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Mathematical models in chemistry lessons

Science and Mathematics Education Conference (SMEC)
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Ines Schmidt

Outline

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1. Framework

- Concept / Definition
- Importance of mathematical models in chemistry lessons
- Process of mathematical modelling

2. Research questions

3. Research project

- Current situation
- Analysis of problems with mathematical modelling

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Concept / Definition

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Mathematical models

- describe facts and data by using mathematical terms, methods or tools, for instance:
  functions, graphs, geometric figures, coordinates etc.

Mathematical modelling

- Process of explaining facts and data by creating and using mathematical models

Importance of mathematical models

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- The mathematization of chemical terms and phenomena allows an explanation by interpreting mathematical formulations in terms of content [Höner (1996)]
- A mathematical analysis of chemical processes can help to facilitate and deepen the understanding of the underlying chemistry [Harisch (1979)]
- Mathematical modelling in chemistry lessons demands the transfer and usage of mathematical knowledge in new and significant situations and thus can support the comprehension of the modelled terms and foster problem solving skills [Borneleit, Danckwerts, Henn & Weigand (2001)]

Mathematical modelling

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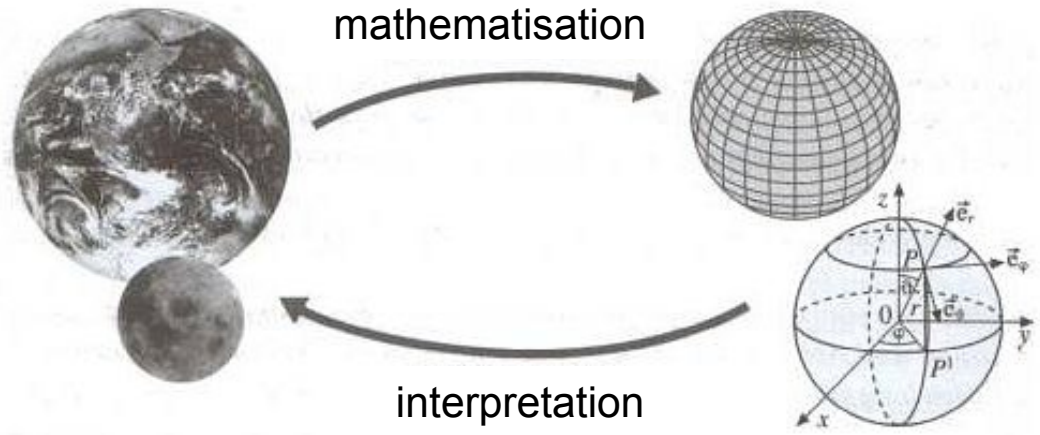
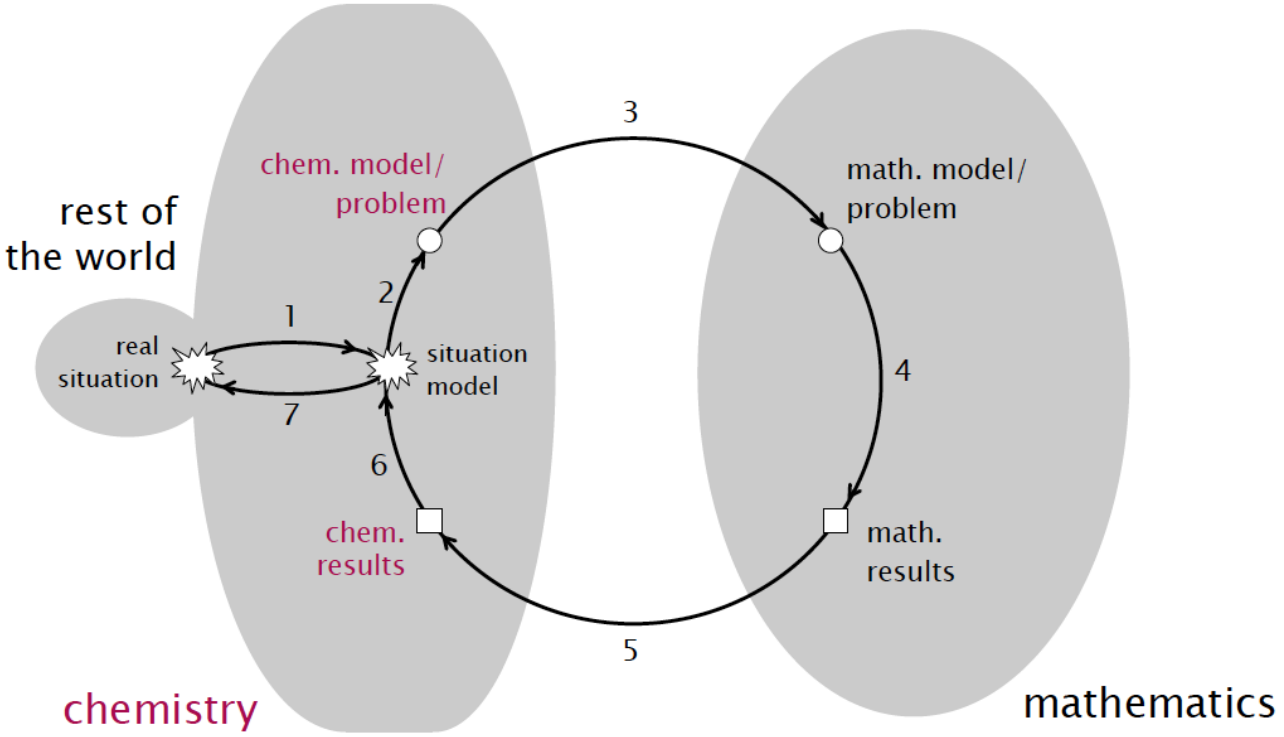
„We talk about modelling when pupils consciously justify or choose mathematical descriptions, a model and its assumptions, and when they validate the efficiency or the limit of the chosen model on the basis of the interpreted results.“ *[Büchter, Leuders (2005)]*



Steps of mathematical modelling



1. constructing / understanding
1. simplifying / structuring
2. mathematizing
3. working mathematically
1. translating
1. interpreting chemically / validating
1. relating

Steps of mathematical modelling according to Blum and Leiß – adapted to the process in chemistry lessons [Schmidt, Di Fuccia (2012)]

Research questions

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1. In which contexts should mathematical models be used in chemistry lessons according to the curriculum?

1. How are mathematical models used in chemistry lessons? Is the use of mathematical models and mathematical modelling taught in chemistry at all?

1. Do issue-specific or general problems occur when pupils pass through modelling processes? For instance:

   - *Do pupils use mathematical models?*
   - *Are pupils able to transfer and apply competences acquired in maths class in chemistry settings?*
   - *Are pupils able to create chemical / mathematical models?*

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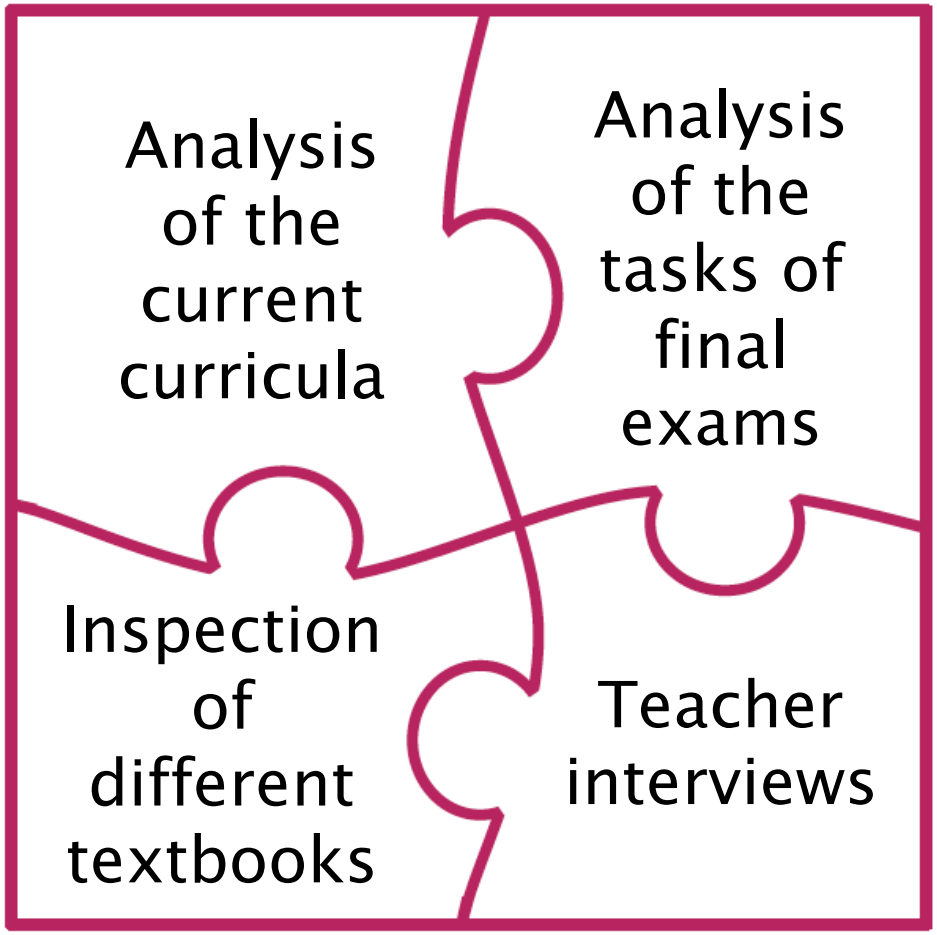
Current situation



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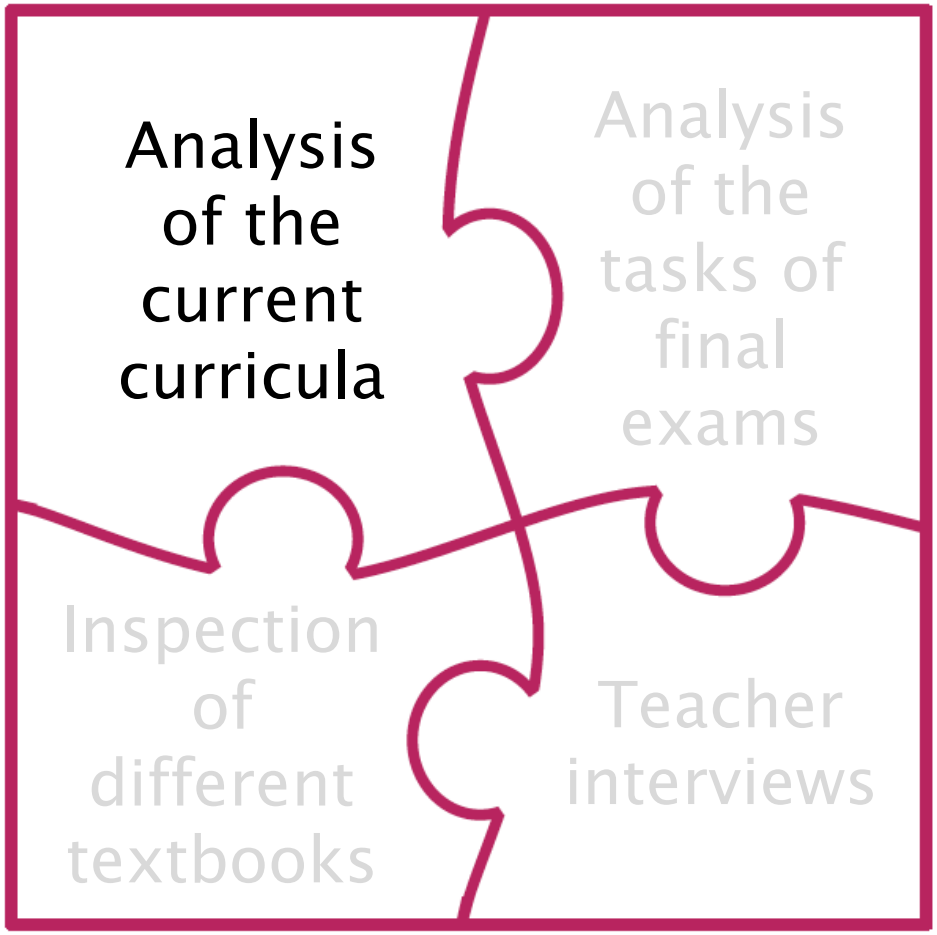

In which contexts should mathematical models be used in chemistry lessons according to the curricula?

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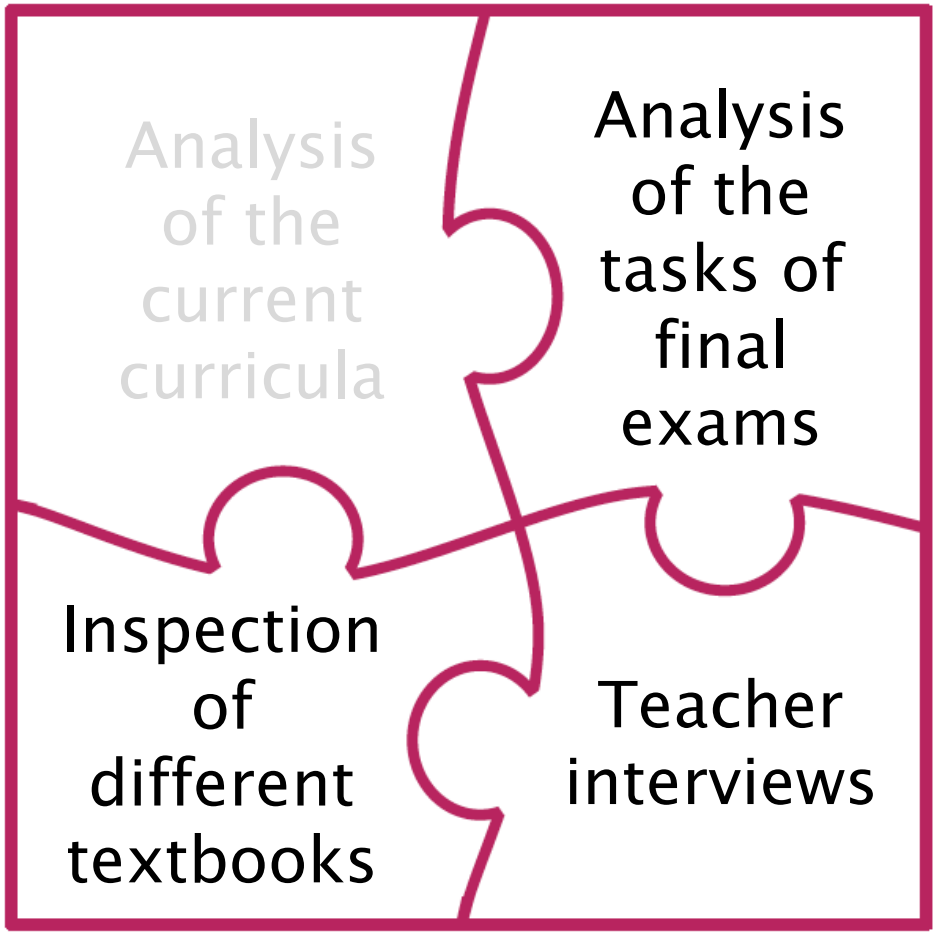

In which contexts should mathematical models be used in chemistry lessons according to the curricula?

How are mathematical models used in chemistry lessons?
Is the use of mathematical models and mathematical modelling taught in chemistry at all?

Analysis of the current curricula

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Topics in which a mathematization is requested – comparison of the federal states of Germany

- Different topics in the different states
- Mathematical views are more extensively requested in advanced courses than in basic courses in all states
- The curricula differ in the recommendations of how mathematical views should be implemented in chemistry lessons

Analysis of the current curricula

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Explicit recommendations of how mathematical views should be taught in chemistry lessons

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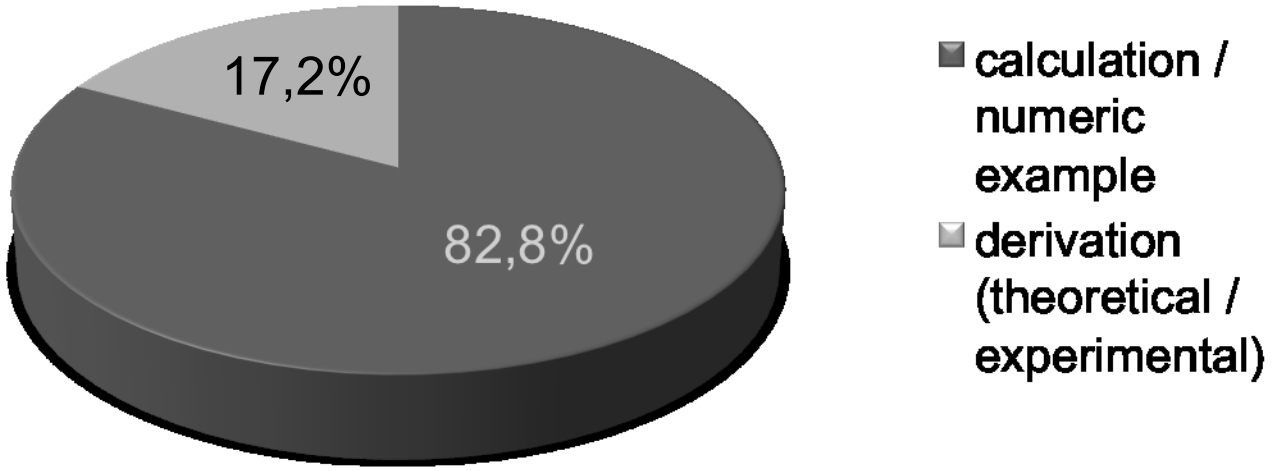

Inspection of textbooks

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Preliminary results

- 99.6 % of tasks with a mathematical share require exclusively calculating and application / finding results by using given mathematical models of chemical terms
- 0.4 % of these tasks require mathematical modelling / a derivation
- In 36.0 % of the chapters, which aim at using mathematical models, a theoretical derivation is given by the textbook
- In 36.5 % of those chapters, an example of how to use the mathematical model (calculating) is given by the textbook

Teacher interviews

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Preliminary results

- Derivations are nearly never implemented in basic courses
- In advanced courses, derivations are almost exclusively presented by the teacher
- Examples of calculations are always given before pupils have to calculate on their own
- According to the teachers, derivations can help to foster understanding, if pupils are good at mathematics
- The fewer pupils from one class are good at mathematics, the fewer mathematical models are used in chemistry
- Pupils often lack elementary chemical knowledge

Research questions

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Analysis of the modelling process

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Design of the study

- Use of tasks with incremental (stepwise) learning aids as diagnostic tool

  > *Video study*

    - Laboratory study
    - Pairwork

  > *validating the results of using tasks with incremental learning aids through face-to-face interviews / additional loud thinking*

Analysis of the modelling process

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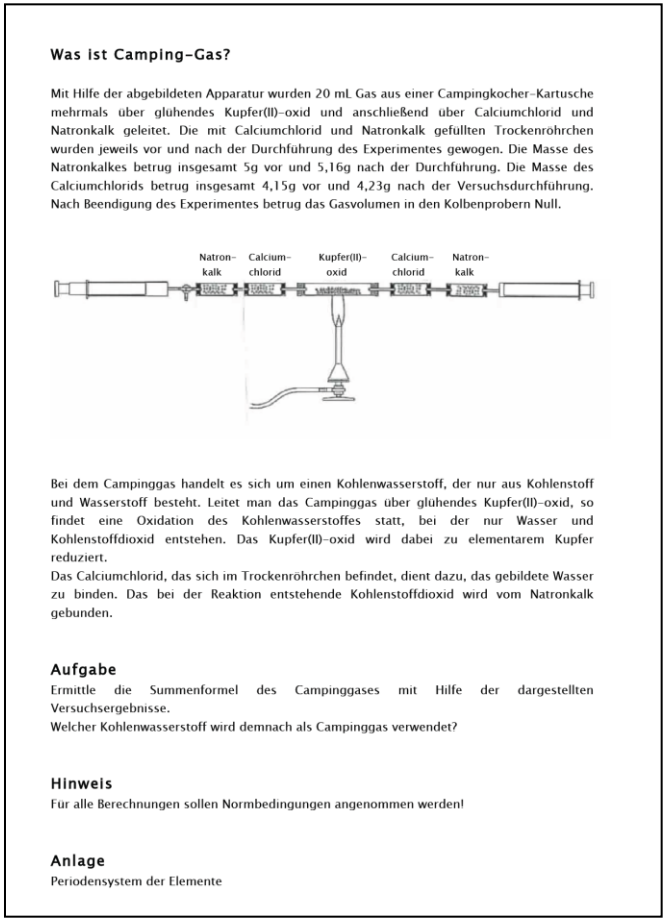
Example

Experimental determination of the molecular formula of camping gas according to Liebig

- Description of the “real situation“ seen as a whole
- Specification of the question



Was ist Camping-Gas?

Mit Hilfe der abgebildeten Apparatur wurden 20 mL Gas aus einer Campingkocher-Kartusche mehrmals über glühendes Kupfer(II)-oxid und anschließend über Calciumchlorid und Natronkalk geleitet. Die mit Calciumchlorid und Natronkalk gefüllten Trockenröhrchen wurden jeweils vor und nach der Durchführung des Experimentes gewogen. Die Masse des Natronkalkes betrug insgesamt 5g vor und 5,16g nach der Durchführung. Die Masse des Calciumchlorids betrug insgesamt 4,15g vor und 4,23g nach der Versuchsdurchführung. Nach Beendigung des Experimentes betrug das Gasvolumen in den Kolbenprobern Null.

Bei dem Campinggas handelt es sich um einen Kohlenwasserstoff, der nur aus Kohlenstoff und Wasserstoff besteht. Leitet man das Campinggas über glühendes Kupfer(II)-oxid, so findet eine Oxidation des Kohlenwasserstoffes statt, bei der nur Wasser und Kohlenstoffdioxid entstehen. Das Kupfer(II)-oxid wird dabei zu elementarem Kupfer reduziert.
Das Calciumchlorid, das sich im Trockenröhrchen befindet, dient dazu, das gebildete Wasser zu binden. Das bei der Reaktion entstehende Kohlenstoffdioxid wird vom Natronkalk gebunden.

Aufgabe
Ermittle die Summenformel des Campinggases mit Hilfe der dargestellten Versuchsergebnisse.
Welcher Kohlenwasserstoff wird demnach als Campinggas verwendet?

Hinweis
Für alle Berechnungen sollen Normbedingungen angenommen werden!

Anlage
Periodensystem der Elemente

Example of mathematical modelling

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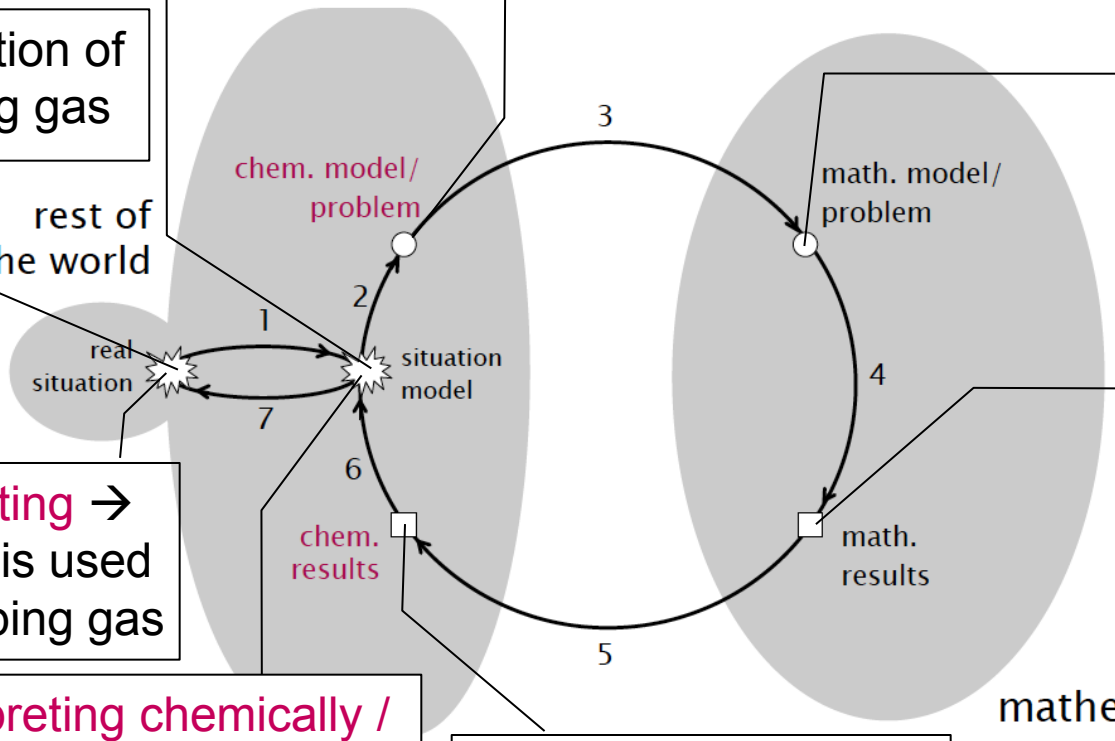
1. understanding:
Molecular formula C_xH_y is sought

2. structuring → chemical model:
a C_xH_y + b CuO → c CO_2 + d H_2O + e Cu
Number of atoms does not change during a chemical reaction

0. oxidation of camping gas



3. mathematizing → math. model:
c = a•x
a•y = d•2

4. working mathematically → math. results:
x = 4
y = 10

7. Relating → butane is used as camping gas

6. interpreting chemically / validating
→ C_4H_{10} is alkane/ butane

5. translating
→ chem. result: C_4H_{10}

Summary and outlook

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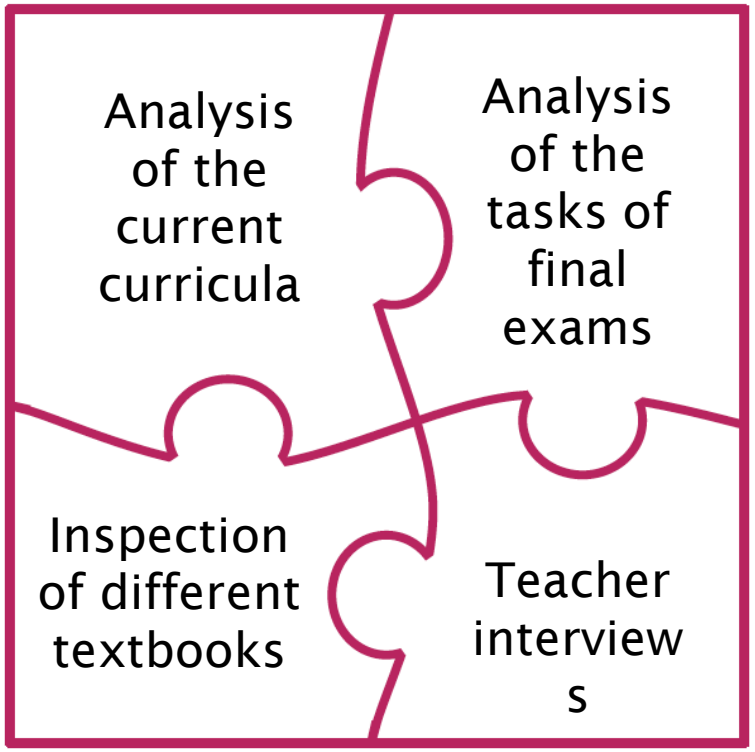
Current situation



Mathematical modelling

- Definition of the term
- Process of mathematical modelling
- Analysis of problems with mathematical modelling
- Tasks with incremental learning aids as an diagnostic tool

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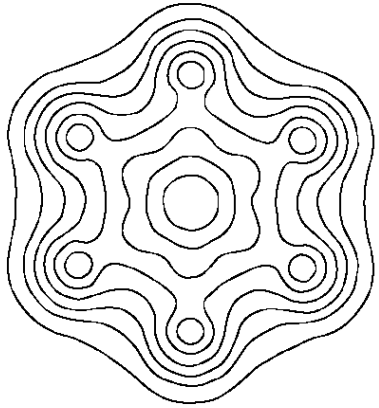
thanks!



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questions?

suggestions!

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References

Beck, U., Markic, S., Eilks, I. (2010): Modellierungsaufgaben im Chemieunterricht. In: *PdN Chemie in der Schule* 6/59, 5 – 7

Borneleit, P., Danckwerts, R., Henn, H.-W., Weigand, H.-G. (2001): Expertise zum Mathematikunterricht in der gymnasialen Oberstufe. In: H.-E. Tenorth (Hrsg.) (2001): *Kerncurriculum Oberstufe*. – Weinheim: Beltz, 26 – 53

Borromeo Ferri, R. (2007): Modelling problems from a cognitive perspective. In C. Haines, P. Galbraith, W. Blum, S.Khan (eds) *Mathematical Modelling (ICTMA12): Education, Engineering and Economics*. Chichester, Horwood Publishing, 260-270.

Borromeo, R., Leiß, D., Blum, W. (2006): Der Modellierungskreislauf unter kognitionspsychologischer Perspektive. In: *Beiträge zum Mathematikunterricht 2006, Vorträge auf der 40. Tagung für Didaktik der Mathematik*. Hildesheim und Berlin: Franzbecker

Büchter, A., Leuders, T. (2005): Mathematikaufgaben selbst entwickeln. Lernen fördern – Leistung überprüfen, Berlin: Cornelsen Scriptor

Hänze, M., Schmidt-Weigand, F., Stäudel, L. (2010): Gestufte Lernhilfen. In: Boller, S., Lau, R. (Hrsg.) (2010): *Innere Differenzierung in der Sekundarstufe II – Ein Praxishandbuch für Lehrer/innen.* Weinheim, Basel: Beltz

Schmidt-Weigand, F. & Hänze, M. (2009): *Incremental support in learning with worked examples: A quasi-experimental field study.* Paper presented at the 13th bi-annual meeting of the European Association of Research on Learning and Instruction, Amsterdam, the Netherlands.

Harisch, F. (1979): Mehr rechnen im Chemieunterricht! In: *NiU Physik / Chemie* 2/27, 57-60

Höner, K. (1996): Mathematisierungen im Chemieunterricht - ein Motivationshemmnis? In: *ZfdN* 2/1996, 51-70

Leisen, J. (1999): Methodenhandbuch deutschsprachiger Fachunterricht. Bonn: Varus

Schmidt, I., Di Fuccia, D.-S. (2012): Mathematisches Modellieren im Chemieunterricht, In: Bernholt, S., Gesellschaft für Didaktik der Chemie und Physik (GDCP), *Tagungsband z. Jahrestagung in Oldenburg 2011 - Konzepte fachdidaktischer Strukturierung für den Unterricht,* Berlin, Lit-Verlag, 515-517

Analysis of the modelling process

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Use of tasks with incremental learning aids as diagnostic tool in analysing problems with mathematical modelling

- Tasks with incremental learning aids [Leisen (1999), Hänze et al. (2010)]

… allow students to deal with complex tasks.

… are predestinated for tasks aiming at application and transfer of content.

… are suitable for tasks showing a linear structure.

… may be designed in respect of the single steps of the modelling process.

Analysis of the modelling process

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Use of tasks with incremental learning aids as diagnostic tool in analysing problems with mathematical modelling

- Tasks with incremental learning aids [Leisen (1999), Hänze et al. (2010)]

… allow a clear distinction of the individual steps in the modelling process.

… can be designed as assistance to differentiate between chemical, mathematical as well as learning and procedural strategies.

… facilitate a categorisation of the problem areas regarding mathematical modelling in chemistry lessons, which lead back to mathematical and chemical competences.

Analysis of the modelling process

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Designing the tasks with incremental learning aids as diagnostic tool

- Small incremental steps to differentiate clearly between the single steps in reasoning
- Differentiation between

1. aids, which give a hint at the next step of the modelling process in general

1. aids, which concretise the next step in the cycle and its realisation