the endeavor 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

“The term 'general education' ... 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 which mastery is historically regarded as being necessary and indispensable” (Tenorth 1994, 7; emphasis by C.B.).

Following *Klafki (1995)* chemistry-related general education (as a specific part of Scientific Literacy) should be that area of education which is addressed to **all** people, contributes to the individual's **formation of versatility** and takes place **in the medium of the general global problems focused with the perspective of chemistry**. Whereas *Blankertz' (1980)* understanding of chemistry-related general education is **the effort for specialization in the field of chemistry**; but only, when it is the effort for “**enlightened specialization**”!

1 Chemistry-related general education between wish and reality: *Hypotheses and questions*

➔ *Hypothesis 1: Consensus-Dissent-Hypothesis*

Hypothesis 2: Educational conflict of the generations

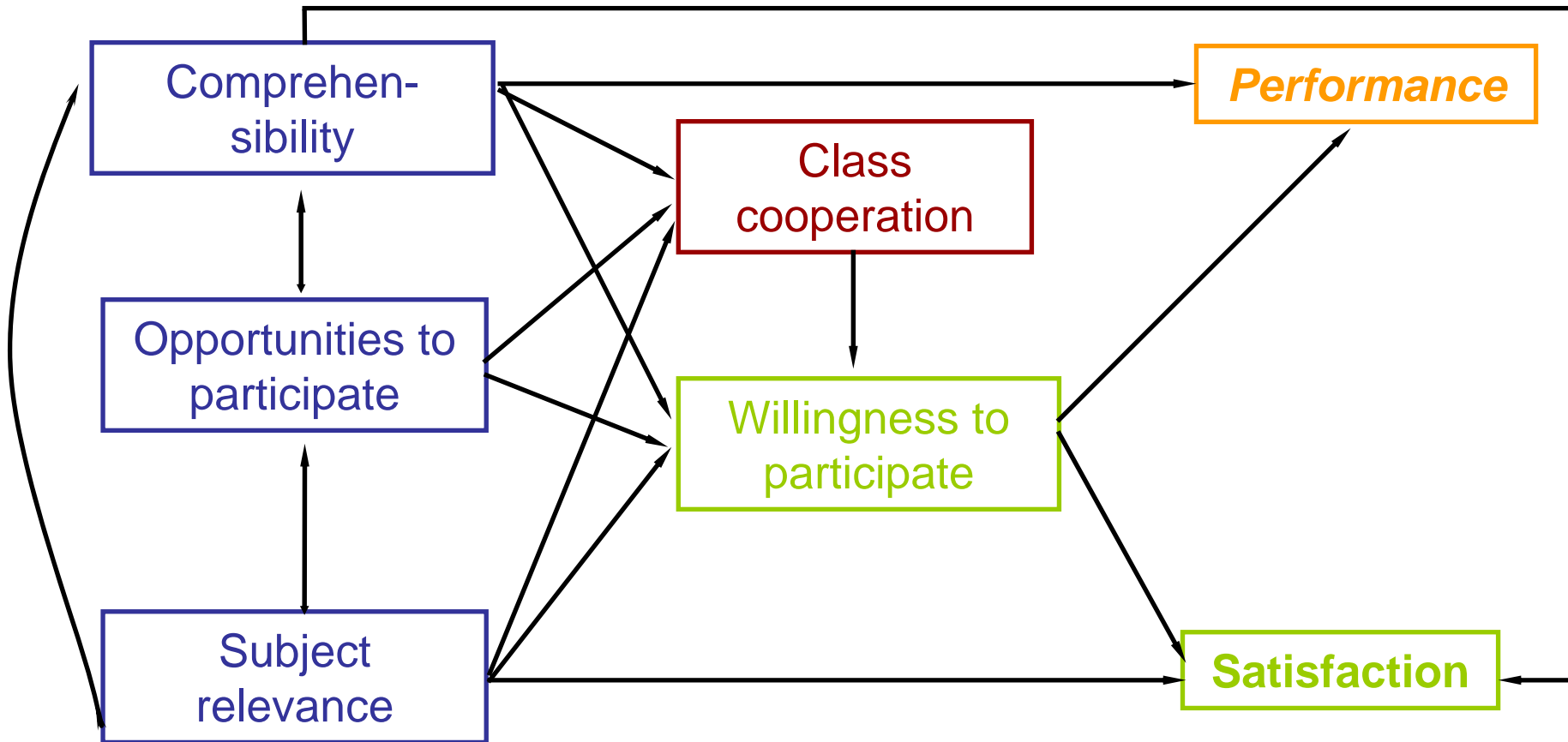
➔ *The educational intentions and the educational offers in chemistry classes are dominated by the adults' conceptions of good general education, whereas the grown-ups' educational interests stay behind.*

Hypothesis 3: Versatility-versus-One-sidedness- or Unbalanced-Balance-Hypothesis

➔ *There is a unbalanced balance between the central intentions of chemistry related general education and the chemistry related specialization done in schools.*

➔ *What knowledge, abilities and attitudes are regarded as being necessary and appropriate in the framework of chemistry-related education and in which areas do young people's and adults' ideas of chemistry-related education differ?*

2 Theoretically based Motivational-Learning-Environment-Model



Theoretical Basis:

- Achievement Motivation Theory
- Socialpsychology
- Pedagogical Interest Theory
- Learning and Classroom Climate Research

2.1 Development of the MoLE-Instruments for Analysis of Students' Perceptions and Wishes

Three different MoLE-Instruments for **Biology-**, Chemistry- and **Physics-**Instruction

Three (*plus one*) different questionnaire versions:

- Students' Perceptions in general
- **Students' Inclinations**
- **Students' Perceptions of Today's Lesson**
- *Students' Wish-to-Reality-Differences*

Two Items per Motivation Indicator for each Questionnaire Version:

In my opinion the topics covered in chemistry class are...
very useful [7] [6] [5] [4] [3] [2] [1] completely unimportant
for me (for my everyday life).

That topics in chemistry are a matter of my everyday life is...
very important [] [] [] [] [] [] [] completely unimportant

*In my opinion the topics covered in chemistry class today are...
very useful [] [] [] [] [] [] [] completely unimportant
for me (for my everyday life).*

C. Bolte (2006)

Seven (*plus one*)
Motivation Indicators:

Comprehensibility

Opportunities to
participate

Subject relevance

Subject orientation

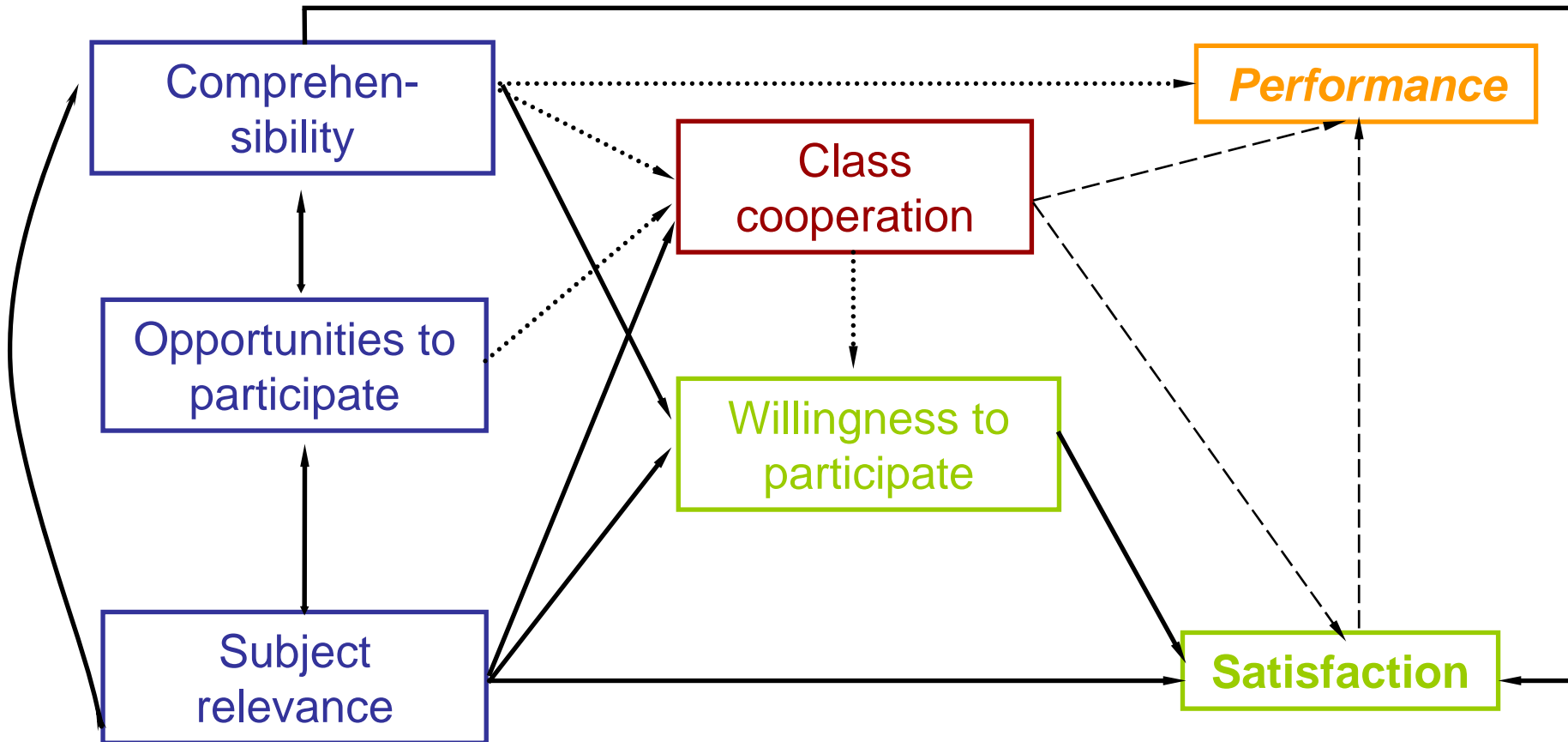
Class cooperation

Willingness to
participate

Satisfaction

Performance

2.2 Empirically sound Motivational-Learning-Environment-Model



- > **Significant path; expected and identified in all analyses**
-> Significant path; expected but only identified in some analyses
- > *Significant path; not expected but identified in some analyses*

2.3 Analysis of the Students' MoLE – Assessments differentiated by subjects

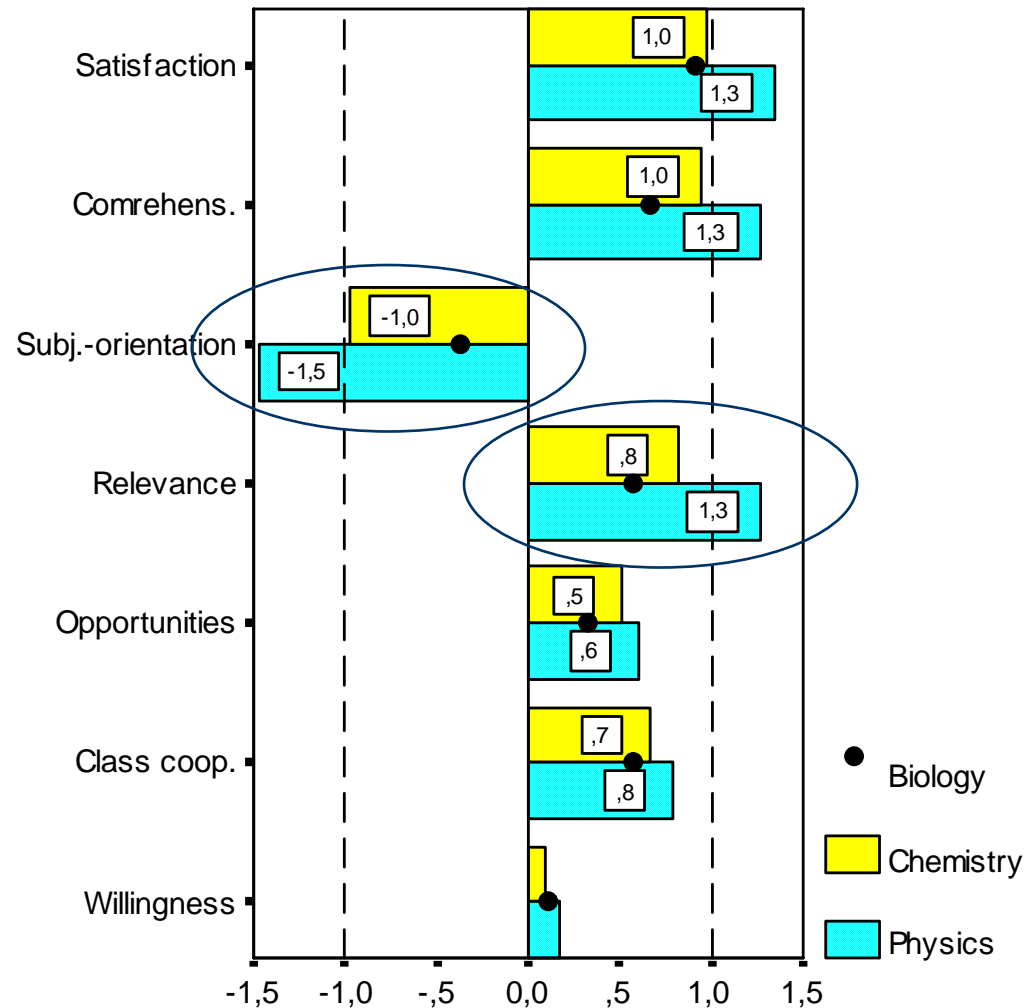


Fig. 1: Comparison of the (normalized) Wish-to-Reality-Differences in relation to the estimation of MoLE-Indicators for biology, physics and chemistry classes in Sek. I

2.3 Analysis of the Students' and Teachers' MoLE-Assessments of Chemistry Classes

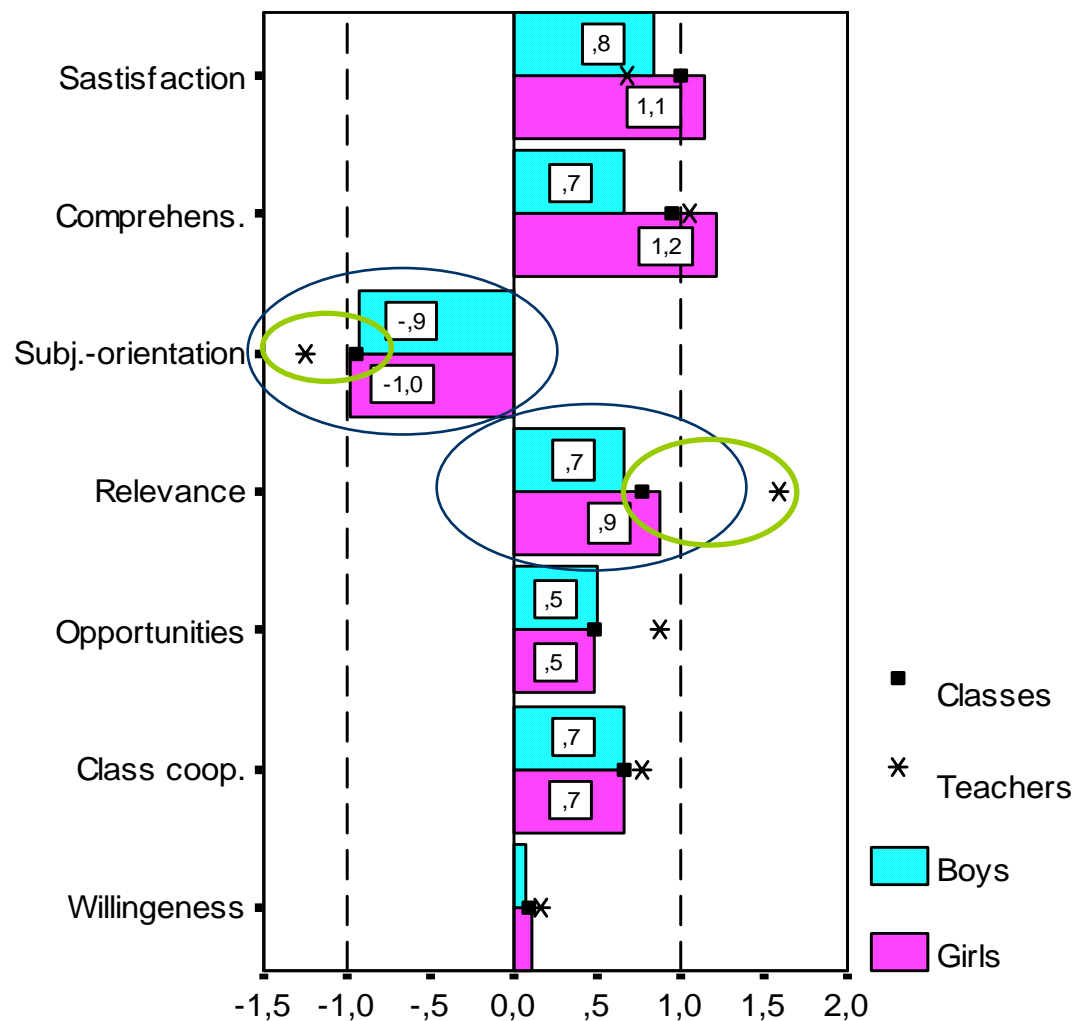


Fig. 2: Comparison of the (normalized) Wish-to-Reality-Differences in relation to the assessments of the MoLE-Indicators for chemistry classes in Sek. I

2.4 First Conclusions from the MoLE-Analyses

- ✓ Comparison of Wish-to Reality-Differences points to some (important) reasons why many students end their **physics and chemistry classes** at the earliest possible grade
 - teachers of chemistry and physics should choose more topics which are relevant to students' with respect to their every day life,
- ✓ **female students** assess the learning environment in chemistry classes less favorably than male students do,
- ✓ **teachers** have problems to anticipate their students' learning environment assessment and need help for the evaluation of the learning climate in their classes,
- **teachers** are not easily inclined to change the subjects of their instruction to topics of increased relevance although their own estimation would support this.

➡ *Again we ask: What knowledge, abilities and attitudes are regarded as being relevant, necessary and appropriate in the framework of chemistry-related education and how do we know, what the relevant topics are?*

3 Contours of desirable chemistry-related general education

in the light of the curricular Delphi-Study in Chemistry

Characteristic elements of *curricular* Delphi-Studies according to Häder and Häder (1998, 10-11) and Frey (1980, 32)

- fixed group of participants, so-called experts,
 - several rounds,
 - formalized questionnaire,
 - calculation of statistically secure group answers,
 - group answers are fed back to the participants
 - participants do not know each other's names.
- *criteria for choosing the participants,*
- *guidelines for focusing of the opening question related to a special anticipated answering format for the participants.*

Who is to be questioned?



How is to question?

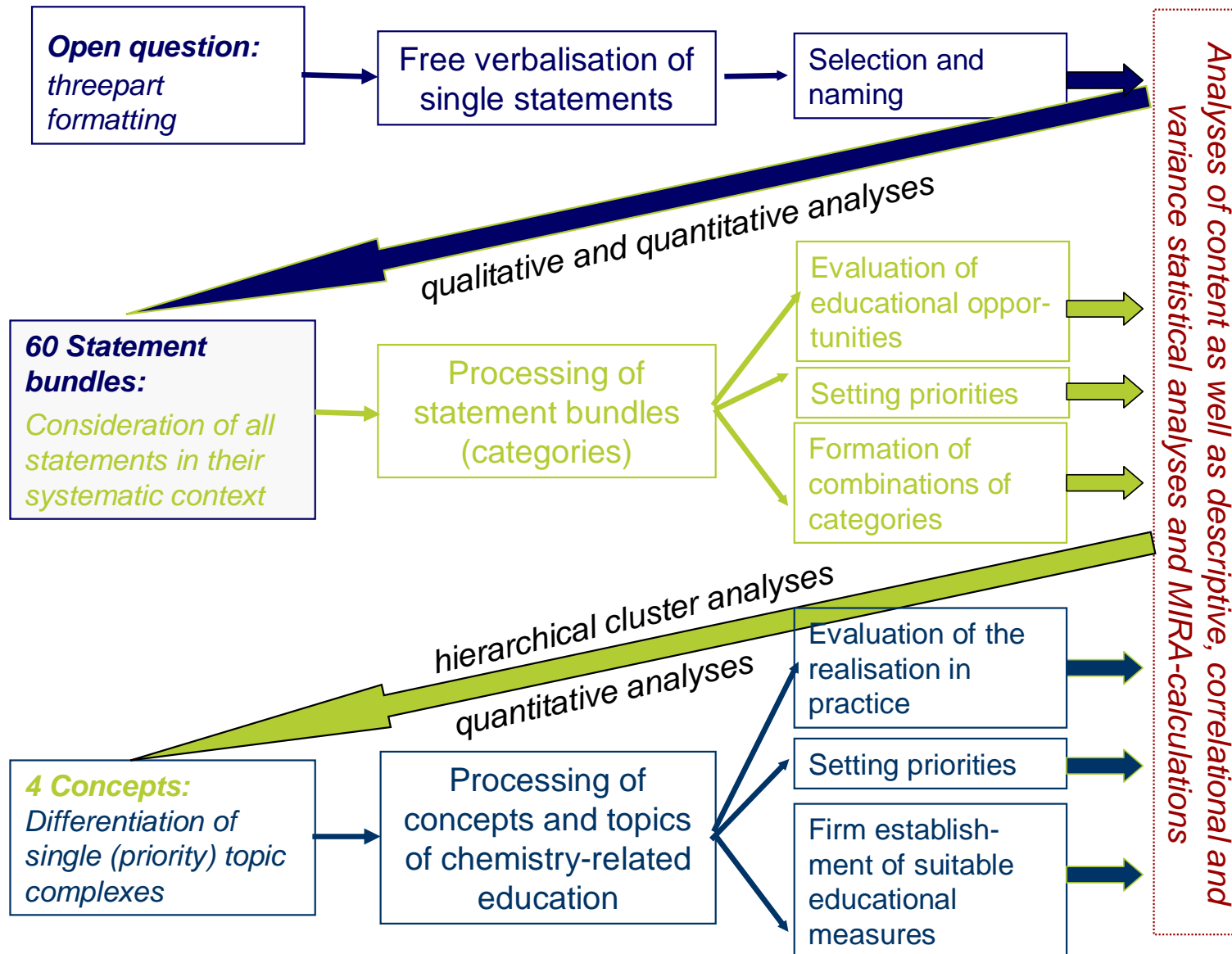
What has to be questioned?

3.1 Question of the Curricular Delphi-Study in Chemistry

“What kind of chemistry-related general education makes sense and is pedagogically desirable for the individual in today’s society and in the near future?”

(following: Häußler et al. 1980; Mayer 1992)

3.2 Design of the Curricular Delphi-Study in Chemistry



3.3 Sample of the Curricular Delphi-Study in Chemistry

Achtung Stichprobe 2. Runde ändern

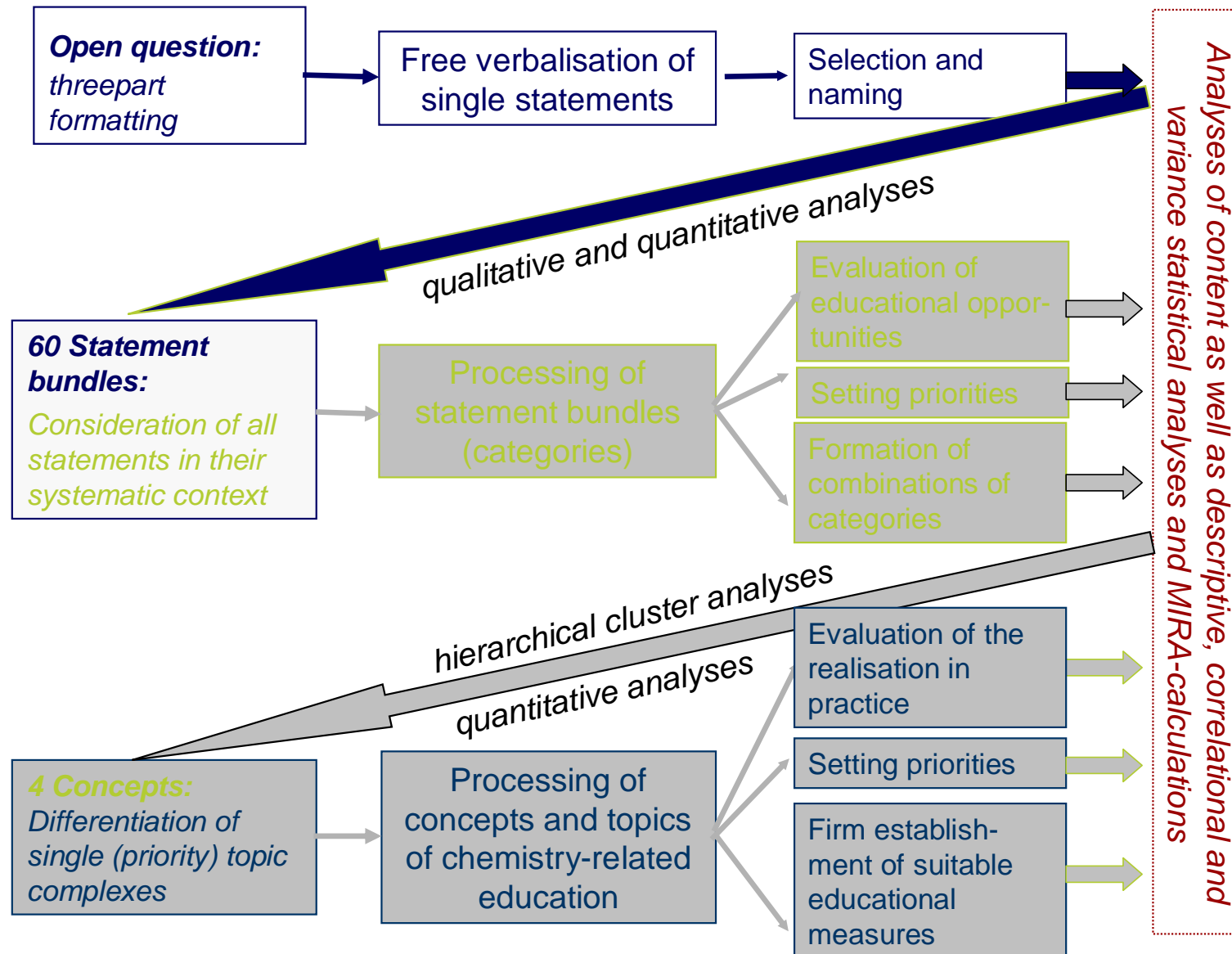
group I:
students ($n_s=30$)

group II:
teachers and trainee teachers
($n_t=22$)

group III:
educators and in-service teacher
educators ($n_d=30$)

group IV:
natural scientists ($n_n=21$)

3.4.1 Design of the Curricular Delphi-Study in Chemistry – 1st Wave



3.4.1 Results: Category system

1st Wave: Qualitativ analysis

Motivation, Situations or Contexts: 12 Categories related to

- individual education (3)
- individual (every day related) contexts and situations (7)
- science (2)

Concepts, Areas or Perspectives: 34 Categories related to

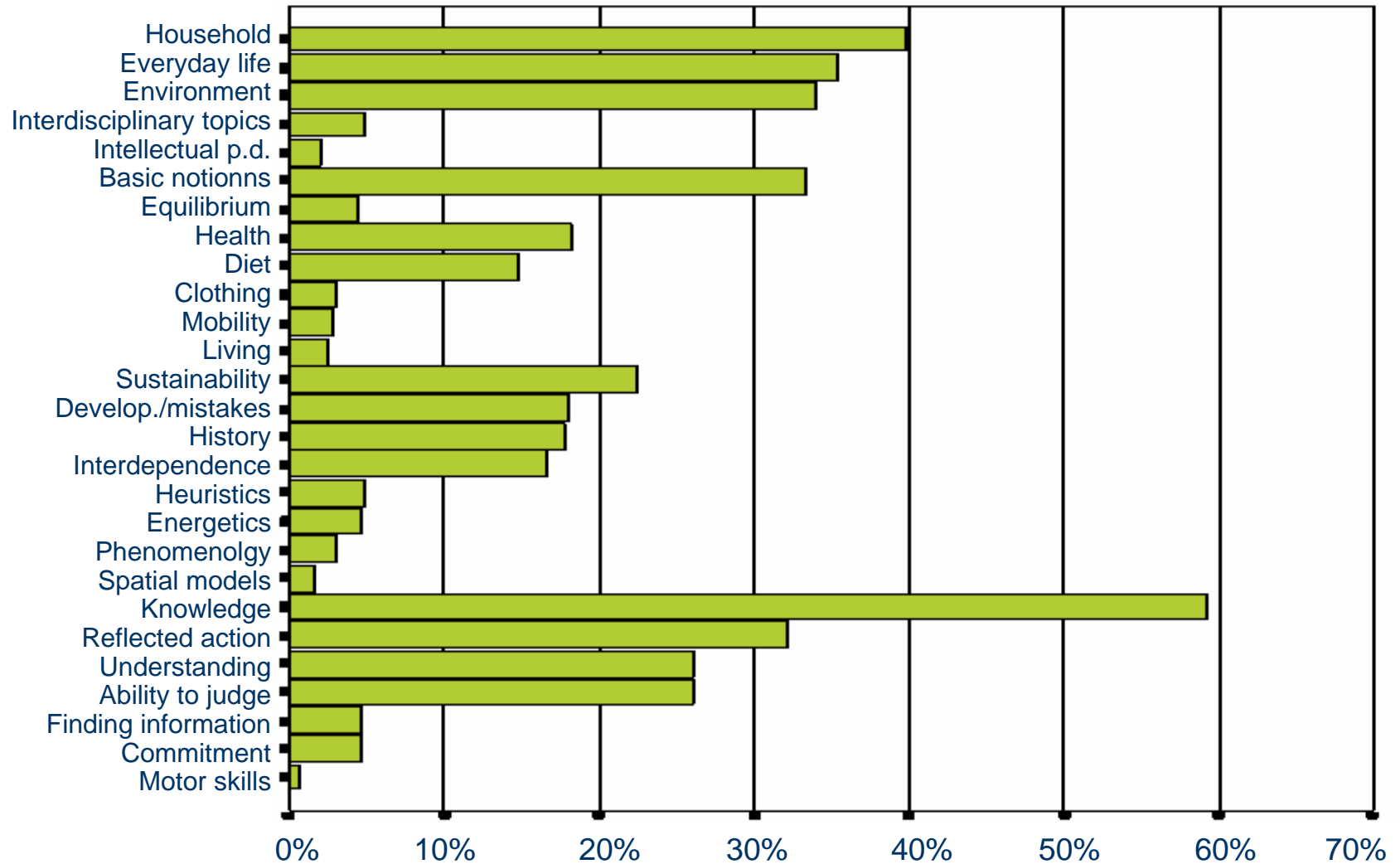
- basic concepts of chemistry (9)
- topics of chemistry with reference to every day life (10)
- perspectives of chemistry and perspectives from which one can explain as well chemistry as every day life related facts (15)

Qualifications: 14 Categories related to

- cognitive processes (6)
- emotional processes (1)
- motor skills (1)
- attitudes (1)
- psychomotorical processes (1)
- processes of action and behavior (4)

3.4.1 Results: Groups' Opinions in general

1st Wave: Descriptiv statistics



(n = 482)

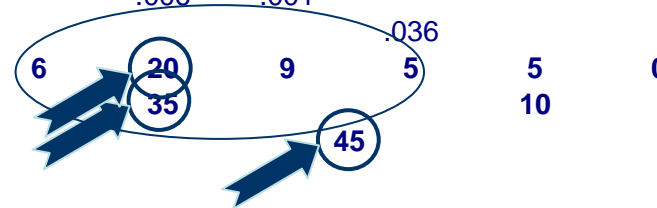
3.4.1 Results: Groups' opinions

1st Wave: Variance- and *descriptive* statistics

22 Categories

| | Significance level of the comparison between the groups of the total sample | | | | | |
|-------------------------|---|------|------|------|------|-----|
| | S/T | S/E | S/N | T/E | E/N | T/N |
| General p.d. | .036 | .005 | .015 | | | |
| Emotional p.d. | | .000 | .014 | | | |
| Nature | | .000 | | | .001 | |
| Chemistry as a science | | .006 | | .010 | .000 | |
| Interdisciplinarity | | .001 | | | | |
| Inorganic compounds | .009 | .000 | | | | |
| Equilibrium concept | | .001 | | | | |
| Cycles of matter | .017 | .004 | .028 | | | |
| Qualitative analysis | .044 | .000 | .014 | | | |
| Quantitative analysis | | .001 | .001 | | | |
| Energetics | | .005 | .026 | | | |
| Spatial models | | .046 | | .046 | | |
| Heuristics | | .000 | | | .004 | |
| Epistemolgy | .044 | .000 | | | | |
| Perception (experience) | | .000 | .045 | | | |
| Understanding | | .001 | | .002 | .005 | |
| Transfer | | .005 | | .023 | | |
| Sensitivity | | .000 | | | .036 | |
| Ability to judge | .003 | | .033 | | | |
| Proper handling | | .025 | | | | |
| Ability to communicate | | .006 | .001 | | | |
| Reflected action | | | | .036 | | |

Number:



1st Consensus-Dissent-Hypothesis

22 categories were in 45 cases quoted significantly different by two or more groups.

2nd Hypothesis of the educational conflict of the generations

35 differentiations are to identify between the students' group and one of the adults' groups;

❖ 20 of this significant group-differences were analysed by the comparison of the students' and the educators' group.

The 'brave' objectives of the educators do not seem to be those the students have!

3.4.1 Results: Groups' opinions

1st Wave: Variance- and descriptive statistics

22 Categories

- General p.d.
- Emotional p. d.
- Nature
- Chemistry as a science
- Interdisciplinarity
- Inorganic compounds
- Equilibrium concept
- Cycles of matter
- Qualitative analysis
- Quantitative analysis
- Energetics
- Spatial models
- Heuristics
- Epistemology
- Perception (experience)
- Understanding
- Transfer
- Sensitivity
- Ability to judge
- Proper handling
- Ability to communicate
- Reflected action

Number:

Following Questions:

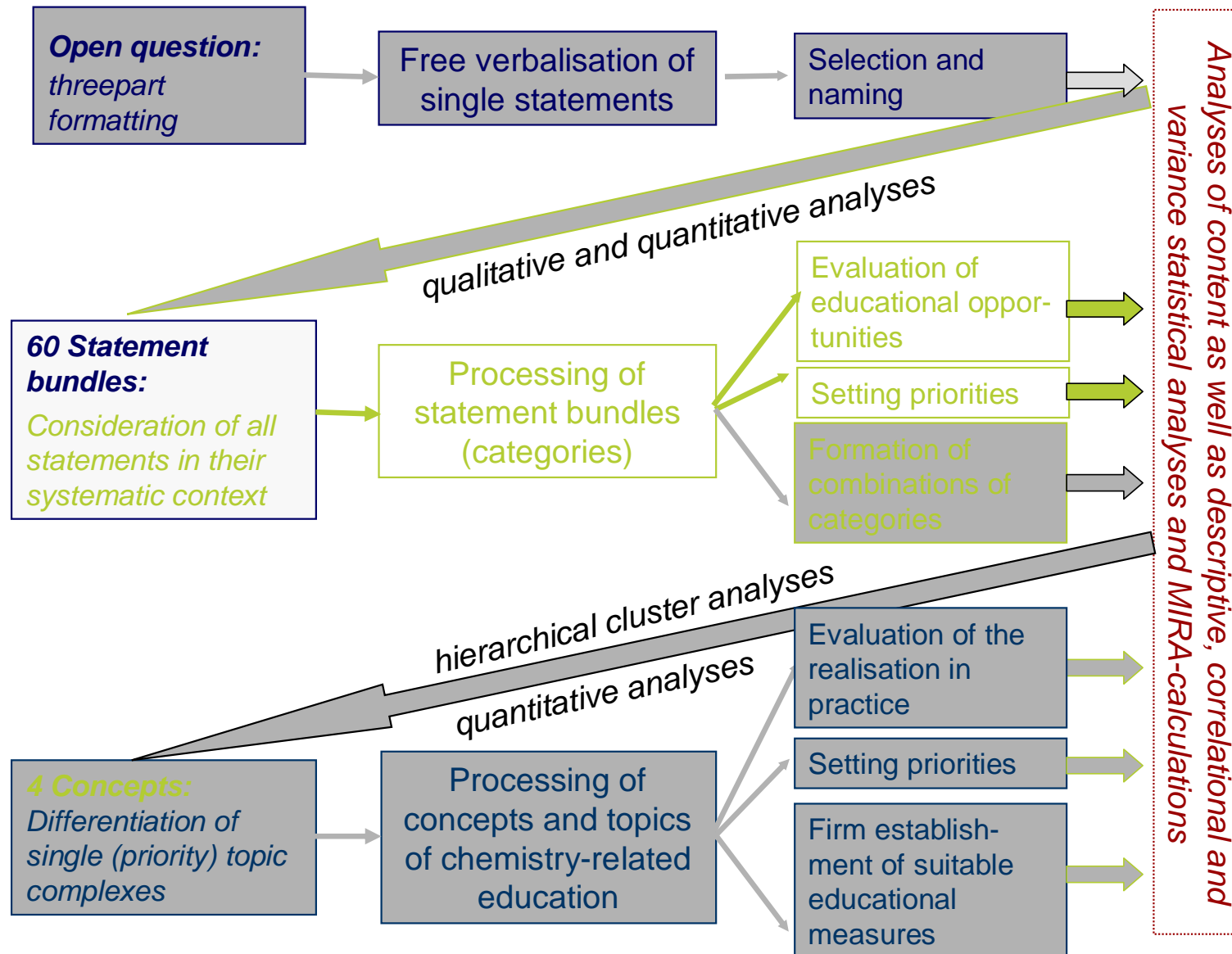
- **Relevance-Question:**
Do students indeed assess the factors of education they seldom mentioned as less relevant?
- **One-sidedness-Question:**
Do the categories, which were seldom mentioned by the students, so rarely take place in chemistry instruction, that this might be the reason hence the students did not or did just in single cases focus on this factors of education?
- **Versatility-One-sidedness-Question:**
w.o.w.: How varied or one-sided do experts assess conventional chemistry instruction?
- **Validity-Question:**
Is the classificationsystem not valid?

Mean of the category-hits in a specific groupe and in the total sample

| S | T | E | N | ges. |
|------|------|------|------|------|
| 3,1 | 14,4 | 15,2 | 14,4 | 13,1 |
| 0,0 | 4,8 | 12,7 | 6,5 | 7,3 |
| 4,6 | 14,4 | 24,7 | 8,6 | 14,8 |
| 13,8 | 16,3 | 32,9 | 10,1 | 19,7 |
| 0,0 | 4,8 | 8,9 | 2,9 | 4,9 |
| 1,5 | 13,5 | 14,6 | 7,2 | 10,3 |
| 0,0 | 1,9 | 8,9 | 3,6 | 4,5 |
| 1,5 | 12,5 | 12,0 | 10,1 | 10,1 |
| 0,0 | 6,7 | 10,1 | 6,5 | 6,9 |
| 0,0 | 4,8 | 8,9 | 10,1 | 7,1 |
| 0,0 | 2,9 | 7,0 | 5,8 | 4,7 |
| 0,0 | 0,0 | 4,4 | 0,7 | 1,7 |
| 0,0 | 3,8 | 10,8 | 1,4 | 4,9 |
| 0,0 | 6,7 | 11,4 | 3,6 | 6,4 |
| 0,0 | 5,8 | 9,5 | 5,0 | 6,0 |
| 15,4 | 19,2 | 39,2 | 21,6 | 26,2 |
| 3,1 | 4,8 | 15,2 | 11,5 | 10,1 |
| 0,0 | 3,8 | 10,8 | 2,9 | 5,4 |
| 12,3 | 34,6 | 24,7 | 28,1 | 26,2 |
| 33,8 | 15,4 | 17,7 | 14,4 | 18,5 |
| 1,5 | 4,8 | 11,4 | 14,4 | 9,4 |
| 24,6 | 43,3 | 26,6 | 33,8 | 32,2 |
| 35 | 11 | 30 | 14 | ./. |

Furthermore, 33 categories were only stated by the students in less than 5 % of their answers; 16 categories were not mentioned at all!

3.4.2 Design of the Curricular Delphi-Study in Chemistry – 2nd Wave (Part I)



3.4.2 Results: Groups' opinions in general

2nd Wave: Descriptive statistics

| Priority | P* _g |
|---------------------|-----------------|
| Understanding | 4,2 |
| Inquiry | 4,2 |
| Motivation/interest | 4,1 |
| Knowledge | 4,1 |
| Basic notions | 4,1 |
| Experience | 4,0 |
| Environment | 4,0 |

Validity-, Relevance- and Versatility-Question:

The classification system is valid, hence following the participants' opinions (students as well as adults), it reflects important and relevant aspects of a chemistry related (general) education.

Furthermore all participants' groups quote for a varied oriented chemistry instruction.

Unbalanced-Balance-Hypothesis:

„[Chemistry-]Instruction is – like every human practice – not perfect!“

(Petersen & Priesemann 1980, 36)

But, the balance between a general education in chemistry and a specialization in chemistry as a science is hardly unbalanced - to be precise:

The 'chemistry related and enlightened specialization' is disadvantaged!

One-sidedness-Question:

From the participants' view the subject related elements of chemistry as a science dominate one-sidedly what is going on in chemistry related general education.

3.4.2 Results: Groups' opinions in general

2nd Wave: Descriptiv statistics

Recommendations for practice

- support interests as well as the ability of reflected action and judgment,
- take up interdisciplinary topics especially from the fields of health and diet
- show up connections between current chemical and interdisciplinary projects of research,
- make potential and actual, positive as well as negative, developments which are (can be) caused by technology and consumption a subject of discussion and discuss them against the setting of different values,
- pay particular attention to the comprehensibility of factual connections.

| | Priority-Practice-Difference | D* _g |
|-------------------------------|------------------------------|-----------------|
| Motivation/Interest | | 1,7 |
| <i>Values</i> | | 1,5 |
| Ability to judge | | 1,5 |
| Reflected action | | 1,5 |
| Multi-disciplinarity | | 1,5 |
| <i>Health</i> | | 1,4 |
| Scientific Inquiry | | 1,4 |
| Understanding | | 1,4 |
| Pleasure | | 1,4 |
| General p.d. | | 1,3 |
| Experience | | 1,3 |
| <i>Current chem. research</i> | | 1,3 |
| Interdisciplinary topics | | 1,3 |
| Heuristics | | 1,3 |
| Sustainability | | 1,3 |
| <i>Cycles of matter</i> | | 1,2 |

5 Final remark: Back to the future

“There is **nothing** chemical that really has to be made the subject of discussion in school“ (expert 58/09221-W1-2; emphasis as in the original).

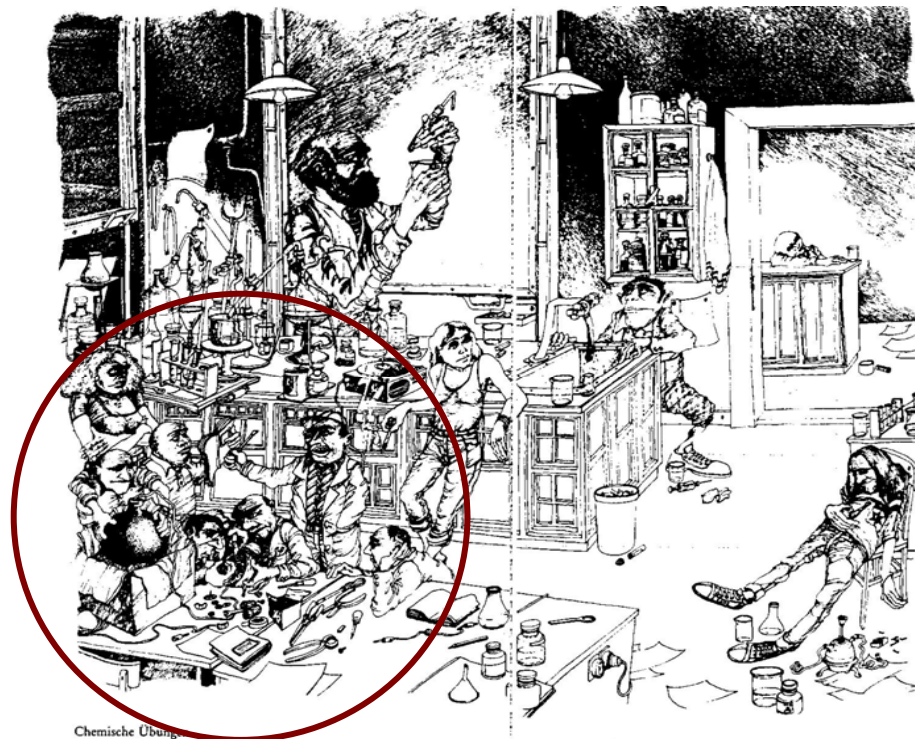
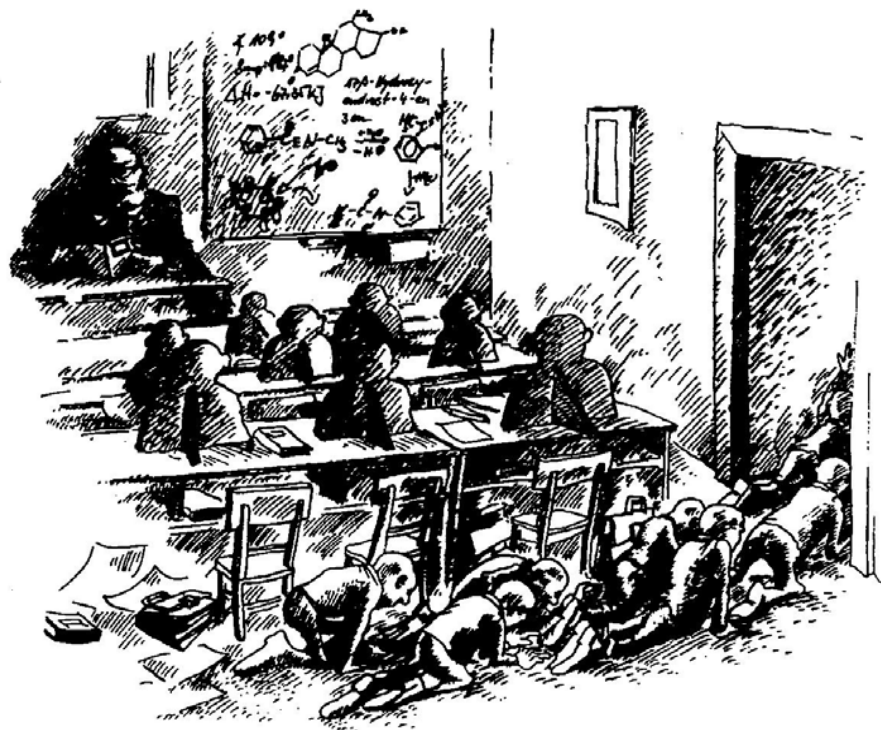
“There is **a lot of** chemical that really has to be made the subject of discussion in school!“

„... now, we have researched enough, and I get totally bored of that. All these specialities, they don't interest me anymore; only the applications, they really do appeal me.“

(Letter from Liebig to Wöhler, 1841)

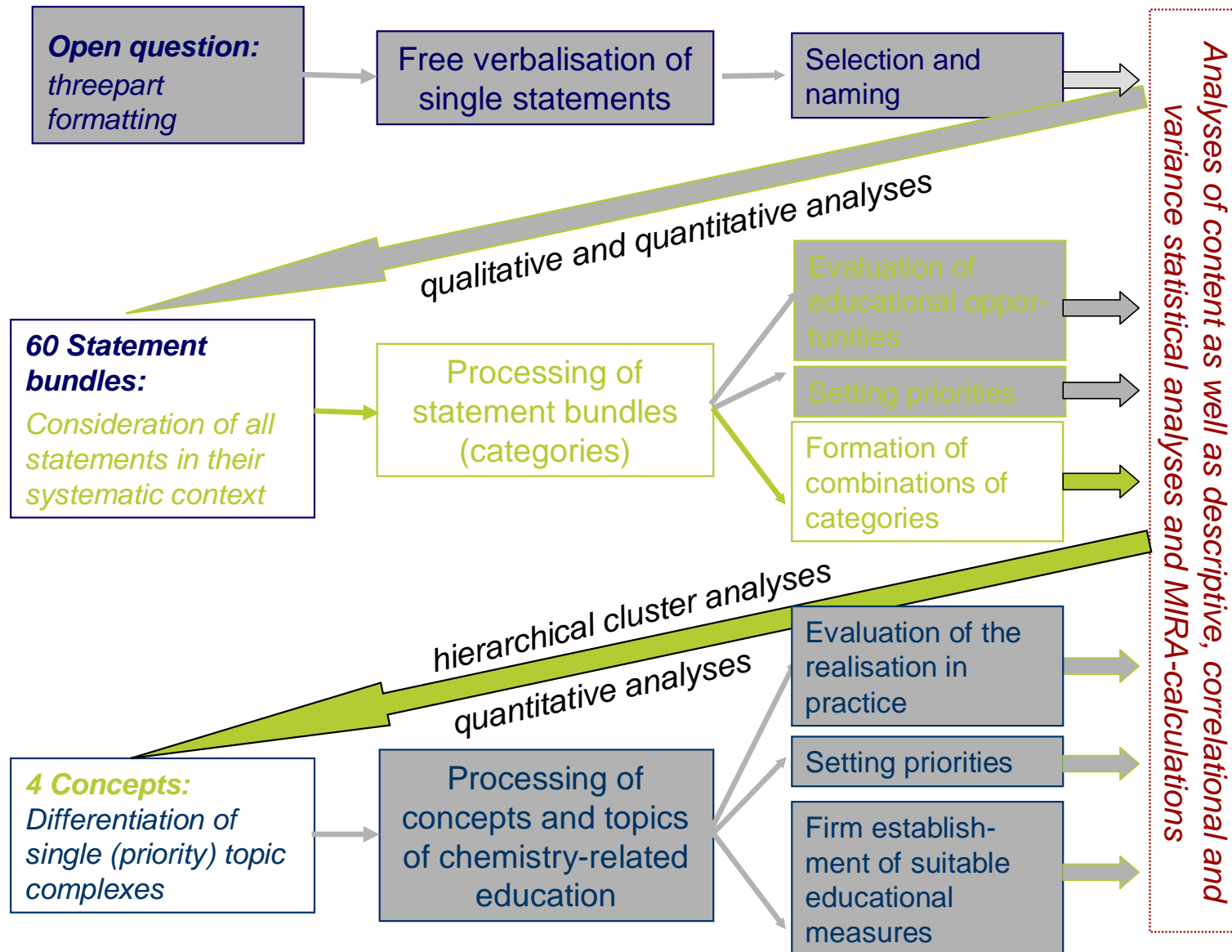
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Thank you for your
patience and attention!



Popularity and Relevance of Science Education and Scientific Literacy

4.4.2 Design of the Curricular Delphi-Study in Chemistry – 2nd Wave (Part II)

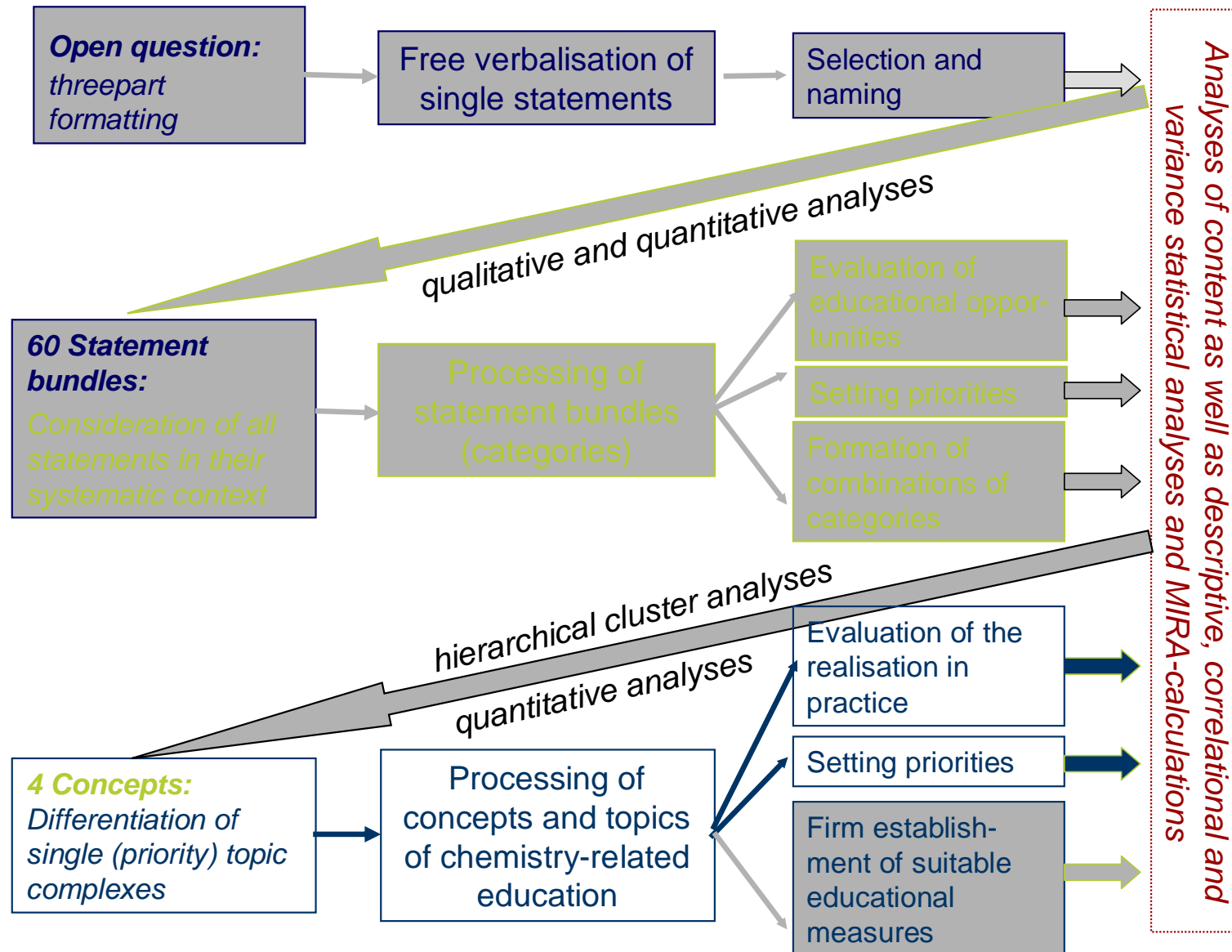


4.4.2 Results: Conceptual frames for education

2nd Wave: Hierarchical Clusteranalyses

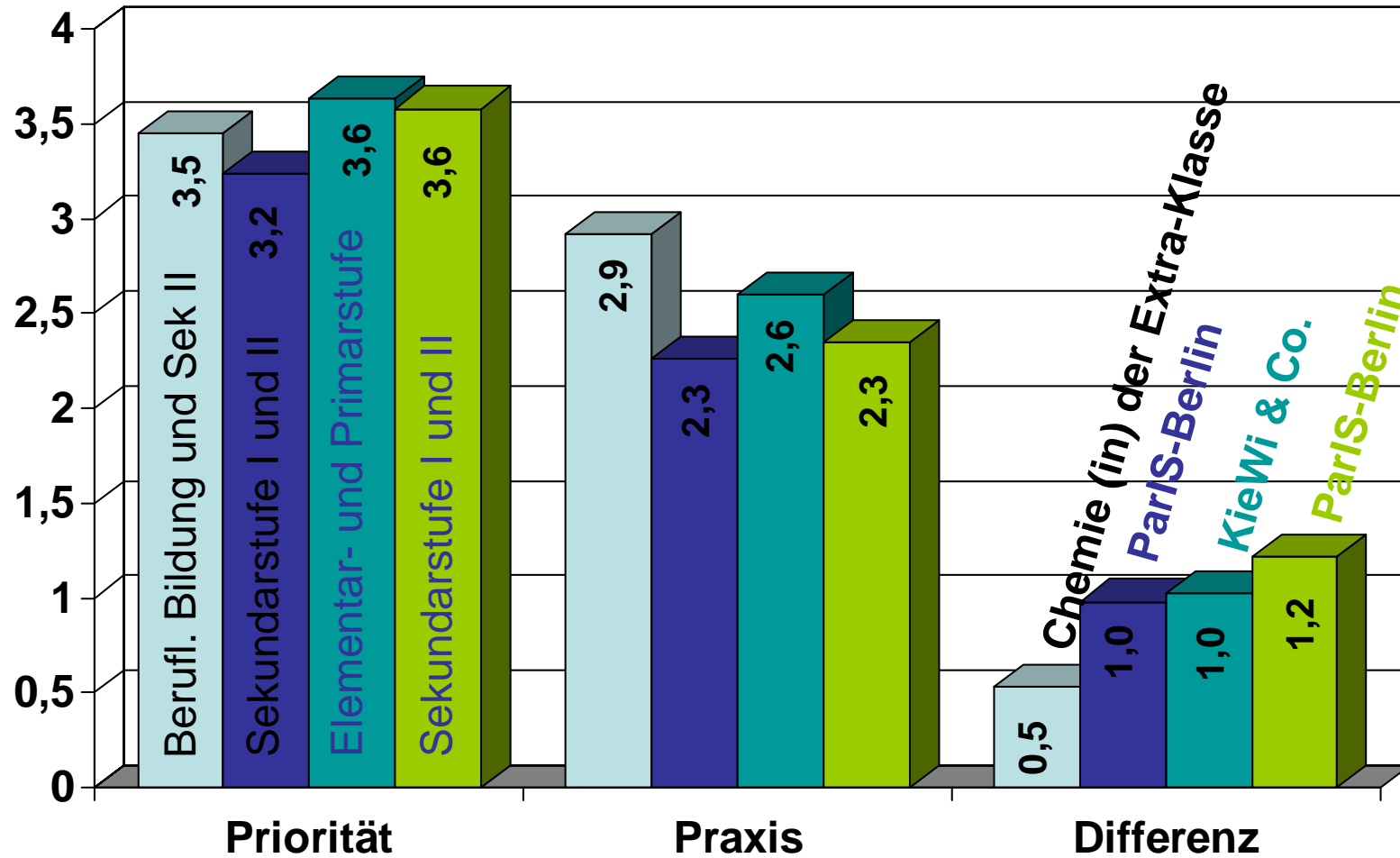
| | | | |
|--|---|---|---|
| A: Intellectual education | | B: General education | |
| <u>Intellectual personality development</u> | Equilibrium-concept Scientific inquiry Qualitative analysis Quantitative analysis Energetics Kinetics Spatial models Heuristics Epistemology Knowledge of the basics Understanding Proper handling Transfer | <u>General personality development</u> | Current chemical research Current interdisciplinary research Phenomenology Finding information Working with sources Motor skills Ability to communicate (Social) commitment, cooperation |
| <u>Chemistry as a science</u> | | Media Leisure Profession Interdisciplinary topics Basic notions Mobility Interdependence <u>(Fatal) Developments</u> History of science/chemistry | |
| Technical jargon Donator-acceptor-concept Particle-concept Inorganic compounds Organic compounds Energy-concept | | | |
| C: Emotional education | | D: Worldly and pragmatic education | |
| <u>Emotional personality development</u> | <u>Nature and natural phenomena</u> Fire – Energy Water – fluid subst. Earth – solid subst. Air – gaseous subst. | Household Everyday life Environment Cycles of matter Nutrition Health | Clothing Living/Housing Values Sustainability <u>Reflected action</u> <u>Ability to judge</u> |
| Experience (perception) Sensitivity, attitudes Motivation / Interest | | | |

4.4.3 Design of the Curricular Delphi-Study in Chemistry – 2nd and 3rd Wave



4.4.3 Results: Conceptual frames for education

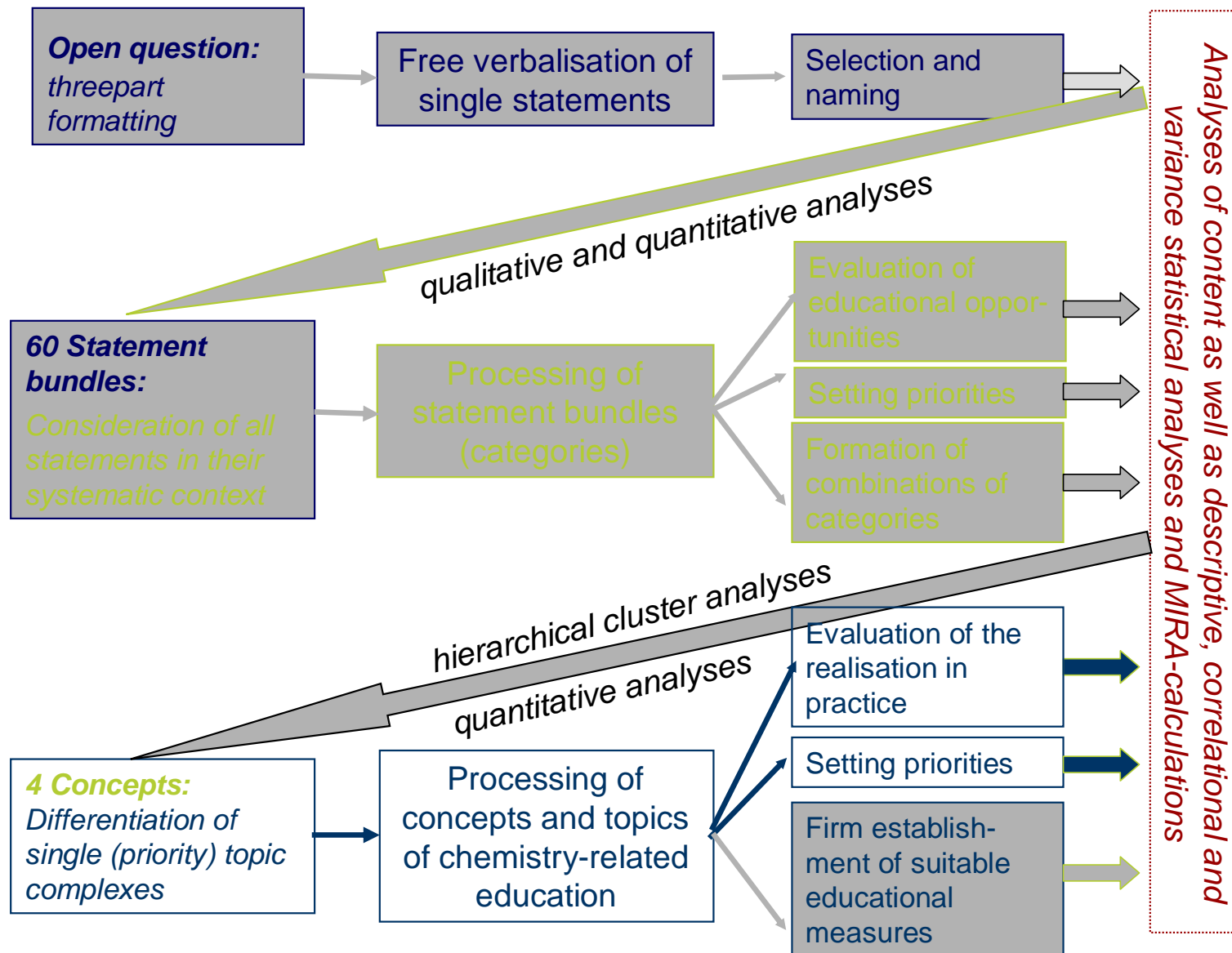
2nd and 3rd Wave: Descriptiv statistics

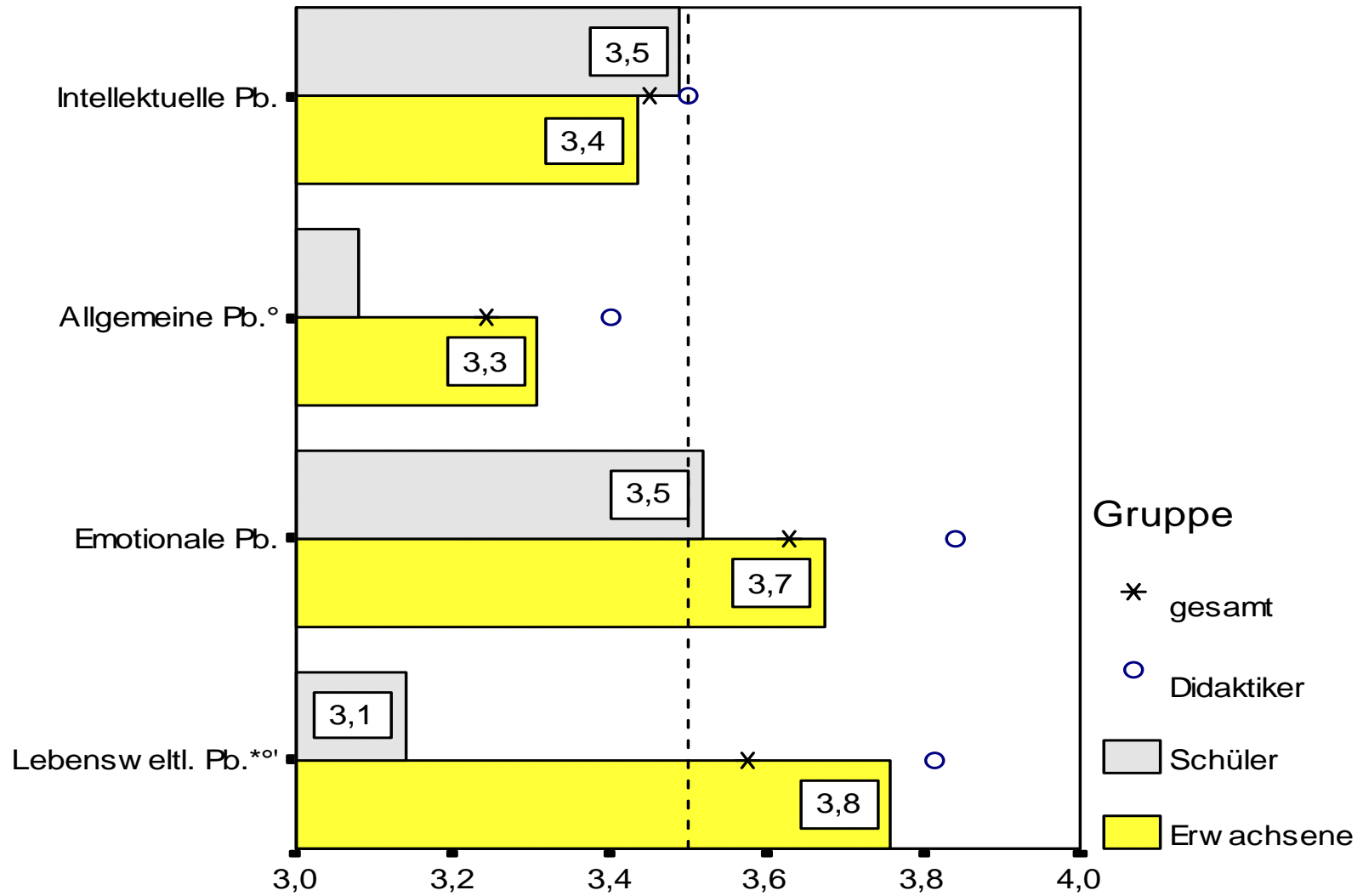


Normierte Summenscores - Gesamtstichprobe

Intellectuelle Bildung Allgemeine Bildung Emotionale Bildung Lebensweltl. Bildung

3.2 Design of the Curricular Delphi-Study in Chemistry





3.6 Ergebnisse: Konzeptionelle Rahmungen Normierte Praxis-Einschätzungen

